



Ministry of Transport, Public Works
and Water Management

Performance Based Navigation (PBN)

ROADMAP for the Kingdom of the Netherlands 2010-2020





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and Water Management

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Ministry of Transport, Public Works and Water Management
Directorate General of Civil Aviation and Maritime Affairs
The Hague, Netherlands

&

Directorate of Civil Aviation
Netherlands Antilles

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May 2010

Dear Members of the Aviation Community,

We have come a long way from the earliest radio navigation aid which was conceived in 1929. The next breakthrough was the Instrument Landing System (ILS) originating from as early as the late Thirties to safely and reliably guide aircraft towards the runway and its principle is still applied today. With the advent of GPS in the early Eighties for civil use, a myriad of potential navigation applications became available which changed the way we navigate today and will fundamentally change future navigation. Due to the continued efforts of ICAO a globalised definition and implementation guidance for Performance Based Navigation (PBN), which is foreseen to ultimately rely on GNSS only, has been made available. I am keen to implement PBN in the Kingdom of the Netherlands which we have already formalised by agreeing to ICAO's Resolution 36-23 where States amongst others are requested to produce a PBN plan.

Benefits of applying PBN can already be seen in present day operations in the Netherlands. For example, the use of night-time transitions at Schiphol during which aircraft perform low noise arrivals over the North Sea, and the ongoing trials to facilitate more accurate departure routes to avoid populated areas near the airport. But more is needed to achieve the goals we have set out in the Luchtvaartnota where we strive to excel in a sustainable and competitive air transportation system in the Kingdom of the Netherlands.

I am proud to present to you the PBN Roadmap of the Kingdom of the Netherlands with regard to Performance Based Navigation (PBN) up to 2020. This roadmap was prepared by the Netherlands Task Force (TF) PBN set up in 2008. Civil and military aviation stakeholders participated in the TF PBN as well as expert groups in the Caribbean part of the Kingdom of the Netherlands. The large variety of airspace users poses a challenging environment since civil and military operations, needs and requirements differ indeed as well as differences in operations between commercial airliners and recreational airspace users. Despite this variety, a consolidated roadmap was produced which has the potential to facilitate all airspace users.

The PBN Roadmap describes the rationale for PBN, the potential benefits of applying PBN and it defines proposed milestones within the navigation domain.

The road ahead is paved but to keep a straight track, the continued commitment of the aviation community in the Netherlands will be essential. Additionally, specific navigation mandates need to be set at European level to assure a smooth transition between the individual ECAC States. Already the ongoing SESAR programme addresses these important steps but actions at national level are required. It goes without saying that the PBN Roadmap is aligned with the SESAR targets as well as ICAO's vision on the Caribbean and South America (CAR/SAM) region.

Last but not least, merely fulfilling navigation needs is not enough to realise the anticipated benefits of PBN; also communication, surveillance and ATM systems and tools will be equally important and need to be addressed in parallel.

Thank you for your continued support and active participation in setting the scene for the implementation of PBN in the Kingdom of the Netherlands and I look forward to welcoming initial PBN initiatives in the very near future.

THE DIRECTOR GENERAL FOR CIVIL AVIATION AND MARITIME AFFAIRS,



Mark Dierikx

Executive summary

In future aviation concepts developed within SESAR and NextGen, the use of Performance Based Navigation (PBN) is considered to be a major ATM concept element. ICAO has drafted standards and implementation guidance for PBN in the ICAO Doc 9613 “PBN Manual”. The PBN concept represents a shift from sensor-based to performance based navigation based on criteria for navigation accuracy, integrity, availability, continuity and functionality. Through PBN and changes in the communication, surveillance and ATM domain, many advanced navigation applications are possible to improve airspace efficiency, improve airport sustainability, reduce the environmental impact of air transport in terms of noise and emission, increase safety and to improve flight efficiency.

It is evident that the application of GNSS will become even more common within the next decade. This calls for a preparation of the corresponding navigation infrastructure as well as (inter)national regulation and policy to facilitate the use of (augmented) GNSS during all phases of flight.

At the 36th General Assembly of ICAO held in 2007, the Kingdom of the Netherlands agreed to ICAO resolution A36-23 which urges all States to implement PBN. States are therefore requested to produce a PBN plan by the end of 2009. The second part of the ICAO resolution calls for specific navigation applications, referred to as Approach Procedures with Vertical guidance (APV), to be implemented at relevant instrument runways by 2016.

To achieve the ICAO resolutions as well as formulate a national vision for PBN, a Task Force (TF) PBN was established in 2008 within the Netherlands in which civil-military aviation stakeholders participated. It was the remit of the TF PBN to provide a vision and roadmap up to 2020 for PBN operations in the Kingdom of the Netherlands. In parallel, expert meetings have taken place to address PBN for the airport and airspace infrastructure in the Caribbean part of the Kingdom of the Netherlands. Also an initial consultation of the general aviation community has taken place.

The PBN Roadmap describes the rationale for PBN, the potential benefits of applying PBN and it defines milestones within the navigation domain taking into account all airspace users.

It is foreseen by the TF PBN that the first step will be to mandate RNAV1 for all IFR traffic in all TMAs in the Netherlands in 2012. With RNAV1, a common navigation infrastructure will become available which aids in defining a more optimised airspace, route structure and low-noise arrival/departure procedure definition to start implementing the objectives stated in the “Luchtvaartnota”.

Between 2010 and 2016, conventional non-precision approach (NPA) procedures for all instrument runways are supplemented with approaches that provide vertical guidance by means of barometric altimetry (APV based on Baro-VNAV), and where beneficial also by means of GNSS (APV based on SBAS). By 2016 all conventional NPAs will be replaced by APV Baro-VNAV and/or APV SBAS. The rationale to replace the conventional NPA procedures by APV based on Baro-VNAV and/or SBAS is to further enhance safety during the approach and can potentially reduce landing minima. Airlines will need to hold an operational approval to conduct RNP APCH operations which is currently already required to perform e.g. RNAV (GNSS) approach procedures.

Rationalisation of ground based nav aids such as VOR and NDB will take place during 2010-2020. Gradually, VORs and NDBs can be decommissioned provided that aircraft entering the FIR AMS have obtained sufficient equipage levels. This will require RNAV1 and RNP APCH mandates to be set by the Dutch Ministry of Transport. The current DME/DME infrastructure will be maintained and may even require extension in order to serve all parts of the Netherlands. When a multi-GNSS constellation (e.g. GPS & Galileo) is fully operational and aircraft fleet readiness reaches a particular level, then sole GNSS operations without a corresponding DME/DME infrastructure becomes possible. This is however foreseen for the timeframe 2020+.

Although the navigation specification for Advanced RNP-1 (A-RNP1) is not yet developed by ICAO, the TF PBN and Eurocontrol believe that this is the ultimate navigation requirement from en-route up to the intermediate approach segment.

With A-RNP1, on-board monitoring and alerting combined with accurate navigation will pave the way for advanced ATM concepts foreseen in SESAR such as 4-D business trajectories. The TF PBN aims to mandate A-RNP1 in 2018, but timescales will be in line with international developments.

Finally, application of the most stringent navigation specification, i.e. RNP AR APCH is currently not foreseen at airports in the Netherlands.

ILS will remain, up to 2020 and beyond, the prime source of guidance for precision approaches and landings since augmented GNSS (GBAS) has not yet been defined for Cat II/III operations and GNSS is expected to follow up ILS instead of MLS.

In a formal sense, State¹ Aircraft are exempt from any mandates and/or requirements proposed in the PBN Roadmap, however the military airspace user strives towards implementing navigation equipment in line with the PBN Roadmap where it benefits the military, albeit may lag behind the civil airspace users.

General aviation users conducting VFR flights are not affected by the milestones in the PBN Roadmap.

With the exception of RNAV1, mandates formulated in this PBN Roadmap are currently in line with the mandates proposed by Eurocontrol and ICAO EUR PBN. National mandates therefore depend on the European regulatory and certification process (EASA).

The ATM environment in the Caribbean part of the Kingdom of the Netherlands differs from the situation in the Netherlands due to the use of oceanic and remote continental routes where the application of PBN is more common. GNSS-based arrival and departure routes are to be published onwards from 2011 and a gradual replacement of conventional NPA procedures by APV Baro-VNAV procedures will take place from 2010-2016 in line with the ICAO resolution 36-23. In the long-term (2016+), GNSS is expected to be the primary navigation infrastructure for the en-route, terminal and approach/landing flight phase. During 2013-2016 TMAs with high traffic complexity and movements will consider mandating the use of RNAV1 or Basic/Advanced RNP-1.

In the PBN Roadmap a general vision and major milestones with regard to navigation have been formulated. The next step will be to prepare an action plan for the aviation community for each navigation milestone.

¹ Aircraft used in military, customs and police services qualify as State Aircraft. Aircraft on a military register, or identified as such within a civil register, shall be considered to be used in military service and hence qualify as State Aircraft. Civil registered aircraft used in military, customs and police service shall qualify as State Aircraft.

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Foreword

The PBN Roadmap was produced mainly during 2009 by the Task Force PBN under the leadership of the Directorate General of Civil Aviation and Maritime Affairs of the Ministry of Transport, Public Works and Water Management.

The scope of the PBN Roadmap is the Kingdom of the Netherlands and comprises the Netherlands and the Caribbean part of the Kingdom of the Netherlands.

Through the dedicated commitment of the organisations that participated in the TF PBN* and the ATM Expert Group for the Caribbean**, a consolidated vision and a roadmap towards PBN implementation in the Kingdom of the Netherlands was established. The support of the military organizations to the TF PBN has been provided by the military subject matters experts. The Ministry of Defence and the Military Aviation Authority support the general vision laid down in this roadmap, but will keep the right to concur to the military frame of reference when necessary.

The General Aviation community in the Netherlands represented by KNVvL and AOPA Europe have been consulted and results have been incorporated in this document.

Regardless of the inevitable changes due to developments in regulations, legislation and CNS/ATM development (e.g. SESAR and NextGen), the TF PBN is convinced that a firm basis for PBN implementation in the Kingdom of the Netherlands has been achieved.

Robin Valkenburcht,
Chairman Taskforce PBN

* Members of the TF PBN: Ministry of Transport NL, LVNL, Royal Netherlands Air Force, Military Aviation Authority, CAA-NL, Amsterdam Airport Schiphol, KLM Royal Dutch Airlines, Eurocontrol MUAC, NLR.

** Members of the PBN expert group: Ministry of Transport NL, CAA-NL, Directorate of Civil Aviation Netherlands Antilles, Department of Civil Aviation Aruba, Netherlands Antilles ATC, Aruba Airport Authority, Princess Juliana International Airport Enterprise NV, Curaçao Airport Holding.

DISCLAIMER

The contents of this document represent the vision at the moment of writing of the organisations that participated in the TF PBN and organisations that have been consulted. The PBN roadmap is inextricably linked to international visions and roadmaps set out by e.g. ICAO EUR TF PBN (WP/04), EUROCONTROL, FABEC, SESAR and NextGen which in turn rely on developments in the air transportation sector.

All formal mandates will be communicated via aeronautical information publications (AIP/AIC).

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1 Introduction



The ATM system for the Kingdom of the Netherlands faces major changes instigated by international developments such as SESAR, FABEC and NextGen, the continued global harmonisation as pursued by ICAO and national priorities and needs. Enabling technology, such as Communication, Navigation and Surveillance (CNS), is required to establish a novel way of performing ATS. Also new requirements for Airspace Organisation and Flow Management will be needed. In this document the focus is on the navigation domain whilst recognising the interdependence with other domains such as Communication and Surveillance. This document sets out a roadmap for Performance Based Navigation (PBN) for the Kingdom of the Netherlands. The scope of this roadmap covers the Kingdom of the Netherlands which comprises:

- The Netherlands
- Aruba and Netherlands Antilles (the five islands of Bonaire, Curaçao, Saba, St. Eustatius and St. Maarten (Dutch part))

Developments that impact the Dutch ATM system include international developments such as SESAR (Single European Sky Aviation Research) and FABEC (Functional Airspace Blocks Europe Central) as well as national priorities with regard to e.g. sustainable airport development by means of Table of Alders¹, revised national aviation policy², further strengthening Mainport Schiphol and intensifying civil-military co-operation. One of the fundamental changes as foreseen in SESAR is the gradual move towards a system that is based on 4D Business Trajectories and the extensive deployment of satellite-based navigation.

Developments that impact the Caribbean ATM system include international developments such as NextGen and the ICAO PBN Roadmap for the CAR/SAM region. Currently the annual rate of traffic growth in Curaçao FIR is at an average of 3.3% with the advent of new routes and airlines increasing operations as Caribbean destinations have become more popular. Due to the large influence of American carriers, airlines and ATC are familiar with PBN operations. For example: the LATAM/CAR RNAV Route program (2006) led to the shortening of routes in the WATRS (West Atlantic Route System) area which includes the San Juan CTA/FIR and has reduced lateral separation criteria. Application of 50 NM lateral separation between aircraft either authorized RNP-10 or RNP-4 has been introduced and a redesigned route structure has been implemented in 2008.

On the other hand, traffic is diversified and large range of navigational capabilities to operate in airspace that may also comprise non-radar environment. In comparison with the European situation, capacity bottlenecks are a lesser problem in the Caribbean part of the Kingdom but there is a need for improved airport access.



The previously mentioned developments intensify the need for changes in the navigation domain and consequently targets have to be set by the involved stakeholders. Stakeholders include the Civil and Military Regulatory Authorities, ANSP organisations, Airspace Users and Airport Operators. Inherent to changes in CNS/ATM are the relatively long lead-in times to achieve these targets. The aim of this document is therefore to provide a consolidated vision of stakeholders and a rationale for these targets to expedite the implementation process. Ultimately, the roadmap leads to a seamless transition towards the SESAR and NextGen concept and ultimately the global harmonisation of the ATM system.

An important step in the navigation domain has been made by ICAO by asking States for commitment to implement the PBN concept. This commitment has been confirmed by the Kingdom of the Netherlands. The PBN concept describes the various navigation applications and how such applications can be implemented.

¹ Table of Alders - Short- and Medium term vision Schiphol (Dutch: Alderstafel, 2007/2008)

² Dutch Aviation Policy (Dutch: Luchtvaartnota, 2009)



- Military Aerodrome
- Military Aerodrome with civil use
- Civil Aerodrome

At the 36th General Assembly of ICAO held in 2007, the Kingdom of the Netherlands agreed to resolution A36-23 (see Annex I) which urges all States to implement PBN. States are therefore requested to produce a PBN plan by the end of 2009.

The second part of the ICAO resolution calls for specific navigation applications, referred to as Approach Procedures with Vertical guidance (APV), to be implemented at relevant runways by 2016.

To achieve the ICAO resolutions, a Task Force (TF) PBN was established in 2008 within the Netherlands in which civil-military aviation stakeholders participate. It is the remit of the TF PBN to provide a vision and roadmap for PBN operations in the Kingdom of the Netherlands. In parallel, expert meetings have taken place to address PBN for the airport and airspace infrastructure in the Caribbean part of the Kingdom of the Netherlands. The PBN Roadmap is intended to assist the main stakeholders of the aviation community in planning future transition and their investment strategies.

Particular attention is given to State aircraft³ which for technical or operational reasons, can not always comply with specific equipage requirements and operate as Operational Air Traffic (OAT). Situations may therefore exist where State aircraft require access to airspace to fly as General Air Traffic (GAT) despite not being equipped in accordance with the civil requirements. On the other hand, it is recognised by the military that it is best interests of all airspace users when this situation is minimised as far as possible. For this reason the Eurocontrol Civil/Military Interface Standing Committee (CMIC) has defined guidance with regard to State aircraft equipage requirements and associated exemptions⁴.

Finally, to illustrate that the global aviation community fully supports the transition to PBN, an Industry PBN Declaration that complements resolution A36-23 was issued.

³ Aircraft used in military, customs and police services qualify as State Aircraft. Aircraft on a military register, or identified as such within a civil register, shall be considered to be used in military service and hence qualify as State Aircraft. Civil registered aircraft used in military, customs and police service shall qualify as State Aircraft

⁴ Eurocontrol CMIC, "Policy Guidance For The Exemption Of State Aircraft From Compliance With Specific Aircraft Equipage Requirements". 4 March 2003



Industry Declaration in support of Performance-based Navigation (PBN)

We, as representatives of the air transportation community,

Affirming our joint responsibility to seek continual improvements to the safety, access, capacity, efficiency and environmental sustainability of the air transportation system,

Recognizing that Performance-based Navigation (PBN) provides a catalyst for these improvements to air traffic operations, while enabling a seamless and cost effective solution throughout the entire flight,

Recognizing the work of ICAO in formulating and publishing globally harmonized Area Navigation (RNAV) and Required Navigation Performance (RNP) provisions, now known as Performance-based Navigation (PBN),

Recalling that Resolution A36-23 of the 36th ICAO General Assembly whereby States are urged to implement PBN procedures in accordance with the established timetable,

We resolve:

To support the timetable set out by ICAO for the global implementation of PBN,

To collectively work to facilitate the implementation of PBN, and

To assist States, regions and other stakeholders in their development and execution of a complete PBN implementation plan.

We call upon:

All leaders of the civil aviation community, to fully support implementation of PBN into the air navigation system according to the ICAO provisions and established timetable.




Roberto Kobeh González, Council President

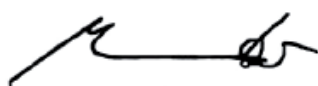



Giovanni Bisignani, Director General and CEO




Alexander ter Kuile, Secretary General




Marc Baumgartner, President & CEO




Capt. Carlos Limon, President

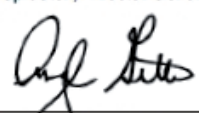



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François Gayet, Chairman




Angela Gittens, Director General




Matthew S. Zuccaro, President




William R. Voss, President & CEO

2 Rationale and scope



The growth of the air transportation system is currently (2009) decreasing, however expectations point towards regaining its growth potential in the next decade. A positive side-effect of the current stand-still does pose an ideal point in time to re-evaluate goals and ambitions and to initiate changes to the ATM system.

Besides the expected growth of air traffic, air transportation is also becoming more diversified by the introduction of VLJs (Very Light Jets), VLA (Very Large Aircraft; e.g. Airbus A380) and UAS (Unmanned Aerial Systems).

Airspace is available to all airspace users including commercial civil airline operators, military airspace users, general and business aviation. A future ATM system needs to cater for this large array of aircraft capabilities which can range from basic VOR/DME navigation to state-of-the art FMS and GNSS avionics. The complexity of military operations also has its bearing on the use and management of airspace. Military objectives are not driven by economic transportation motives but by operational needs such as training and executing military missions.

With regard to operations in the Netherlands, the SESAR concept addresses these issues and has proposed the steps needed to satisfy all airspace users.

The ATM situation in the Caribbean (i.e. Aruba and Netherlands Antilles) is more linked to NextGen since it is partially located in the NAM and CAR/SAM area. Due to the geographical location, the ATM environment comprises areas in which no radar coverage is currently available and poses other navigational requirements than in Europe.

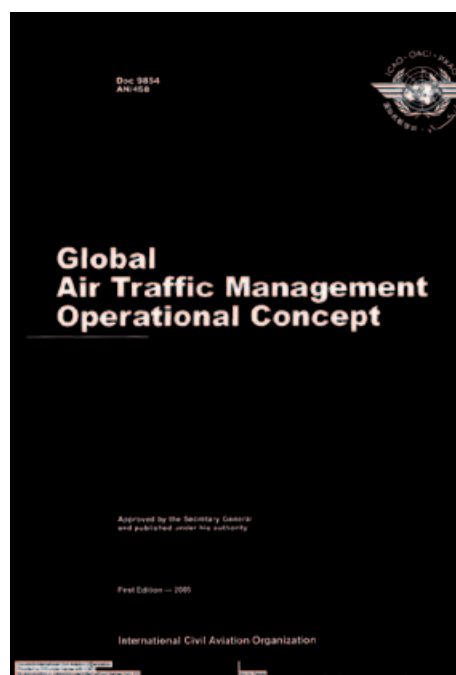
For the Kingdom of the Netherlands as a whole, it is evident that an increase in capacity of the ATM system is needed to accommodate future traffic flows as well as increasing flight efficiency. A fundamental change lies within environmental objectives which are becoming increasingly more important.

Aviation history has shown that the introduction of new navigation requirements from definition to implementation can take up to 20 years. Examples include amongst others RNAV, MLS and GNSS. The development of a vision for future navigation requirements and associated actions needed, can shorten the introduction. The Roadmap contained in this document describes the vision and action plan.

The [Ref. 19, ICAO Global ATM operational concept] provided the basis for the introduction of PBN and outlines the technical recommendations regarding navigation, harmonisation and transitioning towards satellite navigation, curved RNAV approaches and implementation of APV to replace NPA (Non-Precision Approach) which lack vertical

guidance. By accepting ICAO resolution 36-23, the Kingdom of the Netherlands is committed to drafting a PBN roadmap by the end of 2009 and to gradually implement APV procedures for relevant instrument runways by 2016. ICAO sets the following targets: 30% by 2010, 70% by 2014 and 100% by 2016.

The [Ref. 7, SESAR ATM target concept] was developed in line with the recommendations set out in the ICAO Global ATM Concept. It is SESAR's ultimate goal to allocate to each flight in the ECAC area a 4D Business Trajectory which is defined by position and time. In parallel, the [Ref. 6, Eurocontrol Navigation Strategy] calls for GNSS as the primary positioning sensor and ultimately as the sole positioning sensor. For the Caribbean area, the developments foreseen in FAA's NextGen programme are more appropriate but do not differ significantly with regard to navigation from the SESAR vision.



3 The PBN Concept



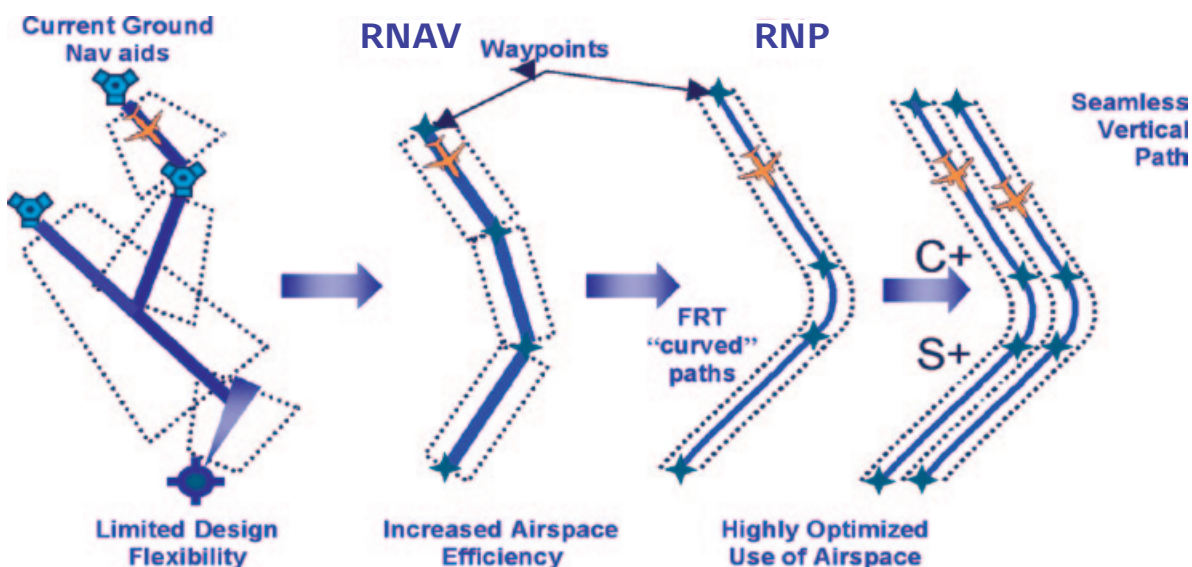
Introduction

As demand for air transportation services increases, States are faced with finding solutions to safely increase capacity, efficiency, and access, e.g. to terrain challenged airports. These constraints are largely a result of reliance upon conventional ground based navigation aids (e.g., VOR, DME, NDB, ILS), which limit routes and procedures to the physical locations of ground-based navigation aids. These ground-based systems have served the aviation community well since inception; however, they do not permit the flexibility of point-to-point operations available with PBN to meet the challenges of today and the future.

The illustrations depict the constraints associated with conventional, ground-based sensor specific routes/procedures and the flexibility and benefits of performance based, non-sensor specific navigation (both RNAV and RNP).

Performance requirements are identified in navigation specifications, which also identify the choice of navigation sensors and equipment that may be used to meet the performance requirements. These navigation specifications provide specific implementation guidance for States and operators in order to facilitate global harmonization.

Figure 3-1 Comparison between conventional navigation via ground-based nav aids, RNAV to RNP to PBN.



The [Ref.18, ICAO PBN Concept] specifies that aircraft RNP/ RNAV system performance requirements be defined in terms of accuracy, integrity, availability, continuity and functionality required for the proposed operations in the context of a particular airspace concept, when supported by the appropriate navigation infrastructure. In that context, the PBN concept represents a shift from sensor-based to performance based navigation based on criteria for navigation accuracy, integrity, availability, continuity and functionality.

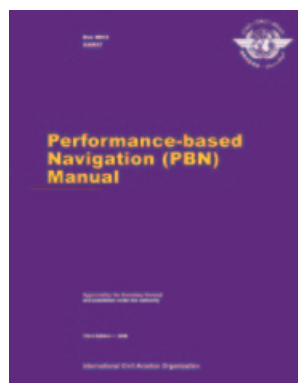
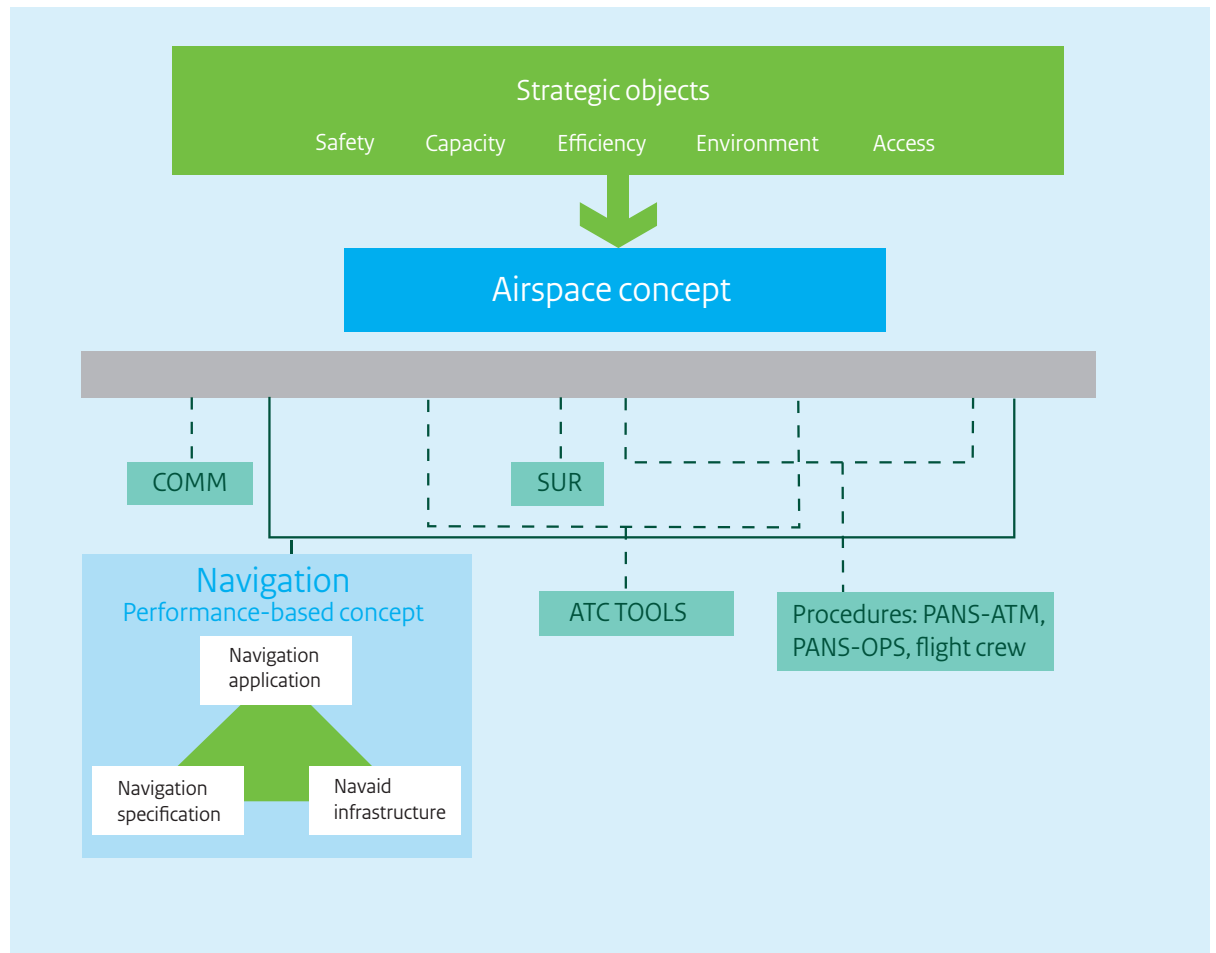


Figure 3-2 Context of PBN as technological enabler for achieving strategic ATM objectives [Source: ICAO PBN Manual].



Context of PBN

Strategic objectives drive the general vision of the airspace concept. These objectives are identified by civil and military airspace users, civil and military ANSPs, airports as well as environmental and government policy. Strategic objectives put requirements on various enablers of an airspace concept such as Communications, ATS surveillance, ATM (see Figure 3-2).

For the future Dutch ATM system strategic objectives have been formulated by the Ministry of Transport, Public Works and Water Management in the [Ref. 21, “Luchtvaartnota”]¹. Chapter 4 elaborates on this document in relation to PBN.

Focussing on the enabler **NAVIGATION** in the figure above, there are three components for the application of PBN:

- 1 The navaid infrastructure
 - VOR, NDB, DME, TACAN, ILS, MLS and GNSS
- 2 The navigation specification
 - RNAV specifications: RNAV 10, RNAV5, RNAV2, RNAV 1
 - RNP specifications: RNP4, Basic-RNP 1, RNP APCH, RNP AR APCH
 - The navigation specification is used by a State as a basis for the development of their material for airworthiness and operational approval. A navigation specification details the performance required of the RNAV system in terms of accuracy, integrity, availability and continuity; which navigation functionalities the RNAV system must have; which navigation sensors must be integrated into the RNAV system; and which requirements are placed on the flight crew.

¹ The scope of the “Luchtvaartnota” is the development of civil aviation, however, where relevant, developments with regard to military aviation are also included.

- With regard to RNAV and RNP specifications it is essential to understand the difference. On-board performance monitoring and alerting is the main element that determines if the navigation system complies with the necessary safety level associated to an RNP application; it relates to both lateral and longitudinal navigation performance; and it allows the aircrew to detect that the navigation system is not achieving or cannot guarantee with a certain level of integrity, the navigation performance required for the operation. RNP systems provide improvements on the integrity of operations and this may permit closer route spacing. This allows only RNP systems to be used for navigation in a specific airspace. The use of RNP systems may therefore offer significant safety, operational and efficiency benefits.

Applying the above components in the context of the airspace concept to ATS routes and instrument procedures results in the navigation application shown below. Note that the current Basic-RNP 1 navigation specification is not allowed for the final approach. The final approach segment can only be flown when the aircraft is either certified for RNP APCH or RNP AR APCH operations.

Table 3-1 Overview of the navigation application as defined in the ICAO PBN Manual. The figures shown represent the 95% total system accuracy requirement in NM.

NAVIGATION SPECIFICATION	FLIGHT PHASE							
	En Route Oceanic / Remote	En Route Continental	ARR	APPROACH				DEP
				Initial	Intermed	Final	Missed	
RNAV 10 (RNP 10)	10							
RNAV 5		5	5					
RNAV 2		2	2					2
RNAV 1		1	1	1	1		1	1
RNP 4	4							
Basic-RNP 1			1	1	1		1	1
RNP APCH				1	1	0.3	1	
RNP AR APCH				1 - 0.1	1 - 0.1	0.3 - 0.1	1 - 0.1	

Summary of PBN Navigation Specifications

With regard to PBN, EASA is responsible for drafting and formalising European standards with regard to navigation [Ref. 3-5, EASA AMC 20-26/27/28].

The table below shows the main characteristics of the currently defined PBN Navigation Specifications. For details refer to [Ref. 18, ICAO PBN Manual].

Table 3-2 Details for each PBN navigation specification.

PBN Navigation specification	On board performance monitoring & alerting	RF path terminator in functional requirements	Navigation accuracy (on final approach)	EASA regulation/ standard	Remarks
RNAV 10			10 NM	AMC 20-12	
RNP 4	✓		4 NM	No doc	GNSS required
RNAV 5			5 NM	AMC 20-4	B-RNAV
RNAV 1			1 NM	AMC 20-16 ¹	P-RNAV
B-RNP 1	✓		not defined	No doc	GNSS required
A-RNP 1	✓	ICAO PBN "to be developed"	not defined	No doc	ICAO PBN "to be developed"
RNP APCH				AMC 20-27 ²	- GNSS required - RNAV (GNSS)
- NPA - APV Baro-VNAV	✓				
- APV SBAS I - APV SBAS II			0.3 NM	AMC 20-28 ³ (currently in review phase)	LPV using SBAS (e.g. EGNOS for EUR region, WAAS for US region)
RNP AR APCH - APV Baro-VNAV	✓	✓	0.3 - 0.1 NM	AMC 20-26 ⁴	- GNSS required - RNP SAAAR (USA)

¹ AMC (Acceptable Means of Compliance) 20-16 replacement of JAA TGL10 (PRNAV). Under development

² AMC 20-27 containing the AMC for the Airworthiness Approval and Operational Criteria for RNP APPROACH (RNP APCH) Operations Including APV/ Baro-VNAV Operations.

³ AMC 20-28 containing the AMC for the Airworthiness Approval and Operational Criteria for Area Navigation (RNAV) for Global Navigation Satellite System (GNSS) approach operation to Localiser Precision with Vertical Guidance (LPV) minima using a Satellite Based Augmentation System (SBAS).

⁴ AMC 20-26 containing the AMC for the Airworthiness Approval and Operational Criteria for Required Navigation Performance (RNP) Authorisation Required (RNP AR) Operations.

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4 PBN and the Dutch Aviation Policy



4.1 Dutch Aviation Policy

For the future Dutch ATM system strategic objectives have been formulated by the Ministry of Transport, Public Works and Water Management in the “Luchtvaartnota”. This document contains a vision on aviation for the next twenty years as well as objectives and required developments in the ATM domain. The “Luchtvaartnota” is based on three pillars: to compete, to accommodate and to excel.

Since these objectives have an impact on the airspace concept, of which navigation (PBN) is one of the technological enablers, a summary of the three main objectives of this vision is given below:

1 Objectives for “Accommodation by means of airspace access”

- Development of ATM concept of operations that can accommodate the high traffic density at Schiphol to further strengthen mainport Schiphol’s network function
- Accommodation of traffic that does not directly contribute to strengthening Schiphol’s hub function at airports of national importance (e.g. Lelystad, Eindhoven)
- Accommodation of military mission and exercises
- Accommodation of general aviation
- Cost reduction for airlines through efficient routing and optimal flight profiles
- Minimise CO₂ emission and noise hindrance

The required ATM developments for this objective include:

Redesign airspace and route network

- Advanced application of flexible use of airspace by means of dynamic airspace sectorisation. Airspace segments are temporarily allocated based on the civil demand and need for airspace to accommodate military missions and/or exercises
- Definition of an additional (civil) route to South-east and military Cross Border Area (CBA) in the East of the Netherlands
- Simplified route structure for accommodating flight to/ from Schiphol in combination with improved traffic flows from/to Lelystad and Eindhoven airport. This requires airspace and route modification as well as optimisation of airspace planning and allocation process

Redesign of the ATM concept of operations

- Current objectives:
 - Operational concept based on the most efficient route, i.e. shortest route with minimal emission and noise. This can only be achieved by means of an international mandate for the required navigation

and communication equipment

- Realisation of procedures and technical support for all weather operations
- Introduce CDAs using fixed routes

• Objectives for the Mid-term (up to 2020):

- In general, the goal is simplification of the route structure, concentration of routes and to introduce fixed routes for Schiphol, Eindhoven, Lelystad and Rotterdam to enable optimised climb and descent profiles (CDAs)
- Implementation of optimal CDAs for the majority of arrivals during night-time as well as day-time operations and may include an increase of the transition altitude

• Objectives for the long-term (2025+):

- ATM concept based on planned 4D-trajectories as foreseen in SESAR which are supported by e.g. reliable (satellite-based) navigation systems and advanced aircraft separation systems

2 Objectives for “Excel in the reduction of emission and noise hindrance”

In the Covenant “Geluidshinder” a number of ATM developments are currently being considered for implementation and are directly related to PBN:

- Fixed arrival routes
- CDAs
- Improvement of the predictability of traffic flows
- Route optimisation by e.g. arrivals via North-sea and parallel SIDs
- Fixed radius turns during arrival/departures to ensure minimal track dispersion and to define arrival/ departure routes to avoid overflying populated areas

3 Objectives for “Accommodation of General aviation”

It is the government’s aim to ensure that general aviation users are accommodated. Specific ATM requirements from the “Luchtvaartnota” include:

- Business aviation: improve navigational support by e.g. GPS-based approaches to increase airport access
- General aviation: development of avionics to increase situational awareness of pilots

In addition to the “Luchtvaartnota”, the Kingdom of the Netherlands agreed to ICAO resolution A36-23 to gradually replace NPA by APV procedures (30% by 2010, 70% by 2014 and 100% by 2016).

4.2 Expected benefits of PBN in the Kingdom of the Netherlands

PBN defines both lateral and vertical navigation for both straight and curved flight paths, and will be used for the next generation air traffic systems.

The extend of actual benefits listed below that can be achieved depend on the airspace configuration, type of airport and traffic mix and the implementation of other enablers in the CNS/ATM domain.

Safety

- PBN reduces the risk of Controlled Flight Into Terrain (CFIT) accidents by providing a very precise lateral and vertical flight path according to [Ref. 16, Eurocontrol APV Baro Safety Assessment]
- PBN provides consistent, stabilised approaches to all runway ends, which is a significant benefit for smaller airports that lack the capability for precision approaches
- The increased pilot situational awareness further enhances the safety level of operations

Environment

- PBN routes may be more direct, reducing the track miles flown, which means lower fuel use and lower emissions. This benefit is generally easier to realise for the en-route phase however possibilities do exist for the terminal area
- PBN is an enabler for Continuous Descent Operations (CDO¹) since a fixed lateral path is needed. CDOs reduce noise hindrance, fuel burn and emission levels. At Schiphol, the period in which CDAs are flown is planned to be extended and other airports may start implementing CDAs as well
- PBN-based procedures offer more flexibility to define approach and departure routes in order to avoid populated areas and reduces track dispersion. This is of particular importance for Schiphol but also for all other airports
- Indirectly, the reduction in emission through enhanced route design and usage provides a path for airline growth when the Emission Trading Scheme (ETS) for aviation is implemented

Capacity and efficiency

- APV procedures facilitate approaches to runways that currently do not have a straight-in approach, e.g. Schiphol runway 24

- Nearly all runways in the Netherlands have a conventional NPA procedure either as back-up or primary approach. The APV procedures with vertical guidance may lead to lower landing minima, thus increasing the use of a runway during lower visibility operations or in the event of an unserviceable ILS. In turn this can reduce the number of diversions
- PBN is an enabler for independent parallel approaches and/or departures at Schiphol
- Enables closely spaced parallel tracks in the en-route segment as well as Fixed Radius Transitions (FRT) for increased fuel efficiency, increased airspace capacity and reduced flight time variance
- PBN poses more flexibility for route design in view of the redesign of the airspace in the Netherlands. PBN may reduce airspace conflicts between adjacent airports and some cases between civil routes and airspace used by the military
- Reduction of controller workload due to predictable traffic flows and potential for less dependencies in inbound-outbound traffic flows and less need for radio communication
- RNAV or RNP-based holdings may require a smaller amount of airspace
- The final approach segment can be designed closer to the airport through usage of RF-legs
- GNSS-based final approaches (e.g. GBAS or SBAS LPV) eliminates the need to safeguard ILS protection areas. When the ILS protection areas do no longer exist then the runway can be declared vacated earlier. This reduces the runway occupancy time which in turn may lead to an increase in landing capacity

Infrastructure cost and maintenance

- In view of the replacement of conventional NPAs by APV Baro-VNAV procedures, PBN enables a gradual decommissioning of conventional nav aids such as NDB and VOR. This leads to cost reduction for the users due to eliminating costs for procurement and maintenance.
- In case of GBAS: installation does not need to be installed near runway, one GBAS installation can replace several ILSs and GBAS facilitates flexible procedures for approach and departure. This can benefit smaller airports with little or no conventional nav aid infrastructure.

Interoperability

- PBN and the gradual transition towards GNSS-based RNAV environment is one of the main pillars of the SESAR/NextGen concept which in turn aids in achieving ICAO's Global ATM Concept.

¹ ICAO has formalised the terminology for procedures that facilitate an idle descent in [Ref. 20, ICAO Manual for Continuous Descent Operations]. Although the terminology commonly used in the Netherlands (CDA) is not used in the manual, CDO can be considered to be the same as CDA. ICAO decided to replace the terminology to avoid confusion with CDFA (Continuous Descent Final Approach) which only applies to the final approach segment.

Military mission Effectiveness

- The KPA “Mission effectiveness” requires flexibility to enable last minute airspace changes, unhindered use of training airspace and maximum flying distances of 100 NM between training area and the airbase concerned. PBN may be able to facilitate a more flexible and/or optimal routing.

5 PBN developments for The Netherlands

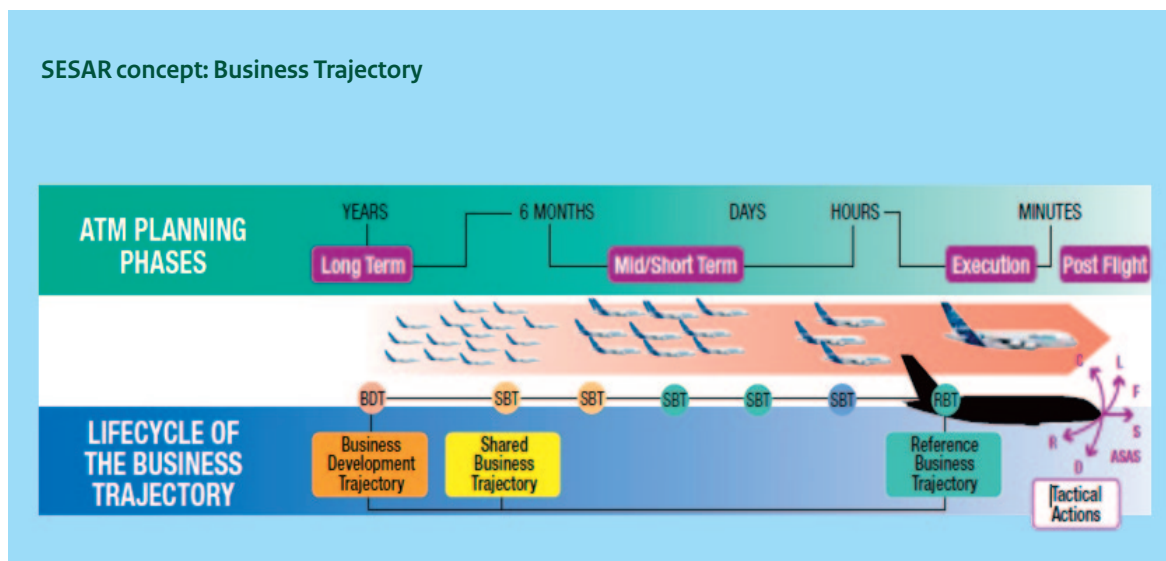


5.1 En-route

Current situation

In 1998, B-RNAV became mandatory as the primary means of navigation in all ECAC en-route airspace from FL95 and above; VOR/DME remained available for reversionary navigation and for use on some Domestic ATS routes in the lower airspace.

are already capable of flying RNAV1. By adding airborne performance monitoring and alerting functionality to RNAV 1, Basic RNP-1 capability will be achieved. Ultimately, A-RNP1 with RF leg capability within the TMA, Fixed Radius Transition in the en-route segment and Required Time of Arrival (RTA) functionality is needed to cater for 4D Business Trajectories.



Future vision

The development of the en-route segment in the FIR AMS above FL245 should be in line with European developments. [Ref.22, ICAO EUR PBN TF] states that due to the large diversity of the EUR region it is expected that a single RNAV or RNP navigation specification will not be applicable throughout the region. Therefore different implementations of RNAV and RNP navigation applications and associated specifications may be applied by different homogeneous ATM areas.

Below FL245, the NL TF PBN anticipates that RNAV5 (current B-RNAV) is gradually being replaced by RNAV 1 due to developments in the TMA and the fact that the many aircraft

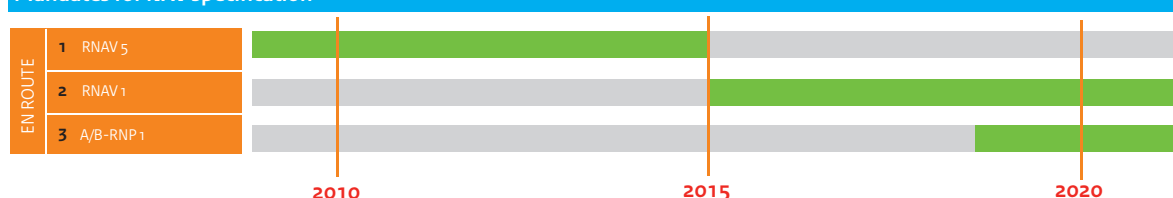
Roadmap

The figure below represents the proposed schedule for mandates for navigation specifications pertaining to the en-route phase.

Referring to the roadmap below:

- 1 RNAV5 will be gradually phased out since it will be followed-up by RNAV 1
- 2 In 2015 RNAV 1 is expected to become mandatory for all IFR flights in the FIR AMS. This applies to IFR flights at and above FL95 since this is already regulated at European level (B-RNAV) and to exempt recreational GA IFR flights. The requirement for the en-route is based on the PBN specification for the terminal area to allow a seamless transition. Refer to Section 5.2 where from 2012 onwards, RNAV 1 is mandated in all TMAs for all IFR flights with a temporary exemption for propeller aircraft.

Mandates for NAV specification



- 3 In 2018 B-RNP1 or A-RNP1 (pending the definition of the navigation specification) is expected to become mandatory for all IFR flights. This applies to IFR flights at and above FL95 to exempt recreational GA IFR flights.

Notes:

- The above timeline sets targets for the regulatory framework to facilitate the foreseen changes to the ATM system. Dates for the actual implementation of e.g. parallel en-route airways remain yet to be determined.
- State Aircraft are exempt from any mandates and/or requirements proposed in this Roadmap. However, the military strives towards implementing navigation equipment in line with the Roadmap where it benefits the militaries albeit with some years delay.

5.2 Terminal Area

Current situation

From 26 October 2006, P-RNAV approval requirements during night-time became effective in the Schiphol TMA. Currently, during night-time (23.00–06.30 LT) P-RNAV (cf. RNAV 1 in PBN terminology) transitions are compulsory for all jet aircraft.

The P-RNAV transitions contain a short CDA segment which reduces noise footprint and reduces fuel consumption for airlines.

During daytime operations RNAV 1 is not mandatory although according to [Ref. 15, ADSE Survey of EHAM operators] approximately 81% of traffic to/from Schiphol holds an operational approval for P-RNAV operations in the TMA. At least 7% is not capable and includes 6% turboprops.

At least 5% is unknown, but estimated to be capable. For 7% the capability is unknown. This suggests that the current aircraft fleet operating at Schiphol that is capable of performing RNAV 1 nears 90%. In order to minimise operations with aircraft that have mixed navigational capabilities, ATC requires a specific minimum aircraft equipage level.

With respect to GA terminal operations, a distinction is made between:

- GA VFR: Visual navigation using a VFR flight chart. The introduction of PBN does not change this since the PBN Roadmap only addresses IFR operations. Occasionally an ADF is used for orientation purposes but in most cases a (hand-held) non-TSO compliant GPS unit is used. Due to the gradual phasing-out of NDBs the ADF will become obsolete.
- GA IFR: The majority of aircraft will fly an (ATS) route from one navaid to another and aircraft may not be RNAV capable.
- Business aviation: Business aviation generally operate IFR flights and are equipped FMS LNAV/VNAV functionality and are able to comply with PBN standards.

The above illustrates that the avionics suite of GA airspace users varies and this has to be taken into account when setting dates for mandates and decommissioning navaids.

Future vision

Due to the high level of P-RNAV (RNAV1) capability, the mandatory use of RNAV 1 in most TMAs (at least in the Schiphol TMA) will be the first step towards more accurate, reliable navigation and more flexibility in route design.

Case: P-RNAV transitions in TMA

- Case: P-RNAV transitions in TMA Schiphol TMA during 2300-0630 LT
- Noise reduction
- Less fuel burn
- Predictable traffic flows



Case: fixed radius turn during SID SPL RWY 24

- Experimental Phase
- Reduction of noise
- Predictable traffic flows
- Less track dispersion



Regarding approach operations during daytime, no routes are defined as radar vectoring is applied when arriving at the Schiphol IAFs.

The use of Required Time of Arrival (RTA) is expected to be introduced from 2015 onwards to facilitate 4D Business Trajectories foreseen in SESAR.

In the longer term, A-RNP¹ with RF leg capability is expected to be required to perform independent parallel CDA operations as well as closely spaced independent parallel SIDs.

With regard to GA IFR operations; it is anticipated that the introduction of PBN will gradually replace conventional routes by RNAV routes. Potentially this may lead to more efficient routing which in turn may lead to cost reductions. At an international level, new requirements based on GNSS and/or DME/DME may become available for GA IFR users. This will most likely require investments by the GA IFR community. Furthermore, as long as IFR training requirements include navigation using conventional nav aids a number of nav aids will be maintained at selected airports.

Roadmap

The figure below represents the proposed schedule for mandates for navigation specifications pertaining to the terminal area.

Referring to the roadmap above:

- 1 RNAV 1 is currently mandatory during night-time operations at Schiphol. In 2010 the mandatory period for RNAV 1 (current P-RNAV) for approach operations in the

Schiphol TMA will be extended on an experimental basis² from 23.00-06.30 to 22.00-06.30 LT. RNAV 1 transitions facilitate CDA operations at Schiphol.

- 2 In 2012 RNAV 1 is mandatory for all IFR traffic in all TMAs with a temporary *exemption for propeller aircraft*. RNAV 1 facilitates the development of e.g. RNAV-based arrival and approach paths as well as RNAV SIDs.
- 3 In 2015 RNAV 1 is mandatory *for all IFR traffic* in all TMAs.
- 4 In 2018 A-RNP³ is mandatory for all IFR traffic in all TMAs and en-route. This also implies that mandatory carriage of GNSS is needed.

The navigation specification for A-RNP1 is not yet drafted by ICAO. Alternatively, instead of A-RNP1, the use of RNAV 1 with RF-legs may also be able to cover most operational needs. This alternative will be pursued by the Netherlands for noise abatement purposes.

From 2020 onwards A-RNP1 with RTA will facilitate 4D Business Trajectories. Besides navigation, also Arrival Management and planning tools for ATC will be required to efficiently utilise fixed routes.

Notes:

- The above timeline sets targets for the regulatory framework to facilitate the foreseen changes to the ATM system. Dates for the actual implementation of e.g. fixed inbound routes remain yet to be determined.
- State Aircraft are exempt from any mandates and/or requirements proposed in this Roadmap. However, the military strives towards implementing navigation equipment in line with the Roadmap where it benefits the militaries albeit with some years delay.

² Following Advice of Table of Alders for medium term development of Schiphol (Oct 2008).

³ Although no navigation specification is yet available, it is anticipated that the A-RNP1 specification includes RF-leg capability.

¹ The ICAO PBN manual currently does not contain navigation specification for A-RNP1.

5.3 Approach and Landing

Current situation

The survey [Ref. 15, ADSE Survey of EHAM operators] showed that 46% of traffic to/from Schiphol holds an operational approval for RNAV (GNSS) approaches. This is equivalent to RNP APCH⁴. Currently only RNAV transitions are published for Schiphol and Maastricht-Aachen Airport.

These figures are expected to rise to 53% in 2010 due to fleet replacements and aircraft that already having airworthiness approval also receiving operational approval.

Approximately 10% of traffic currently has airworthiness approval but no operational approval. Approximately 26% of the traffic is presently not capable of RNAV (GNSS) approaches. This percentage is decreasing and is expected to fall to 23% in 2010. For 6% of the aircraft, their capabilities are unknown but they are estimated to be capable.

Nearly all the traffic approved of carrying out RNAV (GNSS) approaches also has approval for APV Baro-VNAV. Only around 3% of the total traffic is approved for RNAV (GNSS) approaches but not for Baro-VNAV.

This is to show that a gradual increase in RNP APCH capability can be expected, although for a viable implementation higher equipage levels are required.

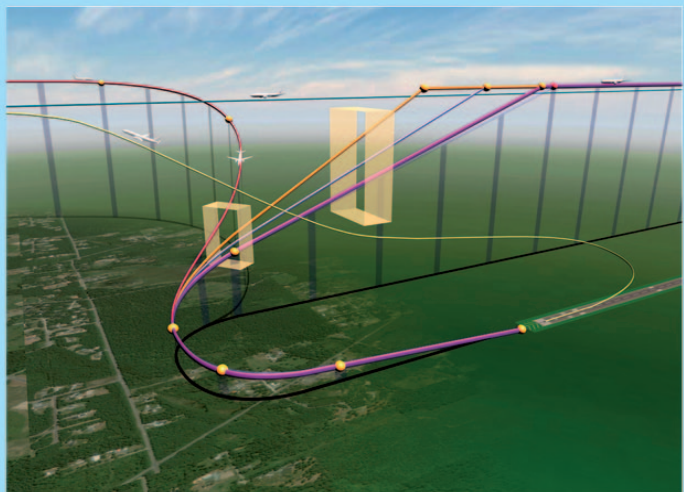
In total approximately 43 NPA procedures are published in the AIP Netherlands. These conventional NPAs serve either as a back-up procedure in case of an unserviceable ILS or as a primary approach procedure for non-ILS equipped runways.

With respect to GA approach and landing operations, a distinction is made between:

- GA VFR: the PBN roadmap addresses IFR operations and therefore does not impact GA VFR operations.
- GA IFR: A mix of capabilities exists. The majority will be able to conduct either VOR/DME/NDB approaches, some will have ILS installed, some will have a TSO-129 certified GPS receiver with waypoint functionality to conduct RNAV (GNSS) NPA approaches and a large amount will have a non-TSO compliant (hand-held) GPS unit installed which cannot be used for IFR approaches.
- Business aviation: Business aviation generally operate IFR flights and are equipped with ILS, FMS LNAV/VNAV (APV Baro-VNAV) and/or FMS LPV (APV SBAS) functionality to conduct approaches. Significant investments are therefore not expected. It is however possible that additional requirements apply to training of flight crew and documentation.

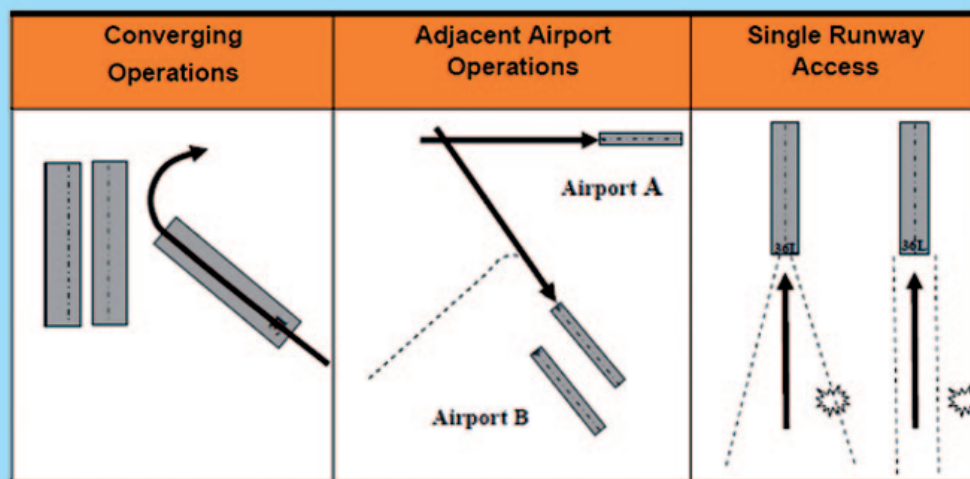
Case: continuous descent approach (CDA)

- Implemented at Schiphol since 2006 during night-time operations
- Reduction of fuel burn, emission and noise
- Predictable traffic flows and less R/T for ATC / pilots



⁴ RNAV (GNSS) procedures require a TSO-C129 compliant GPS receiver which has an alarm limit of 0.3 NM. This is in line with on-board monitoring and alert (RNP) requirements although approach charts continue to use RNAV (GNSS).

Case: Applications RNAV /RNP in approach phase



Future vision

In general, the safety of approaches to airports without ILS (or as back-up procedure for unserviceable ILS) is enhanced by replacing conventional non-precision approaches (NPAs) with APV procedures that offer vertical guidance according to [Ref. 16, Eurocontrol APV Baro Safety Assessment]. In line with the ICAO resolution it is foreseen that for all relevant instrument runway ends APV Baro-VNAV and/or additionally APV SBAS procedure are available by 2016.

Airport access, particularly during low visibility conditions, may be further increased by using technology such as enhanced ILS or MLS or GLS (GBAS).

ILS remains the prime source of guidance for precision approaches and landings.

Moreover, ILS is currently the only system available for CAT

II/III operations. In cases where ILS can not be installed or is not available the use of GBAS may be considered. Initially for CAT I operations and in a later stage for CAT II/III operations. In the long-term, aviation will rely on GNSS only. However, this requires a complete mitigation of GNSS vulnerability issues. One can distinguish between GNSS as primary means of navigation and GNSS as sole means of navigation.

GNSS as primary (but not the only) means of navigation

GNSS is currently used as a primary means of navigation. Like any radio navigation system, GNSS signals are vulnerable to (intentional) electromagnetic interference.

FAA commissioned several studies including John Hopkins University and John A. Volpe National Transportation

Case: SBAS (EGNOS)

- Improved horizontal and vertical accuracy
- Potential for near Cat I performance and curved approaches
- Solution for airports with no, or limited, navaid infrastructure
- Equipment:
 - ground: none
 - airborne: SBAS rx



Example: certified GPS receiver for GA IFR

- GPS 155XL TSO
- TSO C-129 certified
- NO SBAS
- Unit cost: ≈ €2500,-



- GNS 430W
- TSO C-146a certified
- NAV / COM
- SBAS
- Unit cost: ≈ €6000,-



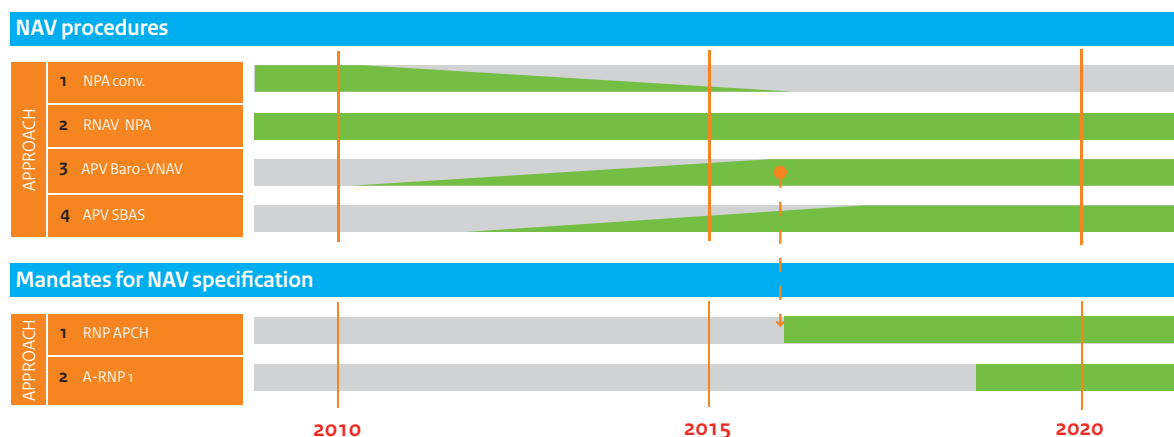
Systems Center to assess the vulnerability of GPS. It was concluded in 2001 that the vulnerability of GPS can be mitigated by a number of measures. These include operating procedures, pilot and ATC training, awareness of GPS characteristics and the availability of additional airborne equipment such as IRS and ABAS, augmentations such as SBAS, the on-board monitoring and alerting provided by RNP systems as well as a fall-back to a ground-based navigation infrastructure such as DME/DME.

GNSS as sole (only) means of navigation:

The previously mentioned vulnerability currently may prevent the sole use of GNSS for critical applications such as final approach. With the advent of GALILEO, multi-constellation GNSS will be available which may reduce the probability that both systems fail due to (intentional) interference. Since GALILEO signal characteristics are similar to GPS, the vulnerability of each system continues to exist. As long as GNSS vulnerability issues have not been mitigated satisfactory, sole means GNSS navigation is not feasible. The approach phase and landing aids are separately detailed below.

Roadmap for the approach phase

The approach phase of flight covers the route from the Initial Approach Fix (IAF) to the FAP/FAF or runway threshold depending on the approach type. Landing aids for Cat I/II/III operations (i.e. ILS, MLS, and GLS) are described following the approach phase.



The figure above represents the timeline for proposed navigation procedures and the mandates for navigation specifications.

Referring to the two roadmaps below:

- 1 Gradual phase-out during 2010-2016 of conventional NPAs such as VOR and NDB without vertical guidance. To be replaced by APV Baro-VNAV (and/or additionally APV SBAS) to include vertical guidance.
- 2 RNAV NPA will be maintained as a fall-back for LNAV/VNAV, for example in case of VNAV failure or cold temperature.
- 3 From 2010 to 2016 publication⁵ of APV Baro-VNAV procedures for relevant instrument runway ends at Schiphol and other airports.
Airlines will require an approval for RNP APCH operations to conduct APV Baro-VNAV and/or APV SBAS approaches, hence a mandate for RNP APCH is foreseen for 2016 (see roadmap "Mandates for NAV specification").

Notes:

- The operational consequences due to the availability of both conventional NPA (NDB or VOR) and APV Baro-VNAV are currently assessed by LVNL. Results are expected early 2010.

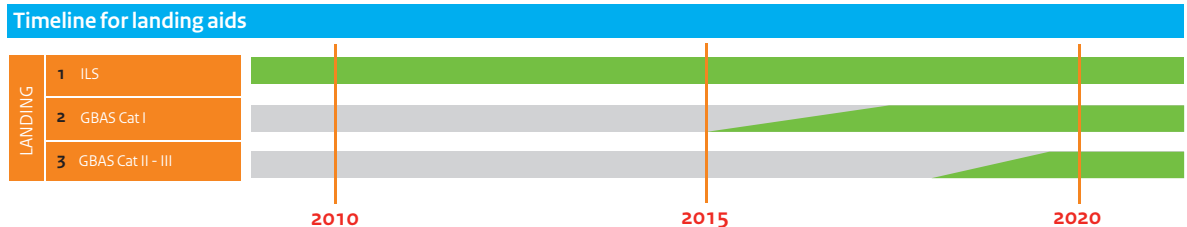
- 4 From 2010 onwards, the EGNOS infrastructure is expected to be fully available⁶ to support SBAS operations, however to benefit from EGNOS a dedicated SBAS receiver is required. Actual timescale for SBAS introduction depend on cost-benefit analysis for airlines and GA IFR user community. These results are currently not known. However, to cater for aircraft (airlines as well as GA IFR) which are equipped with SBAS avionics, APV I procedures on SBAS (EGNOS) are published from 2012 onwards for dedicated instrument runway ends (to be determined) at Schiphol and other airports. The Cat I functionality which is to be provided by EGNOS APV II (200 ft DH) is still under development and may prove to be advantageous for specific airports (to be determined).

⁵ Publications should be in-line with ICAO APV resolution; 30% by 2010, 70% by 2014 and 100% by 2016. Note: the percentages apply to the Kingdom of the Netherlands.

⁶ Pending certification against SES criteria of the EGNOS Service Provider. The Declaration of Verification of EGNOS is expected in June 2010.

Roadmap for the landing phase

Regarding landing aids, the following timeline is foreseen:
Referring to the roadmap below:



- 1 ILS will remain the primary precision (Cat I-III) landing aid.
- 2 GLS Cat I applications are expected to be gradually introduced onwards from 2015. If e.g. curved final approaches during LVP (Low Visibility Procedures) are required then GBAS could be considered, but this currently requires RNP AR APCH approval. GBAS Cat I installations are commercially available and have been installed at some airports (e.g. Bremen and Toulouse airport) and are awaiting operational approval for airlines.
- 3 The application of GLS as Cat II/III landing system can become relevant in case the ILS Cat II/III status of particular runways can no longer be upheld. It is the view of the TF PBN that certified GLS Cat II/III installations and operational experience is not available before 2020. GLS Cat I/II/III will be considered when a multi-constellation (GPS & Galileo) is available to reduce the risk of failure of one of the two failing GNSS constellations. This is also expected 2020+.

Notes:

-The application of MLS is not foreseen in the Netherlands because ILS is expected to be replaced by GLS in the long-term.

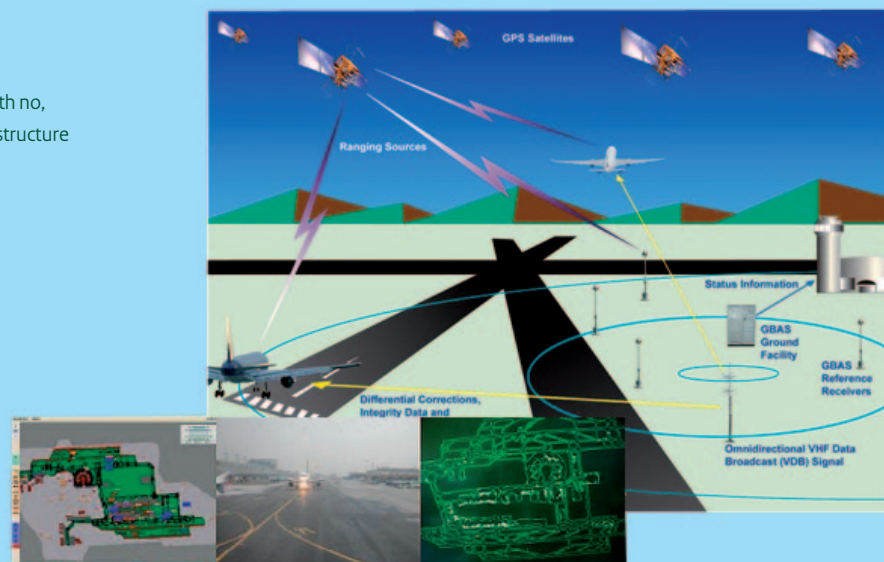
5.4 Ground

Current situation

During most low visibility conditions, the ATC ground capacity is a bottleneck in the total airport capacity. Deploying Transponder Multilateration with ground labeling has already proven to increase ground capacity at Schiphol under low visibility conditions. During Low Visibility Conditions (LVC) Phase A the ground capacity increased from 70 to 80 movements per hour and during LVC Phase B from 70 to 74 [Ref. 17, LVNL Concept of Operations]

Case: GBAS

- Solution for airports with no, or limited, navaid infrastructure



Due to characteristics of ILS, operational measures need to be taken to assure that the ILS localiser/glide slope signals are not disturbed by aircraft and/or vehicles. This leads to an increased separation on final which in turn reduces the landing capacity.

Future situation

Improving the pilot's and controller's situational awareness of aircraft and/or vehicles on the ground can be achieved by e.g. a multilateration system using SSR mode A/C/S transponder transmissions or ultimately ADS-B using GBAS as a positional sensor. On the other hand, given the significant requirements for both ground-based as well as airborne-based equipment needed to conduct ADS-B with GBAS sensory input, it is not expected to be available at airports and aircraft before 2020. An intermediate step is to use GBAS positional input in EFB (Electronic Flight Bag) functions to allow for extremely accurate navigation on taxiways as a means of guidance. This will depend on a Cost-Benefit Analysis of stakeholders.

5.5 Navaid Infrastructure

Current situation

The ground-based navaid infrastructure consists of NDB, (D)VOR, DME and TACAN and serves the following functions:

- Holding fixes
- En-route ATS structure
- Conventional Non-Precision Approach (NPA) procedures as primary IFR capability of non-ILS equipped airports
- Back-up procedure for unserviceable ILS
- Definition of departure and arrival routes

Future situation

In the table below a summary is given per phase of flight of applicable criteria for decommissioning navaid beacons:

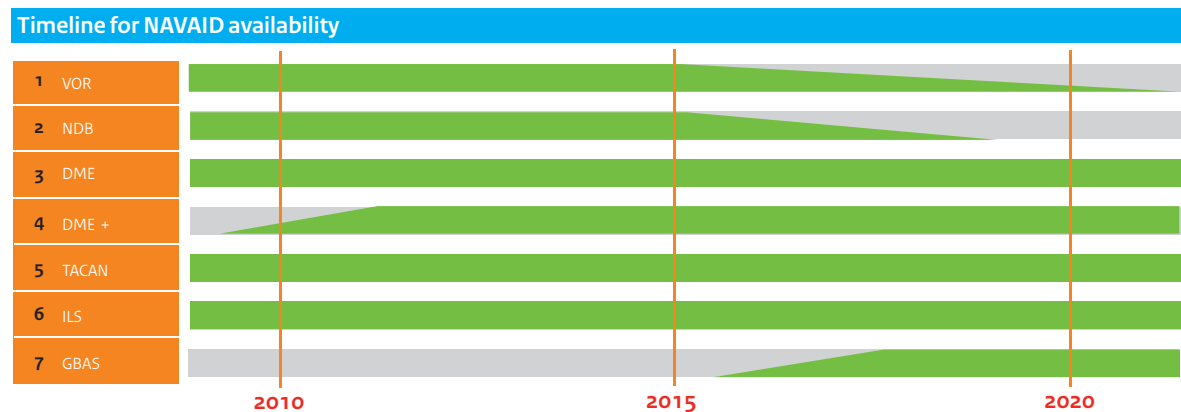
In general, each navaid beacon needs to be evaluated for its function in the approach/departure procedures and whether an alternative procedure is possible. Following this evaluation, the above criteria determine whether or not a navaid beacon can be decommissioned.

In the previous sections the PBN objectives were defined. These objectives need to be supported by a corresponding navaid infrastructure.

	Conventional Procedures	Replacement Procedures	Withdraw of the conventional procedures possible if:	Decommissioning of VOR and NDB if:
En-route	Conventional ATS routes	RNAV routes	Now possible.	Now possible
Terminal	Standard Instrument Departures (SID)	RNAV departures	RNAV 1 mandatory	RNAV 1 mandatory
Approach & landing	Conventional Non-precision approach procedures (NPA)	APV/Baro-VNAV approach procedures or Fall back RNAV(GNSS) NPA	RNP APCH mandatory or A-RNP1 mandatory (not before 2018-2020)	RNP APCH mandatory or A-RNP1 mandatory (not before 2018-2020)

Roadmap

Regarding the availability of navaids, the following timeline is foreseen:



Referring to the roadmap above:

1+2 Relates to PBN Objective 2010-2016 replacement of conventional NPA procedures by APV procedures (§5.3)

Eurocontrol's vision is that, in the existing B-RNAV environment in ECAC, the retention of conventional routes/navigation aids is necessary to provide a reversionary capability for those aircraft equipped with a single RNAV system. When all aircraft are equipped with dual RNAV systems and are operating in a P-RNAV, or better, environment, it will be possible to withdraw all of the conventional route structure. The PBN believes that the above statement does not warrant maintaining a navaid (VOR/NDB) beacon which only serves en-route procedures. Therefore, such beacons can be phased-out now.

A navaid (VOR/NDB) beacon which serves a conventional non-precision approach can be phased-out provided that at least RNP APCH is mandatory. A-RNP₁ mandate for all IFR traffic in all TMAs is expected in 2017.

A navaid (VOR/NDB) beacon which serves en-route procedures and also serves SID procedures can be phased-out provided that RNAV 1 is mandatory. An RNAV 1 mandate for all IFR traffic in all TMAs is expected in 2015.

Notes:

- Similar to civil aircraft, State Aircraft (i.e. NL military as well as NATO) may only be able to conduct approaches using VOR/DME as a back-up procedure for ILS and may not be able to conduct APV Baro-VNAV procedures. This shall be taken into account when setting decommissioning dates for VOR/NDB navaids.

3+4 Relates to PBN objective: 2012 RNAV 1 mandatory (§5.2)

GNSS and DME/DME are both candidate technologies providing sufficient accuracy in order to meet the RNAV 1 requirements.

This requires sufficient DME/DME coverage. Based on an assessment by LVNL it was concluded that the current DME/DME infrastructure is insufficient to provide the RNAV 1 down to 2000 ft over the entire EHAA FIR. Currently, sufficient coverage is provided in the Schiphol area but no RNAV 1 coverage is available in the North-East/East part, and the South part of the Netherlands. To provide full-redundant coverage in the Netherlands, an extension of the DME/DME infrastructure (as indicated by "DME+" in the roadmap above) with approximately 11 DMEs is foreseen. Ultimately, the number of extra DMEs could be reduced to 3 provided TACANs and/or DMEs in Belgium and Germany could be used.

Relates to PBN Objective: 2018 A-RNP₁ mandatory (§5.2)

The primary positioning sensor for A-RNP₁ operations is GNSS. It is expected that in 2018 the GNSS infrastructure will be based on the US GPS constellation. Galileo is not foreseen to be available as a fall-back GNSS infrastructure before 2018. Therefore, a full-redundant DME/DME infrastructure needs to be available. When a multi-GNSS constellation (e.g. GPS & Galileo) is fully operational and aircraft fleet readiness reaches a particular level then sole GNSS operations without a corresponding DME/DME infrastructure becomes possible. This is however foreseen for the timeframe 2020+.

⁹ All mandates to be co-ordinated at European level and pending European mandates.

5 There are no plans to decommission or replace the existing TACANs in the near future, so specific dates are not available.

6 Existing ILS installations are maintained up to 2020+

7 Relates to PBN Objective: >2015 GBAS Cat I applications (§5.3/5.4)

For Schiphol only GBAS Cat III functionality is currently seen as the only potential candidate for a replacement of the ILS⁷. However implementation is not expected before 2020. Pending further investigation GBAS positioning may provide benefits during LVP while taxiing. For other airports, where e.g. an ILS is not installed, GBAS Cat I will be considered. GBAS Cat I applications requires ground-based equipment⁸ to be installed at an airport to cater for e.g. local corrections the GPS positioning and final approach segment upload.

Notes:

- Eurocontrol is in the process of preparing Guidance Material on Rationalisation of Navigation infrastructure. This document may assist stakeholders in drafting their strategy. A first version of the guidance material will be available in 2010 for consultation at NSG level.
- Regarding the monitoring and status of GNSS coverage and DME/DME infrastructure the following requirements are contained in the ICAO PBN Manual⁹:
 - GNSS coverage
ANSPs should ensure that operators of GNSS-equipped aircraft and, where applicable, SBAS-equipped aircraft, have access to a means of predicting the availability of fault detection using ABAS (e.g. RAIM). This prediction service may be provided by the ANSP, airborne equipment manufacturers or other entities [Ref. 18, ICAO PBN Manual, Part B, Chapter 3, §3.2.1.7]. As a result of the last RNAV Approach Task Force meeting (RATF7), Eurocontrol is now planning to make available RAIM and EGNOS predictions via both NOTAMs and a web-based interface.
 - DME-DME coverage: for navigation relying on DME, NOTAMs should be checked to verify the health of critical DMEs if required by the design of the routes. Pilots should assess their capability to navigate (potentially to an alternate destination) in case of failure of critical DME while airborne [Ref. 18, ICAO PBN Manual, Part B, Chapter 3, §3.3.4.1]

A summary of the proposed PBN implementations steps is given in the figure below:

Phase	Period	Proposed implementation objectives	Navaid infrastructure
En-route	Short term 2010-2015	<ul style="list-style-type: none"> ▪ gradual phase-out of RNAV5 	<ul style="list-style-type: none"> ▪ VOR/NDB beacons which are only used for en-route can be phased-out as of today.
	Medium term 2015-2020	<ul style="list-style-type: none"> ▪ 2015 RNAV 1 mandate⁹ (B-RNAV mandate applies above FL95) ▪ 2018 A-RNP1 mandate 	
	Long term 2020+	None currently defined	
	Short term	<ul style="list-style-type: none"> ▪ 2010 RNAV 1 compulsory (2200-0630 LT) at Schiphol airport ▪ 2012 RNAV 1 mandate for IFR traffic in all TMAs with temporary exemption propeller aircraft 	<ul style="list-style-type: none"> ▪ A VOR/NDB beacon which serves an en-route procedure and also serves a SID procedure can be phased-out provided that RNAV 1 is mandatory. DME nav aids maintained and extended where necessary to serve as back-up infra.
	Medium term	<ul style="list-style-type: none"> ▪ 2015 RNAV 1 mandate all IFR traffic in all TMAs (no exemptions propeller aircraft) ▪ 2018 A-RNP1 mandate 	
	Long term	None currently defined	
Approach & landing	Short term	<ul style="list-style-type: none"> ▪ gradual replacement of conventional NPA procedures based on VOR/NDB/DME by APV Baro-VNAV procedures 	<ul style="list-style-type: none"> ▪ VOR/NDB beacon which serves a conventional NPA can be phased-out provided that at least RNP APCH is mandatory. ▪ DME nav aids maintained and extended where necessary to serve as back-up infra
	Medium term	<ul style="list-style-type: none"> ▪ 2016 RNP APCH mandate ▪ 2018 A-RNP1 mandate ▪ continued replacement of conventional NPA procedures based on VOR/NDB/DME by APV Baro-VNAV procedures 	
	Long term	None currently defined	

⁷ Only in case of a sudden fundamental ILS downgrading prior to GBAS Cat III availability, MLS would be the only viable CAT II/III candidate. As long as ILS capability is maintained at CAT II/III level, MLS is not seen as required..

⁸ GBAS ground equipment includes: DGPS receiver and VHF datalink to transmit e.g. final approach segment data to the aircraft.

6 PBN developments for Aruba and the Netherlands Antilles



6.1 En-route

Current

The existing RNAV/RNP routes are already expected to be consistent with the PBN standards. Drivers for change include:

- Standardisation (e.g. WGS84 compliance for Bonaire and application of PANS-OPS criteria instead of TERPS)
 - Improved airport access and increased reliability since the conventional navaid infrastructure is subject to outages.
- Through PBN, the lateral separation has been reduced from 90 NM to 50 NM in most oceanic airspace including the West Atlantic Route System (WATRS).

will be applied. In the continental en-route areas of operation, States/territories may choose to implement RNAV-2 routes to enhance efficiency of airspace usage and support closer route spacing, noting that appropriate communication and surveillance coverage must be provided. The RNAV-2 navigation specification can also be used in certain airspace, where sufficient CNS capability is provided and there are operational benefits.

Medium-term (2013-2016): RNP-2 for remote continental is preferred and RNAV 1/RNP-2 for continental en-route.

WATRS: route redesign

- RNAV route structure (2006)
- Reduced separation 90 NM-50 NM
- RNP-10 criteria
- >40% increased airspace capacity



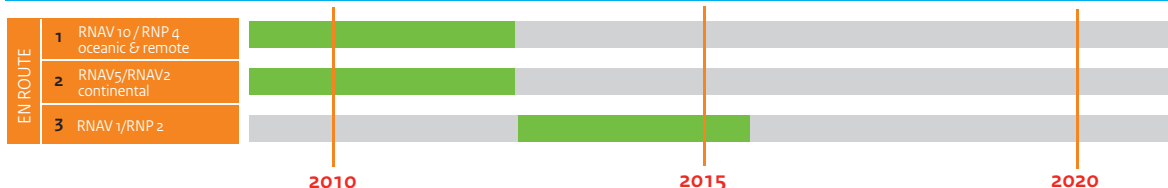
Future vision and roadmap

The en-route operations can be classified as:

- oceanic
- remote continental
- continental en-route

Short-term (2008-2012)¹: oceanic and remote continental routes are expected to be facilitated by RNAV-10 and RNP-4 navigation specification. For the continental routes it is expected that RNAV-5 and RNAV-2 navigation specification

Mandates for NAV specification



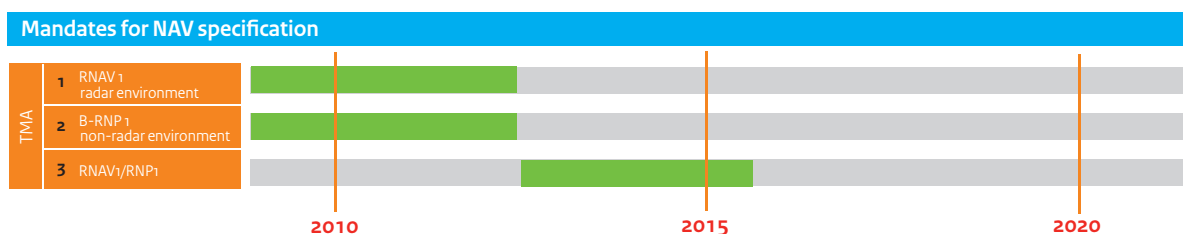
¹ The roadmap shown below is based on [Ref. 10, Draft version of the Curaçao FIR PBN Implementation Plan]. In most cases, no specific mandates have been mentioned in [Ref. 10]. Therefore, for indication purposes only, the timeframe is indicated in the roadmap figures in this document during which a mandate may be issued.

6.2 Terminal Area

Current

Most SIDs and STARs are based on conventional nav aids although some RNAV SIDs are published (e.g. for Juliana TMA).

Future vision and roadmap



Short-term (2008-2012): regarding terminal operations, a radar environment and non-radar environment need to be considered. In a radar environment the application of RNAV 1 is supported through the use of GNSS or ground-based nav aids such as DME/DME. Note that due to geographical constraints, the use of DME poses limitations in the Caribbean region. Mixed operations (RNAV 1 equipped and non-RNAV 1 equipped) are permitted. RNAV (GNSS) arrival and departure procedures are expected to be published onwards from 2011.

In a non-radar environment, the use of Basic-RNP1 is expected to be implemented and relies on GNSS as the main sensor.

Medium-term (2013-2016): in TMAs with high traffic complexity and movements the use of RNAV 1 or RNP-1 will be mandatory. In TMAs with less air traffic complexity, mixed operations (equipped and non-equipped) will be allowed.

6.3 Approach & Landing

Current

All islands support conventional VOR/DME/NDB approaches and in one case (Saba) only published visual approach procedures.

For the airports of Curaçao and Bonaire the development of

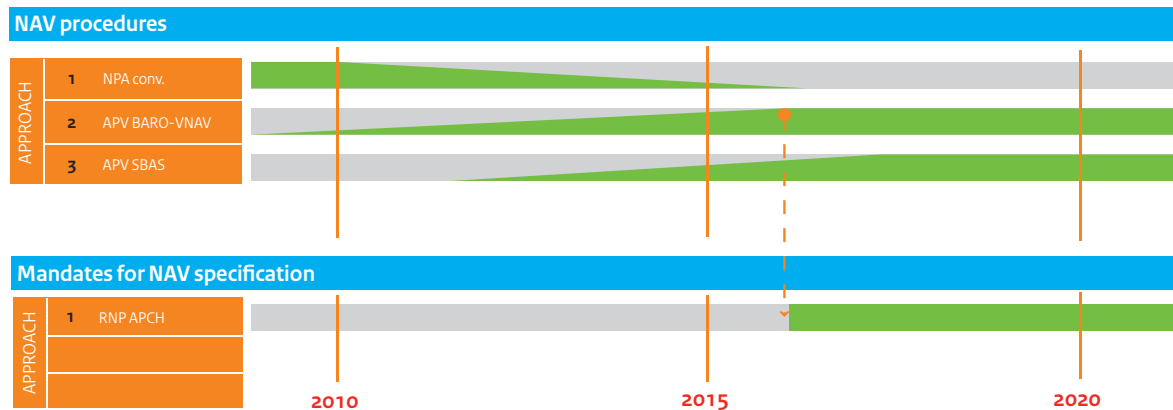
APV procedures has started and are expected to be published in 2010.

Aruba and St Maarten have started the development and publication of APVs.

RNAV (GNSS) SIDS are published for St Maarten and RNAV (GNSS) approach procedures are published for St Maarten and Aruba.

The availability of the ILS Cat I at Aruba and Curaçao airport is operationally limited.

Future vision and roadmap



Short-term (2008-2012): at primarily the international airports, the application of RNP APCH with Baro-VNAV procedures is expected to be implemented in line with the ICAO resolution of 30% of instrument runways by 2010 and 50% by 2012. Targets for SIDs/STARs based on RNAV 1 are set to 50% of international airports by 2010 and 75% by 2012. RNP AR APCH will be considered for airports where operational benefits are obvious.

Medium-term (2013-2016): extended application of RNP APCH with Baro-VNAV or APV at most airports. These applications may also serve as a back-up for precision approaches and provide vertical guidance at runway with precision approach capability. Initial introduction of landing systems based on augmented GNSS. Expansion of RNP AR APCH where there are operational benefits.

6.4 Ground

No PBN developments are currently foreseen.

6.5 Navaid infrastructure

Gradual decommissioning of navaids is expected to take place:

- Aruba : not foreseen
- Bonaire : phase-out of NDB
- Curaçao : not foreseen
- St Maarten : phase-out of VOR and NDB
- St Eustatius : phase-out of NDB
- Saba : not applicable (visual procedures)



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Annex I ICAO Resolution 36-23 on PBN

A36-23: Performance based navigation global goals

Whereas a primary objective of ICAO is that of ensuring the safe and efficient performance of the global Air Navigation System;

Whereas the improvement of the performance of the Air Navigation System on a harmonized, worldwide basis requires the active collaboration of all stakeholders;

Whereas the Eleventh Air Navigation Conference recommended that ICAO, as a matter of urgency, address and progress the issues associated with the introduction of area navigation (RNAV) and required navigation performance (RNP);

Whereas the Eleventh Air Navigation Conference recommended that ICAO develop RNAV procedures supported by global navigation satellite system (GNSS) for fixed wing aircraft, providing high track and velocity-keeping accuracy to maintain separation through curves and enable flexible approach line-ups;

Whereas the Eleventh Air Navigation Conference recommended that ICAO develop RNAV procedures supported by GNSS for both fixed and rotary wing aircraft, enabling lower operating minima in obstacle rich or otherwise constrained environments;

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

Recognizing that implementation of approach with vertical guidance (APV) is still not widespread;

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

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

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

The Assembly:

1. Urges all States to implement RNAV and RNP air traffic services (ATS) routes and approach procedures in accordance with the ICAO PBN concept laid down in the *Performance Based Navigation Manual* (Doc 9613);
2. Resolves that:
 - a) States and planning and implementation regional groups (PIRGs) complete a PBN implementation plan by 2009 to achieve:
 - 1) implementation of RNAV and RNP operations (where required) for en route and terminal areas according to established timelines and intermediate milestones; and
 - 2) implementation of approach procedures with vertical guidance (APV) (Baro-VNAV and/or augmented GNSS) for all instrument runway ends, either as the primary approach or as a back-up for precision approaches by 2016 with intermediate milestones as follows: 30 per cent by 2010, 70 per cent by 2014; and
 - b) ICAO develop a coordinated action plan to assist States in the implementation of PBN and to ensure development and/or maintenance of globally harmonized SARPs, Procedures for Air Navigation Services (PANS) and guidance material including a global harmonized safety assessment methodology to keep pace with operational demands;

3. *Urges* that States include in their PBN implementation plan provisions for implementation of approach procedures with vertical guidance (APV) to all runway ends serving aircraft with a maximum certificated take-off mass of 5700 kg or more, according to established timelines and intermediate milestones.
4. *Instructs* the Council to provide a progress report on PBN implementation to the next ordinary session of the Assembly; and
5. *Requests* the Planning and Implementation Regional Groups (PIRG) to include in their work programme the review of status of implementation of PBN by States according to the defined implementation plans and report to ICAO any deficiencies that may occur.

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Abbreviations


4D	4 dimensions (lateral, longitudinal vertical and time)	KNVvL	Koninklijke Nederlandse Vereniging voor Luchtvaart
ADF	Automatic Direction Finder	LATAM	Latin America
ADS-B	Automated Dependent Surveillance-Broadcast	LNAV	Lateral Navigation
AIC	Aeronautical Information Circular	LPV	Lateral precision with Vertical guidance (APV SBAS I/II)
AIP	Aeronautical Information Publication	LVC	Low Visibility Conditions
AMAN	Arrival Manager	LVP	Low Visibility Procedures
ANSP	Air Navigation Service Provider	LPV	Lateral precision with vertical guidance (APV SBAS I/II)
ANT	(EUROCONTROL) Airspace Management and Navigation Team	MLS	Microwave Landing System
AOPA	Aircraft Owners & Pilot Association	MTSAT	MTSAT Satellite Augmentation System (Japan SBAS)
APV	Approach Procedure with Vertical Guidance	NAM	North America
A-RNP1	Advanced RNP1	NATO	North Atlantic Treaty Organisation
ASM	Airspace Management	Navaid(s)	Navigation Aid(s)
ATC	Air Traffic Control	NextGen	Next Generation (USA ATM system)
ATM	Air Traffic Management	NDB	Non-Directional Beacon
ATS	Air Traffic Services	NPA	Non-Precision Approach
B-RNAV	Basic RNAV	OAT	Operational Air Traffic
B-RNP1	Basic RNP1	OPD	Optimised Profile Descent
Baro-VNAV	Barometric Vertical Navigation	PA	Precision Approach
CAR/SAM	Caribbean / South America	PANS-OPS	(ICAO) Procedures for Air Navigation – Aircraft Operations
CBA	Cost Benefit Analysis	PBN	Performance Based Navigation
CDA	Continuous Descent Approach	PIRG	Planning and Implementation Regional Groups
CDO	Continuous Descent Operations (=CDA)	P-RNAV	Precision RNAV (= RNAV1)
CDFA	Continuous Descent Final Approach	R&D	Research and Development
CFIT	Controlled Flight Into Terrain	RAIM	Receiver Autonomous Integrity Monitoring
CNS	Communications, Navigation, Surveillance	RF	Radius to Fix
CTA	Control Area	RNAV	Area Navigation
CTR	Control Zone	RNP	Required Navigation Performance
DME	Distance Measuring Equipment	RNP APCH	RNP Approach
EASA	European Aviation Safety Agency	RNP AR	APCH RNP Approach with Authorisation Required
EC	European Commission	RTA	Required Time of Arrival
ECAC	European Civil Aviation Conference	SAAAR	Special Aircraft and Aircrew Authorisation Required
EGNOS	European Geostationary Navigation Overlay System (this is the EU SBAS equivalent)	SARPS	(ICAO) Standards and Recommended Practices
EU	European Union	SBAS	Satellite-based Augmentation System
EUROCONTROL	European Organisation for the Safety of Air Navigation	SESAR	Single European Sky ATM Research and Development Programme
FMS	Flight Management System	State aircraft	Aircraft used in military, customs and police services. Aircraft on a military register, or identified as such within a civil register, shall be considered to be used in military service and hence qualify as State Aircraft. Civil registered aircraft used in military, customs and police service shall qualify as State Aircraft.
FPL	Flight Plan	SID	Standard Instrument Departure
FRT	Fixed Radius Transition	SSR	Secondary Surveillance Radar
GAGAN	GPS and Geo Augmented Navigation (Indian SBAS)	STAR	Standard Arrival Route
GAT	General Air Traffic	TACAN	TACTical Air Navigation
GALILEO	European satellite based radio navigation system	TERPS	Terminal Instrument Procedure
GBAS	Ground-based Augmentation System	TMA	Terminal Control Area
GLONASS	Russian satellite based radio navigation system	TSO	Technical Standard Order
GLS	GNSS Landing System	UAS	Unmanned Aerial Systems
GNSS	Global Navigation Satellite System. The GNSS is a generic term for satellite-based navigation, including GPS, SBAS, GBAS, GLONASS, and any other satellite navigation system [FAA AC 20-138A].	VFR	Visual Flight Rules
GPS	Global Positioning System (GPS is a U.S. satellite based radio navigation system)	VLA	Very Light Aircraft
IAF	Initial Approach Fix	VNAV	Vertical Navigation
IATA	International Air Transport Association	VOR	Very High Frequency Omnidirectional Radio Range
ICAO	International Civil Aviation Organisation	WAAS	Wide Area Augmentation System (US SBAS)
IFR	Instrument Flight Rules	WATRS	West Atlantic Route System
ILS	Instrument Landing System		
INS	Inertial Navigation System		
IRS	Inertial Reference System		

Colophon

Performance Based Navigation is a publication of Ministry of Transport,
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