PBN Implementation Plan Sweden

Version 1.00

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1. Background

The ICAO 36th General Assembly, September 2007, agreed on Resolution A36-23 with a requirement that Member States submit national PBN (Performance Based Navigation) implementation plans by the end of 2009. This includes a firm requirement for a stepwise introduction of approaches with vertical guidance.

This PBN Implementation Plan for Sweden has been developed with the participation of the main ANS provider (LFV) and major airlines (SAS, Novair, Skyways).

The PBN Manual provides guidance of RNAV/RNP navigation specifications and encompasses two types of approvals:

- airworthiness, exclusively relating to the approval of aircraft; and
- operational, dealing with the operational aspects of the operator.

RNAV/RNP approval will be granted to operators that comply with these two types of approvals.

The PBN Implementation Plan shall provide guidance to air navigation service providers, airspace operators and users, and international organizations.
It will assist the main stakeholders of the aviation community to plan the future transition and their investment strategies.

The plan has the following strategic objectives:
a) To ensure that the implementation of the navigation item of the CNS/ATM system is based on clearly established operational requirements.
b) To avoid unnecessarily imposing the mandate for multiple equipment on board or multiple systems on ground.
c) To avoid the need for multiple airworthiness and operational approvals for intra- and inter-regional operations.

There are two primary concerns driving the current implementation of PBN in Sweden:

Environment. Swedish stakeholders are aware of the impact that air transport operations have on the environment. To date the main focus has been aircraft noise, but that focus is broadening to include the effect of emissions on air quality and climate.

Efficiency. The combination of advanced navigation technology now available in aircraft and fresh navigation specifications from ICAO offers an opportunity to improve the efficiency of air traffic management in Sweden. It is important to note that efficient air traffic management also contributes to reduced aircraft noise and emissions.

1.1 Traffic Forecast

The decline in traffic remains broad-based, affecting all market segments and nearly all States of Europe. The traffic situation is currently relatively stable. In practice this means that the recovery has been more gradual than forecasted and all major market segments continue to operate fewer flights than in 2008.

According to the Swedish National Aerospace Assessment report, Stockholm ACC expects a 12% drop in traffic in 2009 and Malmö ACC reports a similar forecast. The numbers from the Eurocontrol web-site, the Statistics and Forecast Service (STATFOR) of Eurocontrol, indicate a small growth, with a medium-term forecast (2009-2015) of average annual growth of 2% (flight movements) and a long-term forecast of 3-4%.

2. The PBN Concept

2.1 *Capabilities*

Rather than requiring a certain type of equipment, PBN requires that the user is able to navigate with a defined level of performance within a certain airspace. PBN is a set of parameters describing, among other characteristics, the maximum allowed lateral deviation from an assigned or chosen route and also the deviation along the route. Thus, PBN is a requirement for capability to navigate related to a defined flight path and at any time during the flight.

For arrival, approach and departure phases, PBN includes a limit for lateral and vertical deviation from the assigned flight path. Thus, the airspace can be used more efficiently, including shortening of routes, without the need for repeated changes in the infrastructure. In order to reduce the need for the costly ground-based structure as a primary source, the aim is, in accordance with international agreements, to replace this with augmentation for GNSS while the DME/DME coverage en route is refined for back-up purposes. A number of new DME stations have been installed in parts of Sweden to achieve the required coverage and precision. As a result the VOR network is expected to be obsolete by 2015.

GNSS in combination with other navigation aids can be used as an alternative, or backup, for traditional ILS. The method used in Baro VNAV is to make use of barometric altitude in combination with the lateral position derived from the airborne FMS in order to calculate a vertical profile that will end with a virtual glide path during final approach. As an alternative, SBAS may be used as the source for altitude information.

Aircraft. The aircraft used for 34% of all arrivals to Swedish airports in 2008 were in the “high” (27%) or “high-medium” (7%) equipage category, which means that little or no additional equipment is required to enable RNP AR APCH operations. Such aircraft also have the capability to fly RNP APCH procedures with Baro-VNAV, which is an important consideration with respect to the ICAO PBN resolution. Many operators operate recent-production, well-equipped 737s and Airbus single-aisle aircraft and could benefit from the availability of RNP APCH and RNP AR APCH procedures.

2.2 *Current status of PBN operations in Sweden*

B-RNAV is mandatory for flights in airspace above FL95 within Sweden FIR.

Published procedures, status 1 October 2009:

ESSA Stockholm/Arlanda FMS/RNAV SID based on DME/DME
ESSA Stockholm/Arlanda P-RNAV STAR based on DME/DME and GNSS
ESGG Göteborg/Landvetter P-RNAV SID STAR based on DME/DME and GNSS
ESNZ Åre Östersund och ESPA Luleå/Kallax RNAV Arrival Transitions based on VOR/DME
ESMT Halmstad P-RNAV SID based on GNSS
ESTA Ängelholm RNP APCH based on GNSS and Baro-VNAV
ESSA Stockholm/Arlanda RNP AR APCH RWY 01R

Under development, plans for P-RNAV SID and/or STAR:

ESNZ Åre Östersund (Jan 2010) and ESNU Umeå (Nov 2009) P-RNAV SID/STAR based on GNSS only
ESSA Stockholm/Arlanda P-RNAV SID based on DME/DME and/or GNSS
ESGP Göteborg/Säve (end 2010) P-RNAV SID/STAR based on GNSS only
ESKN Stockholm/Skavsta (end 2010) P-RNAV SID/STAR based on GNSS only

The use of advanced automation tools has enabled Free Route Airspace above FL285, this includes to allow aircraft to receive RNAV direct clearances to the arrival fixes at the beginning of the P-RNAV STARS. This, in combination with CDA clearance, provides a notable step in the improvement of efficiency.

3. Benefits of PBN and Global Harmonization

The widespread implementation of PBN will enable all stakeholders to realize significant benefit. Specifically, stakeholders will see increases in efficiency, safety, access, capacity, and environmental protection. Not all of these benefits provide a financial saving. However, when combined they provide a business case for PBN.

The following table list the most common ways that PBN benefits stakeholders.

STAKEHOLDER	BENEFITS
Aircraft Operators	• Increased safety • Fuel savings • Time savings • Reduced operational variance • Predictability
Air Traffic Control	• Consistent and predictable flow • Reduced time in terminal area • Reduced dependence on ground infrastructure
Airports and Communities	• Reduced noise • Reduced emissions • Less infrastructure • Predictability

Operational benefits

The importance of P-RNAV in the terminal area should be considered in order to provide a link between the enroute and the approach phases. Closed STARs should be considered to the extent possible. Detailes of TMA operations have not been studied but will be assessed when a revised regional strategy is available.

Approach procedures with vertical guidance (APV) can basically be designed for four different reasons.

1) To replace an existing non-precision approach (e.g. NDB or VOR approach). Normally this procedure is designed with a straight final. This procedure is relatively easy to design and offer benefits in form of increased flight safety due to the stabilized vertical profile, and flight crew training benefit due to the similarity with ILS.

2) To navigate around obstacles (e.g. terrain) or noise sensitive areas, or to shorten the approach path. This requires advanced procedure design and advanced airworthiness requirements. The procedure is normally called RNP AR APCH and can be either APV-Baro-VNAV, APV-SBAS or APV-GBAS. The benefits can be flight safety (see 1 above), environmental and financial (fuel saving due to shorter route).

3) To replace existing ILS or to get ILS Cat I, Cat II or Cat III minima where no ILS exist today. The benefit is primarily financial. The aircraft operator will not get increased benefit compared to the ILS. The aerodrome operator will benefit as the existing ILS can be removed. This require APV-SBAS or APV-GBAS.

4) To be a backup for existing ILS installation. Benefit is limited to regularity, as operations can continue also when the ILS is closed for e.g. maintenance.

Cost benefits

<u>Investment costs</u>: the cost of investing in equipment and training and other elements necessary for PBN implementation.

There are some PBN activities that could yield benefit for operators and the environment immediately and with little additional effort. A large number of aircraft operating in Sweden are fully capable of RNP AR APCH operations. Allowing those operators to realize some of the benefit of their capital equipment investment would benefit the entire aviation industry.

The removal of some groundbased equipment will result in lower maintenance costs. While the implementation of APV will include initial costs for procedure design, aerodrome operators will benefit from increased flexibility in future possibilities to adapt traffic flows and procedures in accordance with environmental requirements.

<u>The cost of delaying PBN implementation</u>:

- Fuel and time wasted.
- Unnecessary emissions and noise.

The possible additional costs of delaying PBN implementation in Sweden are high. An estimated nine million kilograms of fuel could be saved annually if those operators currently equipped could fly more efficient tracks. This translates to reduction of emissions by over 30,000 tonnes of CO_2 and over one million kilograms of NO_x. Of course this full benefit would not be possible at the outset. This will also benefit the aerodrome operators in their possibilities to contribute to less impact on the environment and minimize the cost of legal processes.

A key factor is the time required to realize these benefits. It is expected that airlines will gradually transition to newer aircraft or upgrade their existing platforms and by 2020 the majority of scheduled passenger aircraft will be capable of flying RNP AR APCH procedures.

Environmental benefits

One important concern for the implementation of PBN in Sweden is to increase the support of improvements that could reduce the impact on the environment. Taking this a step forward, using best available techniques onboard aircraft together with procedures designed within the criteria of PBN and utilizing the airspace in the most beneficial way would lead to less emission and reduced noise as a result.

4. Challenges

4.1 Increasing Demands

The aviation community in Sweden, in response to market forces and encouraged by European and global initiatives, is striving to advance air transportation by improving air traffic management (ATM). The demand for air transportation remains, while transportation resources shrink and public tolerance for waste, delays, noise, and pollution declines. Aviation stakeholders throughout Sweden are investigating ways to improve safety, reduce environmental impact, expand access, and increase efficiency and capacity.

With the Single European Sky (SES) initiative, the European Commission aims to eliminate the current fragmentation of airspace over Europe, create additional capacity, and increase ATM efficiency. Harmonization among Swedish stakeholders, and with adjacent States, will also be necessary.

Performance based navigation is the foundation for further ATM advances that yield progressively greater benefits including complex flight paths in 4 dimensions and sequencing traffic on those paths.

4.1.1 En route

4.1.1.1 Oceanic and Remote Continental

Not applicable

4.1.1.2 Continental

At the moment no challenges have been identified for the en route phase. Direct routeing is already applied to a large extent and Free Route Airspace is partly implemented.

4.1.2 Terminal Areas (Departures and Arrivals)

It may prove difficult to motivate airport owners to invest in procedure developments, and understand the long term benefits. Airport managers have responsibility for the terminal navigation infrastructure but limited knowledge about the technical and operational aspects of the navigation technology. Currently there is a lack of time-based sequencing tools to conduct mixed-mode operations in TMA.

The transition to the PBN concept may involve demands resulting from;

- Mixed mode operations, during the transition to a complete PBN environment the ATM system will need to handle traffic with different types of capabilities.
- The design must include both the safety of the specific airspace and/or procedure as well as the possibility for ATS to intervene if necessary.
- It may take time before all personnel has gained experience and fully adopted to new working methods.
- Even though the benefits of PBN are known, there is no business model for calculating the financial effects of "less emissions" or "avoiding sensitive areas".

4.1.3 Approach

In addition to the items listed under 4.1.2, the following conditions must be considered

- Airline requests for priorities (as indicated in Appendix C).
- Availability of approved EGNOS services.
- Availability of regulatory framework for GBAS and SBAS.
- Limited resources of staff both at the Regulators office as well as at the ANSP.

4.2 Efficient Operations

There is a delay in experienced efficiency due to lead-times for changes in traffic flows and routes. It is also necessary to cooperate with neighbouring service providers, to increase the geographic area, in order to maximize the possibilities and benefits from the implementation of PBN.

4.2.1 En route

The possibilities to improve efficiency and capacity in the en route phase will be assessed when a revised regional strategy becomes available. At the moment no problems have been identified and no changes are planned for the near future.

4.2.2 Terminal Areas

The benefits for the airlines are significant for all phases of flight, and with respect to the terminal areas this includes:

- For departures - SIDs for all runways that quickly allow aircraft to join their route to destination.
- For arrivals -STARs off every route that provides the least track miles to initial approach fix with a continuous descent profile from top of descent.
- For approaches - lateral and vertical guidance for all runways unless constrained by terrain.

4.2.3 Approach

Swedish airline operators have expressed a wish to have both RNP APCH and RNP AR APCH procedures implemented at certain runways. Reasons may include shorter tracks and improved access. The deployment of RNP AR APCH procedures, as replacement for non-precision approaches, can result in significant benefit to operating minima such as required visibility and decision height (DH). This can result in:

- Saved Flights. Instances whereby a reduced DH to a given runway end will result in fewer flights diverting to alternate airports or cancelling altogether.

- Operational Efficiency. In poor weather conditions, aircraft may have to operate to the runway with the lowest available DH. In many cases this will be at the expense of operational efficiency such as landing with tail wind, or increased track miles flown in a low-altitude, high-drag configuration.

Airline operators have requested that certain aerodromes/runways be given priority in the implementation of APV. Aerodromes that are on the airlines "wish list" for APV are marked in bold in appendix C.

It has also been identified by airline operators that use of RNP AR APCH would enable shorter tracks and should therefore be considered with priority at the following aerodromes;

- Stockholm/Arlanda, ESSA, RWY 26
- Göteborg/Landvetter, ESGG, RWY 03 and 21
- Malmö, ESMS, RWY 35
- Kiruna, ESNQ, RWY 21

- Umeå, ESNU, RWY 14
- Åre Östersund, ESNZ, RWY 30
- Ronneby, ESDF, RWY 01

4.3 Environment

Airports with an instrument runway longer than 1200 m must have an approved environmental court permit that allows aviation operations at that airport. Each such permit has conditions that prescribe aviation ground and air operations, such as hours of operation and restriction of flights over certain populated areas.

Constraints of permit conditions, fragmentation of environmental stakeholders, and the focus on noise to the extent that emissions are increased are challenges to PBN implementation.

It is a great challenge for airport operators to advocate the acceptance of new technologies and the opportunity this brings for route construction at low altitudes where the noise is a factor. There should also be consensus between airports and airlines on the one hand, and environmental authorities, provincial government and municipalities on the other hand, of the possibilities and limitations of designing and flying the PBN procedures.

5. Implementation

During and after the implementation of PBN as part of the airspace concept, the total system needs to be monitored to ensure that the safety of the system is maintained. A System Safety Assessment must be conducted during and after implementation and evidence collected to ensure that the safety of the system is assured.

5.1 Short term (2009-2012)

5.1.1 En route

5.1.1.1 Oceanic and Remote Continental

Not applicable.

5.1.1.2 Continental

In the next years (2010/2011) five additional DME stations are planned that will complete the required DME/DME coverage within Sweden FIR, and thus the VOR network is expected to be obsolete for en route operations by 2012. As a consequence the ANSP should prepare a plan for decommissioning of those VOR stations that are only used for en route purposes.

5.1.2 Terminal Areas (Departures and Arrivals)

The possibility to implement RNAV 1 in radar environment and with adequate navigation infrastructure should be considered as early as possible. As a minimum, Basic-RNP 1 should be considered in non-radar environment.

5.1.3 Approach

RNP APCH with Baro-VNAV at a majority of airports and RNP AR APCH at airports where there are obvious operational benefits from curved approaches.

The CAA rules for design and use of airspace (TSFS 2009:11) will be revised in 2010, aiming at the inclusion of the requirements for APV procedures at all instrument runways. Transitional arrangements will be included in the rules and subject to the outcome of the rulemaking process it is expected that in this time period the first set of runways will be affected (see table in appendix C).

A quick win, with respect to flight safety, may be achieved by concentrating on replacement of procedures based on NDB. The availability of SBAS in the northern part of Sweden is still uncertain and time should be given for the development of suitable solutions. The situation for aerodromes where a precision approach procedure is available at the main runway end will be considered in the rulemaking process with respect to the date for implementation of an APV procedure at that end.

Aerodrome operators are urged to consider the airline operators request for priority as an incentive for early implementation at the aerodromes indicated in Appendix C. This may be either due to a requirement for increased safety or the possibility to shorten routes or to avoid sensitive populated areas.

5.1.4 Helicopter operations

Not applicable (no instrument classified heliports).

5.2 Medium term (2013-2016)

5.2.1 En route

5.2.1.1 Oceanic and Remote Continental

Not applicable

5.2.1.2 Continental

Currently no changes planned. This will be re-assessed subject to a revised regional strategy.

5.2.2 Terminal Areas (Departures and Arrivals)

In order to gain full effect of new procedures it is necessary to consider also other phases of flight and therefore to expand RNAV 1 or RNP 1 applications. Depending on capacity and limited possibilities to handle mixed traffic it may also be necessary to mandate RNAV 1 or RNP 1 approval for aircraft operating in higher air traffic density TMAs (Stockholm, Malmö)

5.2.3 Approach

Expansion of RNP APCH with Baro-VNAV and introduction of RNP APCH with SBAS. Expansion of RNP AR APCH where there are operational benefits. Introduction of landing capability using GNSS and its augmentations.

Transitional arrangements for APV requirements in the rules for design and use of airspace will include remaining sets of runways. The actual determination of categories of aerodromes will be set out in the rulemaking process. Based on technical and operational considerations, it is expected that aerodromes north of Latitude 60N with only non-precision approach procedures will be required to have APV procedures by the end of 2014 and all runways with precision approach procedures will be required to also have APV procedures by the end of 2016.

5.2.4 Helicopter operations

Not applicable (no instrument classified heliports).

5.3 Far term (2017-2022)

T.B.D.

Appendices:

Appendix A (Intentionally not included) – Not applicable, no Oceanic or Remote Continental area.

Appendix B – En route continental implementation schedule by area or city pair

Appendix C – Terminal area and approach implementation schedule by aerodrome

Appendix D (Intentionally not included) – Not applicable, no instrument classified Heliports.

Appendix B

En route continental implementation
Schedule by area or city pair

En route DME/DME coverage south of Latitude 60N in controlled airspace (FL95+) will be completed in the short term period.

En route DME/DME coverage north of Latitude 60N in controlled airspace (FL95+, in mountainous area FL125+) will be completed in the short term period.

Appendix C

Terminal area and approach implementation
Schedule by aerodrome

Note 1: Categories of aerodromes are subject to the outcome of the rulemaking process and some changes to the tables below may result from this. (see also para 5.1.3 about APV at precision approach runway ends)

Note 2: **Bold text** indicates priority requested by airline

Note 3: Date and type of APV (Baro VNAV or SBAS) to be provided later by each aerodrome.

Aerodromes expected to be required, by CAA rules, to implement APV by 2012.

Airport	Locator	Runway	APV planned
Arvika	ESKV	01	(*date*)
Eskilstuna	ESSU	18/36	
Falköping	ESGK	04/22	
Göteborg/Landvetter	ESGG	03/21	
Göteborg/Säve	ESGP	01/19	
Halmstad	ESMT	**01**/19	
Jönköping	ESGJ	**01**/19	
Kalmar	ESMQ	16/**34**	
Karlskoga	ESKK	03/21	
Karlstad	ESOK	03/21	
Kristianstad	ESMK	**01**/19	
Lidköping	ESGL	06/24	
Linköping/Malmen	ESCF	01/19	
Linköping/SAAB	ESSL	11/29	
Ljungbyhed	ESTL	11/29	
Malmö	ESMS	17/35	
Mora/Siljan	ESKM	16/34	
Norrköping/Kungsängen	ESSP	09/27	
Oskarshamn	ESMO	01/19	
Ronneby	ESDF	**01**/19	
Skövde	ESGR	01/19	
Stockholm/Arlanda	ESSA	01L/19R	
Stockholm/Bromma	ESSB	12/30	
Stockholm/Skavsta	ESKN	08/26	
Stockholm/Västerås	ESOW	01/19	
Såtenäs	ESIB	01/19	
Trollhättan-Vänersborg	ESGT	15/33	
Visby	ESSV	**03**/21	
Växjö/Kronoberg	ESMX	01/19	
Ängelholm	ESTA	14/32	
Örebro	ESOE	01/19	

Aerodromes expected to be required, by CAA rules, to implement APV by 2014.

Airport	Locator	Runway	APV Planned
Arvidsjaur	ESNX	12/30	*(date)*
Borlänge	ESSD	14	
Gällivare	ESNG	12	
Gävle	ESSK	36	
Hagfors	ESOH	18/36	
Kiruna	ESNQ	**03**/21	
Kramfors-Sollefteå	ESNK	17/35	
Luleå/Kallax	ESPA	14/32	
Lycksele	ESNL	14/32	
Pajala-Ylläs	ESUP	11	
Skellefteå	ESNS	**10**/28	
Stockholm/Arlanda	ESSA	08/26	
Stockholm/Arlanda	ESSA	01R/19L	
Storuman	ESUD	15/33	
Sundsvall-Härnösand	ESNN	16/34	
Sveg	ESND	09	
Söderhamn	ESNY	30	
Torsby	ESST	16/34	
Umeå	ESNU	14/32	
Vilhelmina	ESNV	10/28	
Åre Östersund	ESNZ	12/**30**	
Örnsköldsvik	ESNO	12/30	

Aerodromes expected to be required, by CAA rules, to implement APV by 2016.

Airport	Locator	Runway	APV Planned
Borlänge	ESSD	32	*(date)*
Gällivare	ESNG	30	
Gävle	ESSK	18	
Hemavan	ESUT	33	