International Civil Aviation Organization

The Tenth Meeting of the ICAO Asia/Pacific Performance-Based Navigation Task Force (PBN/TF/10)

Nadi, Fiji, 11-13 December 2012

Agenda Item 5: State/Industry Updates

PBN IMPLEMENTATION IN SINGAPORE

(Presented by Singapore)

SUMMARY

This paper presents updates on the status of PBN Implementation in Singapore.

This paper relates to –

Strategic Objectives:

A: ***Safety*** *– Enhance global civil aviation safety*

C: ***Environmental Protection and Sustainable Development of Air Transport*** *– Foster harmonized and economically viable development of international civil aviation that does not unduly harm the environment*

Global Plan Initiatives:

GPI-5 RNAV and RNP (Performance-based navigation)
GPI-10 Terminal area design and management
GPI-11 RNP and RNAV SIDs and STARs

1. INTRODUCTION

1.1 At the 36th session of the ICAO Assembly in its Resolution A36-23, States and Planning and Implementation Regional Groups (PIRGs) were requested to develop PBN implementation plans and implement PBN in accordance with the timelines established in those plans.

1.2 Singapore has adopted a 3-phased approach for the implementation of PBN in line with the ICAO Asia-Pacific Regional PBN Implementation Plan. The phased approach allows both ANSPs and aircraft operators to progress in tandem taking into consideration the avionic capabilities and air navigation infrastructures in the Singapore Flight Information Region (FIR). Please see **Attachment A** for the Singapore PBN Implementation Plan and **Attachment B** for the Progress Report.

2. DISCUSSION

2.1 To date, Singapore has been progressing effectively with the established plan. Within the Singapore FIR, in the en-route airspace beyond the surveillance coverage, ATC is able to reduce the longitudinal separation from 80 Nautical Miles (NM) to 50 NM on 40% of the routes from implementing the RNP10 (RNAV10) PBN navigation specifications. For the areas within surveillance coverage, PBN specification such as RNAV5 enables the routes to be spaced closer to one another to increase the capacity within the same finite of airspace especially in areas with high volume traffic.

2.2 In the terminal airspace surrounding Changi airport where the arriving and departing flights manoeuvre from the airport to the en-route airspace and vice-versa, PBN plays a critical role in enhancing safety and optimising the capacity in our terminal airspace. Since 2006, segregated RNAV Standard Instrument Departure (SIDs) and Standard Terminal Arrival (STARs) routes for Changi had been implemented to minimise routes criss-crossing one another and to optimise climb and descent profiles.

2.3 In the approach segment, PBN procedures are also in place to serve as a back-up for the conventional ground-based instrument procedures since 2008. These procedures are currently available on two of the runway ends at Changi (Runway 20R and 02L) and they utilise GNSS for lateral guidance and rely on the onboard avionics to provide the vertical guidance.

Progress Updates

2.4 Recognising the potential benefits that PBN implementation can bring about and to harmonise with the Asia Pacific Regional PBN Implementation Plan, new ATS routes and procedures were developed in close collaboration with neighbouring ANSPs. The areas of collaboration focus on the harmonisation of PBN implementation based on communication, surveillance and navigation capabilities in those areas. Furthermore, prioritisation on areas where high demand of air traffic would bring about the necessary capacity enhancement contributing to optimised flight operations on those areas.

2.5 In February 2012, ATS routes between Singapore and Jakarta FIR serving South East Asia and Australasia was restructured to allow the reduction of separation on two ATS routes, M635 and M774. With RNAV10 PBN specifications, the reduced horizontal separation of 50NM lateral / 50NM longitudinal contributes to a higher opportunity for flights to operate at their optimum flight level.

2.6 Continuous Descent Operations (CDO) procedures were also implemented in March 2012 to enhance efficiency in the terminal airspace using RNAV1 PBN specifications. CDO is an aircraft operating technique aided by appropriate instrument flight procedure design and appropriate air traffic control (ATC) clearances enabling the execution of a flight profile optimized to the operating capability of the aircraft, with low engine thrust settings and, where possible, a low drag configuration, thereby reducing fuel burn and carbon emissions during the descent phase.

2.7 Focusing on high density routes, two RNAV5 routes, M630 and Y339, were established in August 2012 to enhance air traffic management safety and efficiency for flights between Singapore and West Malaysia. The restructured routes allowed for better air traffic management segregating short haul and long haul flights. This contributes to enhanced flight profiles in that area.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note the current status of PBN Implementation in Singapore;

b) note the collaborative efforts between States for PBN implementation; and

c) encourage States to continue in their efforts in PBN implementation to achieve seamless ATM within Asia Pacific Region. .

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Attachment A

Civil Aviation Authority of Singapore

Performance Based Navigation Implementation Plan

SINGAPORE

Version 1.2

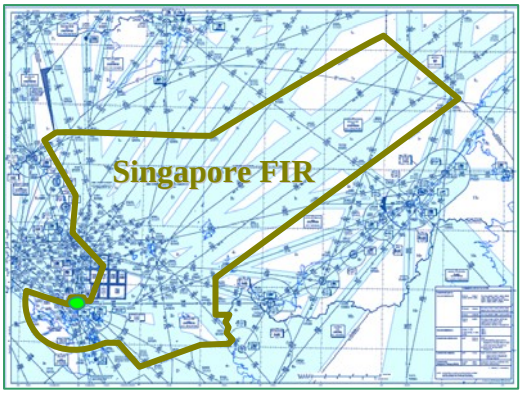
December 2012

Contents

1. Background

1.1 Airspace

The Singapore Flight Information Region (FIR) sits at the southern end of the South China Sea, sharing boundaries with five other neighbouring FIRs; namely Ho Chi Minh, Jakarta, Kota Kinabalu, Kuala Lumpur and Manila FIRs. The airspace within the Singapore FIR is largely oceanic and as such, widespread siting of ground navigational aids is not possible.



Within the Singapore Terminal Area (TMA), high density air traffic movement consisting of international and regional flights into and out of Changi Airport and some 3 airfields within a 40NM radius makes air traffic management a challenge. The presence of military operations adds complexity to air traffic management in the densely packed TMA.

1.2 Communications / Navigation / Surveillance

The Singapore Area Control Centre (ACC) employs a full range of radio communications systems from VHF to HF radios to Controller Pilot Data Link Communications (CPDLC) for air-ground communications. VHF radio supports surveillance control services both within TMA and the En-route sectors within the VHF range. Beyond that, high quality HF radios and CPDLC datalink complete the communications solution.

The largely oceanic airspace inhibits the siting of ground navigational aids. As such, RNAV technology is widely used for enroute navigation. In the TMA however, there is a rich collection of VOR/DMEs and has served as the basis for instrument departure and arrival procedures for the aerodromes within the TMA for many years. With modern aircraft fleets getting equipped with more advance avionics which include satellite navigation capabilities, designing instrument procedures hinged on GNSS will become more and more pragmatic.

As for surveillance, there are the primary and secondary long range radars which provide cover up to about 250NM radius from Changi Airport whereas the two Approach radars are used for surveillance in the TMA. Since 1997, ADS-C has been introduced to augment the surveillance cover for the remaining part of the FIR outside the radar cover. Planning has begun for the implementation of ADS-B operations to enhance surveillance and to bridge parts of the airspace outside radar cover.

2. Area Navigation (RNAV)

2.1 Capabilities

RNAV is the less capable of the two broad PBN navigation specifications. RNAV is suited to the current and legacy aircraft operations however as a stand-alone specification, it is insufficient to support many of the new Air Traffic Management (ATM) applications envisaged in strategic plans.

2.1.1 The RNAV Specifications as stipulated in ICAO PBN Manual are:

a) RNAV 10 - for use in enroute (oceanic) airspace
b) RNAV 5 - for use in enroute (continental) airspace
c) RNAV 2 - for use in enroute (continental) and terminal airspaces
d) RNAV 1 - for use in terminal airspace

RNAV specifications do not require on-board navigation performance monitoring and alerting. RNAV tracks (e.g.: RNAV 5, RNAV 2, RNAV 1) will normally require monitoring by ATC surveillance systems to achieve the desired performance and separation safety standards. This requirement implies near universal surveillance cover for RNAV specifications. In oceanic airspace this surveillance is provided by ADS-C.

3. Required Navigation Performance (RNP)

3.1 Capabilities

RNP is the more capable of the two broad PBN navigation specifications having on-board navigation performance monitoring and alerting. The on-board navigation performance monitoring and alerting is a necessary enabler for the many new ATM applications.

3.1.1 The RNP Specifications as stipulated in ICAO PBN Manual are:

a) RNP 4 – for use in enroute (oceanic) operations
b) RNP 2
c) Basic RNP 1 – for use in terminal area operations
d) Advance RNP 1
e) RNP APCH – for use in the approach phase
f) RNP AR APCH – for use in the approach phase

4. Current PBN Operations in Singapore

4.1 Enroute

RNAV enroute operations in the South China Sea area based on RNP10 requirements began as early as November 2001. The six major routes connecting Singapore and the airports in North-east Asia were arranged in a parallel route structure. Back then, the States involved had agreed on a 60NM lateral and 80NM longitudinal separation based on Mach Number Technique as the standard separation minima for the RNP10 routes.

In July 2008, reduced horizontal separation down to 50NM lateral / 50NM longitudinal based on RNAV10 operation was implemented on two routes, M771 and L642, which catered for the high air traffic flows between Singapore and Hong Kong as well as the airports in China. A quick glance on the four remaining parallel routes in Singapore FIR suggests RNAV10 as the de-facto standard operations to pursue for these routes as well.

In February 2012, restructuring of ATS routes in the south-east portion of Singapore FIR for flights to Jakarta FIR and beyond to Australasia region enabled two routes, M635 and M774, to employ reduced horizontal separation down to 50NM lateral / 50NM longitudinal based on RNAV10 operation.

In August 2012, two RNAV5 routes, M630 and Y339, were established to enhance air traffic management safety and efficiency for flights between Singapore and West Malaysia.

4.2 Terminal Airspace (Departures / Arrivals)

Due to the proliferation of multiple standards for RNAV for use in the TMA by various regions, there were some difficulties encountered when deciding on the standard to adopt for introduction of RNAV SIDs and STARs for Changi. Eventually, Eurocontrol's P-RNAV standard was selected as the model and was implemented in May 2006. The main driver for the new RNAV SIDs and STARs was the need to have a set of TMA routes to better facilitate air traffic management. The introduction of these SIDs and STARs saw some form of segregation between departure and arrival tracks both in the lateral and the vertical dimensions.

4.3 Approach

There are two parallel runways used by civil aircraft at Changi Airport. Arrivals will typically conduct the approach into Changi Airport on the ILS approach procedures, which are available for the four runway ends as the predominant precision approach procedures. The VOR non-precision approach procedures serve as the backup for Changi Runway 2 operations. In April 2005, Baro-VNAV approaches were introduced as backup procedures to supplement Changi Runway 1 (two ends – Changi 20R/ 02L). This improvement is to provide vertical guidance as a safety enhancement over the traditional non-precision approaches.

Due to the small volume of air traffic movements and the nature of the type of operations at Seletar Airport, there is currently no instrument procedure in place. However, future developments with the increase in air traffic movements, Seletar would warrant new instrument procedures to be in place to facilitate the increasing air traffic movements coming in and out of Seletar.

In March 2012, Continuous Descent Operation (CDO) procedures were implemented for arrivals into Singapore Changi Airport. CDO is an aircraft operating technique which enables the pilot to execute an optimised arrival descend profile utilising the onboard capability of the aircraft. CDO is facilitated by appropriate instrument flight procedure design and air traffic control (ATC) procedures.

The vertical profile of CDO takes the form of a continuously descending path with minimum level flight segments to enable smooth aircraft deceleration and configuration prior to an ILS approach. The CDO RNAV STARs were constructed in accordance to ICAO Document 9931 CDO Manual and ICAO Document 8168 Procedures for Air Navigation, Aircraft Operations.

5. Benefits of PBN and Global Harmonization

The introduction of the PBN concept dispels other attempts to breed new specifications which would add confusion to the seemingly difficult task of implementing RNAV or RNP procedures. With clearly spelt out criteria, standards and operational requirements, ANSPs can now focus on areas for improvement and set appropriate target to reap maximum benefits for themselves as well as for airlines, thus reducing time and effort in trying out the various standards.

PBN harmonisation is global. This reassures international airlines to go for suitable fleet equipage depending on the regions that they operate or wish to operate. While

navigation specifications may differ from region to region, certification and approval requirements for each specification have now been made consistent, and operators having attained one type of PBN approval can expect interoperability with another region having the same PBN type as requirement. This enables airlines to look ahead and plan economically, resulting in savings in the long run. As for ANSPs, PBN harmonisation ensures smooth operation between airspaces. Regional air navigation planning should take shorter time than before, bringing forward improvements to route structures which in turn will motivate airlines to get the right equipage early.

Tactically, PBN could be employed to alleviate air traffic issues like TMA congestion. For example, RNAV1 navigation specification supports close track spacing that could be used to segregate traffic flows in different directions. For areas with limited surveillance coverage, RNP1 is a good alternative.

6. Challenges

6.1 Safety Challenges

Safety challenges revolve largely around the safe operation of the ATM system during the transition of PBN operations. Safety gaps will inadvertently occur within the CNS/ATM system noting that PBN addresses only the navigation aspect of the system and advances in navigation may outpace advances in communications and/or surveillance. Safety challenges therefore include:

- ATM system integration to support PBN
- Safety monitoring of ATM system
- Mixed operating environment
- Ensuring satisfactory Target Level of Safety (TLS)
- Continues evolution of PBN navigation specifications and their deployment
- Education and training of stakeholders
- Naming and charting conventions
- Aeronautical data integrity

6.2 Efficient Operations

Efficient operations challenges include the needs of other airspace users in a scenario of mixed operating environment. Effective collaboration with these users such as military organisations and the general aviation community will help to shape the considerations of implementing PBN in Singapore.

6.3 Environment

Environmental challenges include minimising the impact of noise and carbon emissions on both the communities in the proximity of the airport and the global environment. PBN will support the achievement of these goals while preserving aviation safety and efficiencies in the ATM system, but a collaborative approach will be essential to deliver these objectives.

7. Implementation

7.1 Short term

In line with the ICAO Asia Pacific Regional PBN Plan, the time frame for short term

implementation is 2008 – 2012. Singapore's concept for the PBN implementation in the short term for the respective areas is listed as follows.

7.1.1 En route

- RNAV10 for up to 50% of international routes
- RNP4 for heavily utilised routes (up to 25% of international routes)

7.1.2 Terminal Areas (Departures and Arrivals)

- RNAV1 SIDs and STARs will be implemented at Changi.

7.1.3 Approach

- RNP APCH with vertical guidance (Baro-VNAV) will be implemented for remaining Changi runway ends

7.2 Medium term

In line with the ICAO Asia Pacific Regional PBN Plan, the time frame for medium term implementation is 2013 – 2016. Singapore's concept for the PBN implementation in the medium term for the respective areas is listed as follows.

7.2.1 En route

- RNAV10 for up to 75% of international routes
- RNP4 for heavily utilised routes (up to 50% of international routes)
- RNAV5 wherever feasible
- The application of RNP2 would be considered for routes with high traffic density.

7.2.2 Terminal Areas (Departures and Arrivals)

- RNAV1 SID and STAR for Seletar
- Basic-RNP 1 for Changi Departures

7.2.3 Approach

- RNP APCH with vertical guidance (Baro-VNAV) for Seletar

7.3 Far term

In line with the ICAO Asia Pacific Regional PBN Plan, the time frame for far term implementation is 2016 and beyond. In this phase, GNSS is expected to be a primary navigation infrastructure for PBN implementation. States should work co-operatively on a multinational basis to implement GNSS in order to facilitate seamless and inter-operable systems. Singapore's concept for the PBN implementation in the far term for the respective areas is listed as follows.

7.3.1 En-route

- Widespread of RNP4 for most major routes, RNAV10 otherwise
- RNAV5, RNAV2 and RNP2 for heavily utilised routes wherever feasible

7.3.2 Departures and Arrivals

- Basic-RNP 1 for Seletar Departures

7.3.3 Approaches

- RNP AR for Changi and Seletar
- GBAS Landing Systems (GLS) as backups for precision approaches

8. Conclusion

8.1 The global air travelling passenger traffic is anticipated to grow by 4.9% annually from 2011 to 2026. Meanwhile airfreight will rise 5.8% annually in the same period. IATA projected that the greatest demand will come from Asia Pacific region, where airlines will take delivery of 31% of new aeroplanes in the next 20 years. This PBN implementation plan not only set to meet this growing demand but also bring about other operational benefits.

8.2 As the skies get busier with more aeroplanes, PBN will serve to increase airspace safety, capacity and efficiency. Flight times will also be reduced with optimal flight paths design using PBN specifications resulting in fuel saving and enhanced environmental protection.

APPENDIX A

Performance Based Navigation
Implementation Schedule for En-route, Terminal and Approach
In Singapore

	Near Term (2008 – 2012)	Medium Term (2013 – 2016)	Long Term (2016 onwards)
Enroute	RNAV 10 (up to 50%) RNP4 (up to 25%)	RNAV10 (up to 75%) RNP4 (up to 50%) RNAV5 Explore RNP2	RNP4 for most RNAV10 otherwise RNAV5/RNAV2/RNP2 wherever feasible
Terminal Areas	RNAV1 SIDs STARs for Changi	RNAV1 SIDs STARs for Seletar Basic-RNP 1 for Changi Departures	Basic-RNP 1 for Seletar Departures
Approach	RNP APCH APV for remaining Changi	RNP APCH APV for Seletar	RNP AR APCH for Changi & Seletar GLS as backups

PBN IMPLEMENTATION PROGRESS REPORT

State: SINGAPORE Date: 01/12/2012

Designation of PBN Focal Point

Reference: APANPIRG Conclusion 18/55 –Designation of Contact Person for PBN Implementation
"That, by 31 December 2007, States designate a focal contact person responsible for performance based navigation implementation and provide details of the contact person to ICAO Asia/Pacific Regional Office accordingly"

Status: Nominated

Focal Point: Michael Shee
Air Traffic Control Manager
Singapore Changi Airport, P.O Box 1
Singapore 918141
michael_shee@caas.gov.sg
Phone – (65) 6541 2454
Fax – (65) 6545 6516

State PBN Implementation Plan

Reference: APANPIRG Conclusion 21/32 – Development of State PBN Implementation Plan
"That, the States, which have not developed their State PBN Implementation Plans so far, be urged to develop the plan in accordance with the Asia/Pacific Regional PBN Implementation Plan at the earliest and advise the Regional Office of the impediments they are facing in the implementation of PBN."

Status: Adopted by Civil Aviation Authority of Singapore and to be reviewed by ICAO APAC PBN TF

Approach Operations

Reference: ICAO 37th General Assembly Resolution A37/11 which supersedes Resolution A36-23

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

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

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

Status:

Implementation Targets (# of RWY Ends)			**Completed (# of RWY Ends)**		**In Progress (# of RWY Ends)**	
Y2010	Y2014	Y2016	LNAV	LNAV/VNAV	LNAV	LNAV/VNAV
-	2	1	-	2	-	2

Arrival and Departure Operations

Reference: 1) ICAO 37th General Assembly Resolution A37/11 which supersedes Resolution A36-23

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

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

2) Asia/Pacific PBN Regional Implementation Plan v 2.0

"Short-term Implementation Targets: RNAV 1 SID/STAR for 50% of international airports by 2010 and 75% by 2012 and priority should be given to airports with RNP Approach."

"Medium-term Implementation Targets: RNAV 1 or RNP 1 SID/STAR for 100% of international airports by 2016. RNAV 1 or RNP 1 SID/STAR for 70% of busy domestic airports where there are operational benefits."

Implementation Targets (# of Int'l Airports)			**Completed (# of Int'l Airports)**		**In Progress (# of Int'l Airports)**	
Y2010	Y2014	Y2016	Arrival	Departure	Arrival	Departure
-	1	1	-	-	1	1

En-route Operations

Reference: Asia/Pacific PBN Regional Implementation Plan v 2.0

"Short-term Implementation Targets: Re-defining existing RNAV/RNP routes into PBN navigation specification by 2012, Implementation of additional RNAV/RNP routes."

"Medium-term Implementation Targets: Implementation of additional RNAV/RNP routes"

Navigation Specification	**Completed (# of routes)**	**In Progress (# of routes)**
RNAV 10	9	-
RNAV 5	2	-
RNAV 2	-	-
RNP 4	-	-
RNP 2	-	-

Continuous Descent Operations

Reference: APAC PBN Task Force Action Item 6/1

"States are encouraged to consider implementing CDO in accordance with ICAO CDO Manual Doc 9331 on as many STARs as practicable to enhance fuel efficiency, ease pilot and ATC workloads, and reduce emission and noise."

Singapore has implemented CDO on 8 STARs since March 2012.

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