Performance Based Navigation (PBN) Implementation Plan of Turkey

Foreword

ICAO Reference documents:

Global Air Navigation Plan (GANP)
Performance-based Navigation (PBN) Manual (Doc 9613)
Manual on the Use of Performance-based Navigation (PBN) in Airspace Design (Doc 9992)
Procedures for Air Navigation Services — Air Traffic Management (PANS-ATM, Doc 4444)
Procedures for Air Navigation Services — Aircraft Operations (PANS-OPS, Doc 8168)
Continuous Descent Operations (CDO) Manual (Doc 9931)
Continuous Climb Operations (CCO) Manual (Doc 9993)
ICAO Air Navigation Report 2014 Edition
ICAO ASBU Document

EXECUTIVE SUMMARY

This plan describes Turkey's PBN implementation strategy for the next 10 years including strategic objectives, analysis of all assumptions and constraints which have a direct impact on the establishment of PBN procedures, coordination and consultation between all stakeholders, airspace concept to be developed in line with the PBN concept and all the benefits expected from the redesign of the airspace.

ICAO Performance Based Navigation was first introduced in 2008 and became the highest air navigation priority of ICAO. Performance Based Navigation is a shift from sensor based navigation to performance based navigation.

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.

Turkey has agreed with the ICAO Assembly Resolution in Force / ICAO Doc 10022 and this plan emphasizes that Turkey also considers implementation of PBN as its highest air navigation priority.

Finally, Turkey has set its strategic objectives in accordance with the ICAO's Global Air Navigation Plan (GANP), the Aviation System Block Upgrades (ASBUs) and other related guidance material.

TABLE OF CONTENTS

Glossary of Definitions/Acronyms/Abbreviations

The following table provides definitions and explanations for terms and acronyms relevant to the content presented within this document.

TERM	DEFINITIONS
ABAS	Aircraft Based Augmentation System
ACAS	Airborne Collision Avoidance System
ADS-B	Automatic Dependant Surveillance - Broadcast
ADS-C	Automatic Dependant Surveillance – Contract
AMAN	Arrival Manager
AMASS	Airport Movement Area Safety System
ANC	Air Navigation Conference
ANSP	Air Navigation Service Provider
APV	Approach with Vertical Guidance
ASDS	Airport Surface Detection System
ASMGCS	Advanced Surface Movement Guidance and Control Systems
ATC	Air Traffic Control
ATS	Air Traffic Services
Baro-VNAV	Barometric Vertical Navigation
BITRE	Bureau of Infrastructure Transport and Regional Economics
CCO	Continuous Climb Operations
CDO	Continuous Descent Operations
CFIT	Controlled Flight into Terrain
CNS/ATM	Communication Navigation and Surveillance/Air Traffic Management

DARPS	Dynamic Aircraft Route Planning System
DGCA	Directorate General of Civil Aviation
DHMİ	Directorate General of State Airports
DMAN	Departure Manager
DME	Distance Measuring Equipment
EGNOS	European Geostationary Overlay Navigation Service
FMS	Flight Management System
GA	General Aviation
GBAS	Ground Based Augmentation System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HUD	Head Up Display
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
INS	Inertial Navigation System
LORAN	LOng RAnge Navigation
LNAV	Lateral Navigation
LP	Localiser Performance
LPV	Localiser Performance with Vertical Guidance
NAVAID	Navigational Aid
NDB	Non Directional Beacon
NPA	Non Precision Approach
PA	Precision Approach
PANS-OPS	Procedures for Air Navigation Services - Aircraft Operations

PBN	Performance Based Navigation
PIRG	Planning and Implementation regional Group
PNT	Precision Navigation and Timing
RNAV	Area Navigation
RNP	Required Navigation Performance
RNP APCH	RNP Approach
RNP AR	RNP Authorisation Required Approach
SBAS	Space Based Augmentation System
SID	Standard Instrument Departure
SIS	Signal in Space
STAR	Standard Terminal Arrival route
UPR/T	User Preferred Route/Trajectory
VHF	Very High Frequency
VOR	VHF Omni Range
VNAV	Vertical Navigation
VSD	Vertical Situation Display
WAAS	Wide Area Augmentation System

Chapter 1

OVERVIEW

1.1 BACKGROUND

The implementation of Performance-Based Navigation (PBN) is presently the global aviation community's highest Air Navigation priority. It is key to the implementation of ICAO's Aviation System Block Upgrades and is an important enabler for Continuous Descent and Continuous Climb operations.

PBN implementation may involve many different stakeholders and processes including airspace and instrument procedure design, operations approvals, airworthiness, and avionics/ database development.

The continuing growth of air traffic in Turkey will impact today's airspace capacity. Conventional navigation will not meet the increasing demand. As a result of this as well as improvements in technology, new navigation applications are now available to meet future demands.

In conventional navigation, aircraft navigate using point to point method based on the ground based Navigation Aids. Routes are defined by the geographic position of NAVAIDs or fixes based on the intersection of the radials from two **NAVAIDs** including NDB Non Directional Beacon, VOR Very High Frequency Omni-directional Ranges which causes reduced efficiency and capacity owing to the long distances which means more fuel burn as well. But as the technology improves, aircraft started to have the capability to fly from point to point without using ground based sensors. With this capability a new navigation system was developed which is called Area Navigation (RNAV).

Area Navigation is the foundation of Performance Based Navigation. The continuing growth of aviation increased the demands on airspace capacity. As a result of this, Area Navigation systems evolved in a manner similar to conventional ground-based routes and procedures. Improved operational efficiency derived from the application of area navigation techniques has resulted in the development of new navigation applications for all phases of flight.

In Area navigation for the estimation of position, the initial systems used DME and INS (Inertial Navigation System). Airspace was developed based on the performance of the available equipment and specification of requirements were based on available capabilities. Such requirements resulted in delays to the introduction of new Area Navigation system capabilities and higher costs for maintaining appropriate certification. For this reason an alternative method for defining equipment requirements has been introduced. It is called as **Performance Based Navigation (PBN)**.

The PBN concept represents a shift from sensor-based to PBN. 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 (accuracy, integrity, continuity and functionality).

During the last 12 years, Turkey has become one of the most developed States in the aviation sector with a considerable progress over the world average growth rate. The number of passengers and traffic which increased incrementally each year shows that the actions taken has been very successful and seem sustainable.

The first introduction of area navigation came into effect in 2010 with the GNSS based SIDs and STARs in Istanbul Ataturk and Sabiha Gokcen Airports. This continued with the Antalya Airport on 25 August 2011 which is one of the most intensively used airport in Turkey.

1.2 PURPOSE

This plan indicates the strategic objectives of Turkey in the area of PBN implementation of RNAV and RNP air navigation applications and the advantages and benefits that we expect from the new airspace concept. It provides guidance for the ANSP, airline operators and all airspace users on how to implement RNAV and RNP applications, and ensures that necessary steps will be taken with due consideration as it specifies the short, medium and long term objectives.

Recognizing that there are many airspace concepts based on existing RNAV applications, and conscious of the high cost to operators in meeting different certification and operational approval requirements for each application, this plan shows the assessment of the CNS/ATM assumptions, aircraft fleet capability so as to identify which navigation application will be used for implementation. Turkey is aware that the implementation of PBN applications requires to undertake the cost of the certification of the aircraft fleet by the airline operators. Thus, the PBN coordinating committee sought the minimum approval necessary to meet the existing navigation requirements for the intended airspace. Our primary goal is to understand our capabilities by taking into consideration all related assumptions and find out navigation specification that should be chosen to have the highest benefit while keeping the cost minimum that is covered by airline operators.

While reducing the undue costs which the intended airspace concept may impose, The PBN coordinating committee identified that a new standard is needed, this plan identifies the steps required for the establishment of such a new standard and provides a strategy to enhance the implementation of PBN.

Three fundamental points must be understood about PBN:

- PBN requires the aircraft to be capable of area navigation which is enabled through the use of an on-board navigation computer referred to as an RNAV or RNP system;
- PBN creates requirements for airworthiness certification and operational approval to use RNAV or RNP systems in airspace implementations;
- The RNAV or RNP system's functionality as well as its navigation accuracy, enabled by the NAVAID environment of the subject airspace, must conform to the requirements stipulated in the relevant ICAO navigation specification.

Simply put , for PBN both the aircraft and air crew have to be qualified against the particular Navigation Specifications required for operation in the airspace.

1.3 STRATEGIC OBJECTIVES

The implementation of Performance Based Navigation (PBN) is presently the global aviation community's highest Air Navigation Priority. ICAO has developed Aviation System Block Upgrade (ASBU) road map concept to help states set their objectives and enable the adjustment of Continuous Descent Operations and Continuous Climb Operations to achieve an optimized descent and climb profile in the favour of both environment and airline operators for reducing fuel burn. Based on the Blocks represented in the ASBU and in line with the ICAO documents, the strategic objectives of Turkey can be summarized as:

- Optimization of approach procedures with vertical guidance techniques
- Improve flexibility and efficiency in Descent Profiles (CDO)
- Improve traffic flow through sequencing AMAN/DMAN
- Flexible and efficient design of En-route and Terminal Airspace

PBN sets clear performance requirements for flight operations, involves a major shift from conventional ground based navigation and procedures to satellite based navigation and area navigation procedures. PBN is more accurate and allows for shorter and more efficient routes which reduce fuel burn, airport and airspace congestion, and aircraft emissions.

1.4 ASSUMPTIONS AND CONSTRAINTS

The airspace concept to be developed is based upon certain CNS/ATM assumptions. These assumptions must take account of the environment that is expected to exist at the time when the new airspace operation is intended to be implemented. The assumptions that the PBN coordinating committee identified can be summarized as:

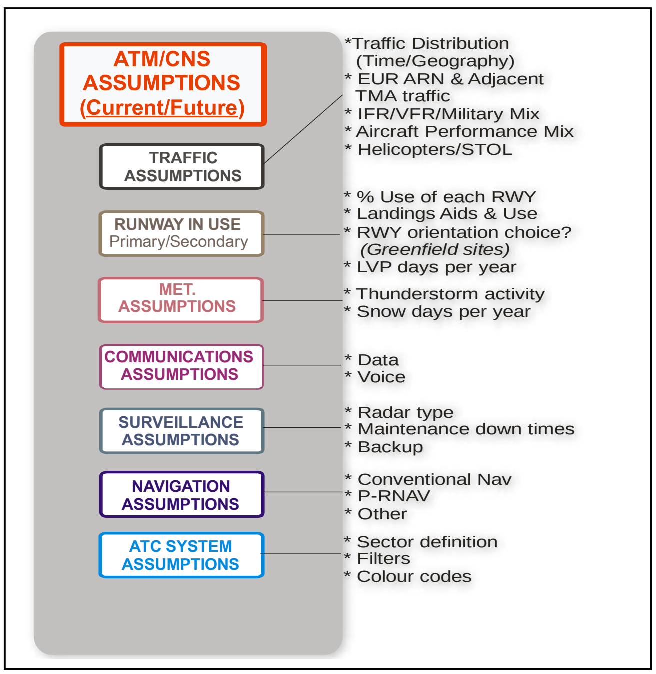

Table 1 – ATM/CNS Assumptions

Turkey has approximately 600 large and business-type aircraft on its register which cover 11 different aircraft make/model/series. The average age of the fleet is 13 years and 10% of the aircraft are older than 15 years. The majority of the aircraft operated by main airline operators have RNAV and RNP capability with the RF functionality.

The PBN coordinating committee has agreed to establish the existing RNAV equipment approval, the actual capabilities and qualifications of the systems being carried and the system upgrades that are expected to be implemented prior to the introduction of the new airspace concept.

A thorough knowledge of fleet capabilities and a realistic understanding of the likely improvements in capability that will be in place prior to the implementation date are required. Over-enthusiastic projections of fleet capability inevitably lead to major project delays and cancellations. For these reasons, the DGCA has established a study group which involves all national aircraft operators and representatives of foreign operators to obtain a realistic estimate of future fleet capabilities and to undertake a realistic cost-benefit analysis throughout the project's life cycle.

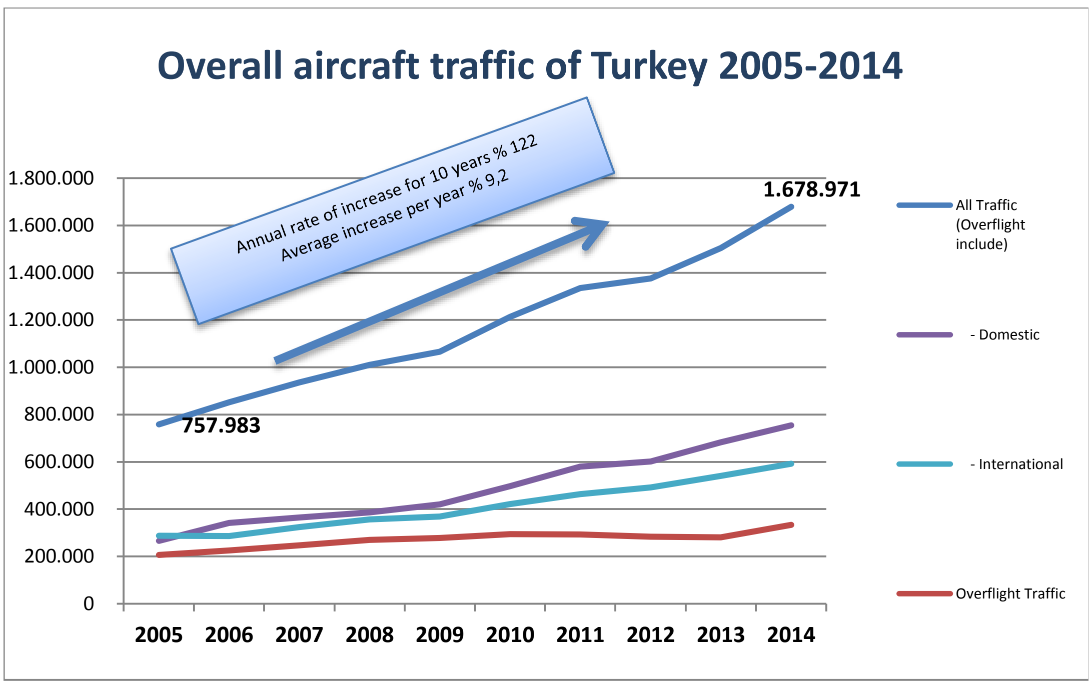

Table 2 – Aircraft Traffic Graph of Turkey 2005-2014

Assumptions made concerning the **traffic demand** is of crucial importance to the design of an Airspace. In Turkey's aviation between 2005 and 2014, overall aircraft traffic including overflights has increased 122% and it reached 1.832.962 in 2015. It is envisaged that the number of traffic would be 1.948.675 and 2.066.841 in 2016 and 2017, respectively.

Standing in contrast to assumptions, constraints should also be identified carefully given the fact that they have a negative impact upon ATC operational requirements of an airspace design. Constraints may arise as the absence of certain elements of ATM/CNS or limitations created by extraneous factors.

Given that constraints may always exist in an airspace, enablers refer to any aspects of ATM/CNS that may be used to mitigate the constraints identified and/or any factors which may be relied upon to 'enable' ATC operations in the airspace designed. The role of **enablers** is to mitigate against **constraints** which have been identified. Consequently this plan highly emphasizes the importance of the in-depth analysis of assumptions, constraints and enablers.

Chapter 2

PERFORMANCE BASED NAVIGATION (PBN)

2.1 PBN CONCEPT

Performance Based Navigation (PBN) is defined as area navigation activities which are conducted as based on performance requirements for aircraft operating along an ATS route, on an instrument approach procedure or in a designated airspace. Performance requirements are expressed in navigation specifications in terms of accuracy, integrity, continuity, availability and functionality needed for the proposed operation in the context of a particular airspace concept.

PBN is one of several enablers of the Airspace Concept Communications, ATS Surveillance and Air Traffic Management (ATM) are also essential elements of an Airspace Concept. The PBN concept relies on the use of area navigation and is comprised of three main components:

Navigation Specification is a set of aircraft and aircrew requirements needed to support performance-based navigation operations within a defined airspace. There are two kinds of navigation specification RNAV (Area Navigation) and RNP (Required Navigation Performance). RNAV and RNP systems are fundamentally similar. The key difference between them is the requirement for on-board performance monitoring and alerting systems. A navigation specification which includes a set of requirements for on-board navigation performance monitoring and alerting systems are referred to as an RNP specification. One not having such requirements is referred to as an RNAV specification. An area navigation system capable of achieving the performance requirement of an RNP specification is referred to as an RNP system.

Navigation Infrastructure is NAVAID infrastructure refers to space-based and or ground-based navigation aids available to meet the requirements in the navigation specification.

Navigation Application is the application of a navigation specification and the supporting NAVAID infrastructure to routes, procedures, and/or defined airspace volume, in accordance with the intended airspace concept.

The airspace design based on PBN begins with developing an airspace concept. The airspace concept describes the intended operations within an airspace and the organization of the airspace to enable those operations.

Airspace Concepts are developed to satisfy explicit and implicit strategic objectives such as:

Safety	Capacity	Efficiency	Access	Environment
Reduce Controlled Flight Into Terrain via lateral & vertical course guidance to runway	Increase the number of air traffic routes to reduce the congestion, accommodate projected growth	Reduce delays that result from excessive "leveling off" flight profiles by implementing CCO/CDO	Improve airport and airspace access in all weather conditions	Reduce noise over sensitive areas
RNP APCH (LNAV/VNAV) To replace circling approach	Parallel RNAV-2 ATS routes between cities	RNAV-1 SID that allow continuous climb to enroute	RNP approach allowing lower minima	Use RF in intermediate or missed approach segment

Table 3 – PBN Gains

Once fully developed, an airspace concept describes in detail the target airspace organization and the operations within that airspace. It addresses all of the strategic objectives and identifies all the CNS-ATM enablers, as well as any operational and technical assumptions. An airspace concept is a master plan of the intended airspace design and its operation.

ICAO has set worldwide guidance for rapid transition to performance based navigation and approaches with vertical guidance. PBN RNAV and RNP navigation specifications define performance and other requirements for aircraft navigating along a route, on an instrument approach procedure or in defined airspace.

Performance requirements are defined in terms of accuracy, integrity, availability, continuity and functionality needed for a proposed operation in the context of a particular airspace concept. Navigation specifications also identify technology, systems and procedures which are recognized as suitable to meet the performance requirement.

Area navigation is the fundamental of PBN and defined as a method of navigation which permits aircraft operation on any desired, pre-planned flight path within the coverage of station referenced NAVAIDs or within the limits of capability of self-contained aids or combination of these. This allows more flexible and efficient aircraft operation compared to the traditional navigation along fixed routes denoted by terrestrial radio navigation aids. Early area navigation systems required ATC navigation integrity monitoring - typically implemented by radar surveillance. The PBN/RNAV specifications are applicable to these systems.

Modern area navigation avionics include onboard navigation computer and performance monitoring and alerting system. This permits the transfer of navigation integrity monitoring to flight crew rather than ATC. This is necessary with very high accuracy navigation (0.3 to 0.1 NM); as it is impractical for ATC to detect errors of this size and there is insufficient time to successfully intervene. Aircraft with RNP capability are also RNAV capable, as mentioned earlier the key difference between RNAV and RNP is that RNP requires onboard performance monitoring and alerting system.

In this sense, RNP systems provide improvements on the integrity of operations; this may permit closer route spacing and can provide sufficient integrity to allow 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 over RNAV systems e.g.:

- Safely allow higher traffic density
- Enable higher accuracy, more efficient and sophisticated approach and departure operations including curved path, particularly useful in terrain and/ or noise challenging areas
- Reduced emissions and noise

The latest edition of PBN Manual, ICAO Doc 9613 contains detailed information with respect to the navigation specifications. This table lists all PBN navigation specifications, along with their typical intended usage. For example RNAV 1 is typically used for SIDs, STARs, and the initial, intermediate and missed approach segments of an approach.

Navigation Specification	Flight Phases							
	Enroute Oceanic/Remote	Enroute Continental	Arrival	Approach				Departure
				Initial	Intermediate	Final	Missed approach	
RNAV 10	10							
RNAV 5		5	5					
RNAV 2		2	2					2
RNAV 1		1	1	1	1		1	1
RNP 4	4							
RNP 2	2	2						
RNP 1			1	1	1		1	1
Advanced RNP	2	2 or 1	1	1	1	0.3	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	
RNP 0.3		0.3	0.3	0.3	0.3		0.3	0.3

Table 4 – PBN Flight Phases

An optional function of Advanced RNP allows accuracy requirements of below 1 nm in terminal airspace applications, for example on the initial, intermediate and final segments of an approach.

2.2 BENEFIT OF PBN and GLOBAL HARMONIZATION

PBN offers significant advantages over the current sensor specific method (which uses ground based navigation aids) to design more efficient airspace, ATS routes, instrument flight procedures (with vertical guidance) and obstacle clearance criteria. Generally, the main benefits can be summarized as follows:

Reduces infrastructure

It reduces the need for and reliance on sensor-specific, ground- based navigation aids – Non Directional Beacons (NDB), VHF Omni Directional Radio Range (VOR), Distance Measuring Equipment (DME);

- It reduces the cost of maintaining the ground- based navigation infrastructure;

Improves operational efficiency

- It allows for more efficient and flexible use of airspace (route design and placement), resulting in increased aircraft fuel efficiency and reduced noise impact) ;

Improves safety

It allows for the design of straight in instrument procedures with vertical guidance, improving both airport accessibility and flight safety;

Reduces environmental impact

It clarifies and simplifies the way in which area navigation systems are used; and

Increases airspace capacity

It facilitates an easier operational approval process for operators by providing a limited set of navigation specifications intended for global use.

The greatest advantages of PBN is that ATS routes do not have to pass directly over ground-based NAVAIDs. PBN makes it possible to place routes in the most optimum locations on condition that the necessary coverage is provided by the ground or space-based NAVAIDS.

This “placement” benefit provides significant advantages. It means that routes can be placed where they give flight efficiency benefits, for example, by avoiding conflicts between flows of traffic. It also means that parallel routes can be designed to avoid having bi-directional traffic on the same route and to provide various route options between same origin and destination airports. Most significantly, perhaps, this placement benefit provided by PBN makes it possible to ensure the efficient connectivity between en-route and terminal routes so as to provide a seamless (vertical) continuum of routes.

PBN routes can shorten the distances, increase the efficiency and reduce the number of conflicts with the flexible design criteria. Similarly, routes can be designed to provide vertical windows supporting continuous descent or climb operations enabling more fuel efficient profiles with reduced environmental impact (noise, CO_2, etc.). The flexible design of parallel routes reduces the congestion and delays that result from excessive “leveling off” flight profiles by implementing CCO/CDO and the workload of air traffic controllers by reducing the radio transmission and vectoring concerning this matter.

2.3 PBN CURRENT STATUS IN TURKEY

2.3.1 CONTINENTAL ENROUTE

No PBN routes are established but in the short term, PBN ATS routes will expected to be established.

2.3.2 TERMINAL AREA (SIDs and STARs)

RNAV 1 The implementation started with the realization of GNSS based navigation SIDs and STARs; published for the Istanbul Ataturk and the Sabiha Gokcen Airports in 2010, continued with Antalya airport on 25 August 2011 and for the Dalaman Airport on 6 March 2014. The latest is published for Trabzon Airport on 28 May 2015.

The published procedures have been revised as needed according to the tactical requirements, the feedback of the operators and final results of the real time simulations took place in EUROCONTROL Training Centre for Istanbul TMA.

RNP 1

RNP 1 SIDs and STARs planned for TMAs without radar services. The intention is to shorten the routes, to ease the separation by segregated SIDs and STARs using the advantages of flexible design of RNP1 . Current implementation status of RNP 1 is:

RNP 1 SIDs for Van Airport for RWY 03 and Kahramanmaras Airport RWY 25 published in 2013.

RNP 1 SIDs and STARs for Denizli Cardak Airport published in 2014.

2.3.3 APPROACH

For the implementation of RNP-APCH procedures with vertical guidance, a stepped approach has been planned and implemented. At first, an instruction covering RNP-APCH implementation procedures including the airworthiness of aircraft has been published in line with EASA 20-27A, Doc 9613, FAA 20-138D on 31 January 2012, with the current revised version of 25 July 2012.

According to the outcomes of the joint meetings with Turkish registered airline operators, a transition plan has been established and number of airports especially at the eastern part of Turkey in high terrain environment has been selected.

The survey and update of current artificial obstacle data have continued during this process. As completed for the first airport in sequence, RNP APCH (LNAV) procedure published for Van airport on 7 February 2013.

During the transition period no significant report concerning the loss or failure of GNSS effecting the implementation of procedure has been received.

Therefore, RNP APCH (LNAV) procedure for Kahramanmaras Airport (RWY 25) and for Dalaman Airport (RWY 19) published in November 2013 and March 2014, respectively.

2.4 PBN APPROACHES WITH VERTICAL GUIDANCE

ICAO defines an APV as "An instrument approach procedure which utilizes lateral and vertical guidance but does not meet the requirements established for precision approach and landing operations". ICAO recognizes Baro-VNAV and augmented GNSS SIS as suitable technologies to support vertical guidance applications and has enabled APV operations through the development of PANS-OPS procedures for both Baro-VNAV and augmented GNSS. APV are grouped as:

RNP APCH - LNAV/VNAV

Baro-VNAV approach procedures that include system performance monitoring and alerting for lateral navigation errors in the GNSS SIS and must meet demonstrated system accuracy requirements for the vertical navigation source (altimeter)

RNP APCH – LPV

- SBAS approach procedures that include system performance monitoring and alerting for lateral and vertical navigation errors in the GNSS SIS.

RNP AR APCH

- Baro-VNAV approach procedures that include system performance monitoring and alerting for lateral and vertical error budget requirements for the vertical navigation source (altimeter).

Intention

The intention of the ICAO recommendation, to adopt PBN, is to standardize and harmonize the deployment of PBN which is recognized as a necessary enabler for modern ATM applications, which will increase safety, operating efficiency and minimize environmental impact.

The intention of the ICAO direction to adopt APV as the primary instrument approach procedure or as a backup to precision approach procedures is to significantly reduce the risk of CFIT, runway undershoot and overrun through the provision of continuous lateral and vertical guidance during instrument approach to the runway. With the introduction of APV, NPA's would be phased out of service resulting in the APV becoming the minimum worldwide standard for an instrument approach to land procedure.

Current status of APV operations in Turkey

There are currently no aerodromes served by RNP AR procedures as by 2016. These are currently being conducted by individual operators on a case by case basis but are undergoing a transition to be made publically available to approved operators.

2.5 AIRCRAFT CAPABILITIES

PBN RNAV is the less capable of the two families of PBN navigation specifications and in Turkey is reliant upon an INS to support the this specification. RNAV is suited to current and legacy aircraft operations however it is insufficient to support many of the new Air Traffic Management (ATM) applications envisaged in strategic plans (eg: 3 dimensional, or 4 dimensional ATM concepts).

PBN RNP is the more capable of the two families of PBN navigation specifications. The on board navigation performance monitoring and alerting are necessary enablers for many new ATM applications envisaged in strategic plans of Turkey. Full RNP capability is available to the latest generation of aircraft such as A320, B737-NG and B787 and may be available to other late generation aircraft via modification processes.

In Turkey, regulations are prepared and published for aircraft approval process for PBN operations. These regulations are SHT-14 for RNAV 5, SHT –RNP- 20-27 for RNP APCH. RNP AR regulation studies are ongoing. At the same time, ICAO Doc.9613 PBN Manual is used for PBN approval processes. List and numbers of types of aircraft which are registered in Turkey with different PBN capabilities are listed in Appendix 1.

2.6 CNS/ATM CAPABILITIES

For the Airspace Concept to be realised, the technical operating environment needs to be agreed. This requires knowledge, as regards the ground infrastructure and airborne capability, as to which CNS/ATM enablers which are already ‘available’, the limitations or constraints which exist and what the future environment which will be need when the Airspace Concept is implemented.

Ground-based radio navigation aids have been the basis of aircraft instrument navigation for many decades in Turkey and currently 227 ground radio navigation (65 NDBs, 61 VORs and 101 Distance Measuring Equipment - DMEs) devices are stationed, which aircraft use to conduct point to point navigation along fixed routes (Route Navigation) and to conduct instrument approach for landing procedures to aerodromes.

The NAVAID Infrastructure is comprised of all navigation aids permitted by PBN, they can be ground or space based. NAVAIDs transmit positioning information which is received by the appropriate on-board sensor providing input to the navigation computer. The air crew in combination with the RNAV or RNP system enables path steering to be maintained along a route within a required level of accuracy.

Ground-Based (or terrestrial NAVAIDs) permitted for use with navigation specifications include DME, and to a more limited extent VOR. NDB is not a PBN positioning source.

Space-Based NAVAIDs are synonymous with GNSS (including augmentation systems). Existing operational GNSS constellations include GPS (USA), GLONASS (Russia) with the following under development: Galileo (EU), Beidou (BDS) and QZSS (Japan). Augmentation systems include wide-area and local area augmentations (termed Satellite Based Augmentation System or Ground Based Augmentation System, SBAS and GBAS, respectively). The space based augmentation system used in Europe is EGNOS.

Each navigation specification stipulates which positioning sensor can be used for a particular navigation application. The only navigation specification with full sensor flexibility is RNAV5. The flexibility reduces the more demanding the navigation specification becomes. The table 5 also shows that only GNSS is able to meet the requirements of all navigation specification. Because GNSS is available globally, it is essential to make GNSS available for aviation use.

NAV SPEC	NAVAID				
	GNSS	IRU	DME/ DME	DME/ DME/ IRU	VOR/ DME
RNAV 10	✓	✓			
RNAV 5	✓	✓	✓		✓
RNAV 2 & 1	✓		✓	✓	
RNP 4	✓				
RNP 2	✓		✓	✓	
RNP 1	✓		✓	✓	
Advanced RNP	✓		✓	✓	
RNP APCH APV Baro	✓				
RNP APCH APV SBAS	✓ + SBAS				
RNP AR APCH	✓				
RNP 0.3	✓				

Table 5 – PBN NAVAID Requirements

Turkey has been recently a part of the METIS project which creates a road map to enable the Mediterranean Region be within the coverage and utilize from the EGNOS. The purpose of this project is to provide, implement and measure the EGNOS signals over this region. As mentioned before, currently Turkey is not wholly within the sufficient area coverage of EGNOS.

In the context of METİS project, Turkey was one of the three states which carried out the testing of the APV procedures based on SBAS.

Basic goals of this trial are to verify that whether EGNOS can be utilized outside of the original coverage and show the benefits that the air navigation service providers could have by receiving SBAS signals.

Tests mentioned above took place between 5-6 November 2009 and Canakkale Airport which is located on the west part of Turkey was selected since it is located within the last border of EGNOS coverage. It was performed a very efficient way and by using EGNOS signals, approach procedures were executed corresponding the ILS CAT I approach.

Given the fact that the majority of the aircraft fleet operating within Turkey is GNSS equipped, the basis of the airspace design will be established as based on GNSS.

GPS signal has been published on relevant part of Turkish AIP. (ENR 4.3) 1575.42 Mhz is covered at Statewide.

Chapter 3

IMPLEMENTATION CHALLENGES

3.1 SAFETY

Safety challenges revolve largely around the safe operation of the ATM system during transition to PBN operations. Gaps will necessarily occur within the CNS/ATM system noting that PBN addresses only the navigation tenet of the system and advances in navigation may out pace advances in communication and/or surveillance infrastructure. Safety challenges therefore include:

- Integration into the ATM system including software enhance to support PBN
- Safety monitoring of ATM system
- Mixed fleet/system operations
- Maintenance of the Target Level of Safety (TLS)
- Continued evolution of PBN navigation specifications and their deployment in the ATM system
- Development of supporting rule set
- Education and training of stakeholders
- Approach naming and charting conventions
- Vertical Advisory versus Vertical Guidance
- Data base integrity and control
- GNSS system performance and prediction of the availability of continuous service
- Scale of change for ATC and Aircrew
- Multiple airspace designs if conventional routes are kept as the back-up network.

3.2 AIRCRAFT EQUIPMENT AND INFRASTUCTURE

ICAO has designed PBN such that it can be supported by terrestrial radio navigation aids or self-contained aircraft navigation systems (inertial and/or GNSS), however Turkish existing network of terrestrial navigation aids is of sufficient density to support PBN navigation specifications. Therefore, PBN implementation in Turkey will be supported by self-contained aircraft navigations systems (inertial and/or GNSS based).

Turkey will maintain a reduced network (“the backup network”) of terrestrial radio navigation aids to provide an alternative means of navigation for terminal operations and Non-Precision Approach (NPA) using conventional navigation procedures.

The existing GNSS prediction service will be retained to support PBN.

The problems experienced in ensuring the accuracy and continuity of satellite signals in transition to the PBN implementation is a major obstacle in Turkey. This problem is also being experienced in many countries. As it is known, in accordance with the decision taken by EUROCONTROL, Turkey is also a member, full transition to PBN implementation has been postponed to 2018. Also studies have been initiated between the satellite service provider TURKSAT, the authority on satellite Information Technology Institution in Turkey, the aviation authority SHGM and the air navigation service provider DHMİ to ensure the accuracy and continuity of signals and the process is ongoing.

3.3 EFFICIENCY AND CAPACITY

The challenges presented by demand, capacity and efficiency in the Turkish aviation industry has an important role in the development of the new airspace concept enhanced by the implementation of PBN.

The PBN coordinating committee consists of regulator, ANSP, airline operators, airport authority, military authority, policy makers and government, aims to create open dialogue on key industry issues and find the necessary solutions to meet the increasing traffic capacity.

3.4 ENVIRONMENT (NOISE AND EMISSIONS)

One of the most effective ways for reducing carbon dioxide in aviation field is to cut fuel consumption by shortening flight distances. With conventional navigation, aircraft flies along a route defined by signals provided by ground navigation facilities so that air routes are designed by the locations of ground radio navigation facilities. This poses limitations in shortening flight distances using conventional navigation. On the other hand, air routes can be set more freely with PBN making it easier to shorten distances and is effective in reducing CO_2.

In establishing new air routes, Turkey will place top priority on shortening flight distances with specific goal to reducing at least 2 NM per departure/arrival route. This will cut fuels consumption by approximately 11.5 billion tons and reduce CO_2 emissions by about 45,000 tons annually, thus simultaneously bringing positive economic effects and solving environmental problems. Furthermore, continuous descent operations (CDO) with optimized thrust power compared with that of sept-down operations would contribute to additional fuel savings.

3.5 APPROACH OPERATIONS

The Augmentation technologies studied included ABAS, and SBAS. The GBAS project has been terminated and passenger demographics combined with existing IFR fleet APV capabilities eliminated GBAS as a feasible option.

ABAS and SBAS remained as feasible augmentation technologies to enable APV operations in Turkey and a study on April 2016 was conducted, the results have been reproduced in the tables below:

Turkish registered aircrafts which have any of PBN authorization	RNP APCH approved aircrafts	RNP APCH (Baro-VNAV) approved aircrafts	RNP AR APCH approved aircrafts
606	429	370	11

Table 6 – PBN Authorization of Turkish Registered Aircrafts

The results of the analysis demonstrate that:
Subsequently the study recommended implementation of RNP APCH - LNAV/ VNAV as soon as practicable with potential investment in a SBAS to support LPV to be determined. The potential investment in SBAS acknowledges the added safety benefit for individual aircraft (largely GA IFR aircraft) irrespective of the number of passengers onboard.

RNP AR operations will provide significant increased safety benefits at non- precision aerodromes and significant environmental and economic benefits at precision aerodromes. Subsequently their introductions are being encouraged and supported by DGCA and DHMİ through the provision of normal regulatory and air navigation services.

Turkey, agrees with the study recommendations and is taking steps to implement barometric vertical navigation through RNP APCH - LNAV/VNAV and RNP AR APCH design criteria consistent with the PBN concept.

Chapter 4

IMPLEMENTATION

The intent is to roll out a series of initiatives to align existing RNAV applications to PBN specifications and/or to introduce new ones in phases based on priority, starting from near term to long term. The type of PBN navigation specifications to be introduced depends on the airspace in study and operational needs, taking into account fleet readiness and other considerations such as operating costs and impact to the environment. The PBN strategic objectives will serve as a guide for identifying areas of improvement.

For en-route PBN implementations, it is common that most ATS routes traverse multiple FIRs. As such, the effectiveness of en-route PBN implementations is highly dependent on the coordination efforts among neighbouring States. Such coordination normally entails a great deal of effort and a lengthy process and quite often, it may be more expedient if route structures were reviewed on a regional basis.

4.1 SHORT TERM

(2016-2018)

4.1.1 CONTINENTAL EN-ROUTE

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.

RNAV 5 is the most seen Navigation Specification for continental en-route flight phase. RNP 2 also supports the en-route continental airspace concept but it can be flown by only GNSS equipped aircrafts. **RNAV 5** enables the design of parallel routes which reduce the necessity of the radio transmission between pilot and controllers and increase safety by reducing the possibility of head on conflict.

Existing en-route network is currently based on Conventional methods in Turkey and as the first step RNAV 5 application will be designed in coordination with European Region and neighbor states. All existing RNAV routes will be changed to RNAV 5 routes. RNAV 2 and RNP 2 will be introduced to establish unidirectional parallel routes on heavily congested routes to improve air traffic flow and the number of aircraft that can be handled will be increased without adding the workload to air traffic controllers in the future. Those routes will be separated by at least 8NM laterally. In addition, efforts will be made to harmonize navigation specifications on routes connected with the neighbor countries like Ukraine and Bulgaria.

4.1.2 TERMINAL AREA (SIDs and STARs)

Current RNAV STAR and SID will be switched over to RNAV 1 which will also be applied to new STAR and SID during this term. In this case, priority will be given to easing congestion of airspace with high traffic density and reducing the controller's workload. This is both to cope with the congestion and growing air traffic demands and at the same time to improve flight safety by lowering the incidence of aircraft proximity and other safety impediments. When selecting SID courses, RNAV's or RNP track keeping advantages will be utilized to the fullest to give consideration to avoiding heavily populated residential areas. And, continuous descent operations (CDO) will be expanded to all major airports including Istanbul Ataturk and Sabiha Gokcen Airport.

RNAV 1 SIDs and STARs are going to be designed for the airports listed below:

- Bodrum Airport and Ankara Esenboga Airport in 2016
- Izmir Adnan Menderes Airport in 2017

RNP 1 SIDs and STARs are going to be designed for the airports listed below:

- Gazipasa Airport in Antalya in 2016
- The further plan is to realize the similar procedures for 18 more TMAs by the end of 2017.

4.1.3 APPROACH

APV-Baro VNAV will be introduced to all international airports and high traffic domestic airports. At these airports, APV-Baro VNAV will be adopted at non-precision runways without ILS for priority operation replacing non-precision approach procedures and this will help to tackle problems off-set and step-down approach of non-precision approaches and eventually the flight safety and accessibility.

Mixed navigation environment will be inevitable during the transition period. Therefore, taking air traffic control workload into account, instrument approach procedures will be designed as much as possible to have initial approach waypoints correspond with the initial approach fixes of conventional approach procedures. In addition, study on introduction of GBAS will be launched as well.

- RNP APCH (LNAV/VNAV) procedure is planned for Gazipasa Airport by the middle of 2016.
- The implementation of similar RNP (LNAV/VNAV) procedures in Turkey for 12 more airports until the end of 2016.

As is known RNP AR is more than procedure design. It is considered that have some significant operational benefits especially in high terrain environment. Therefore, there may be some advantages to be taken into account especially in the eastern side of Turkey.

Our priority is the finalization of regulatory approach. DGCA has some work in progress to adapt the RNP AR procedures into our National Regulations. Authorisation of Turkish operators RNP (AR) operations is carried out according to ICAO Doc.9613 and EASA AMC 20-26. However, our national regulations about RNP (AR) authorisation (SHT-RNP 20-26) is in draft document and still in progress.

4.2 MEDIUM TERM

(2018-2020)

4.2.1 CONTINENTAL ENROUTE

RNAV 2 or RNP 2 will be applied to new RNAV routes installed during this period. Routes between Turkish airspace and neighbour countries will be straightened out during this period as well and new routes will be established exclusively for overflights in an effort to diversify traffic. Concerned countries will be consulted for the development of new routes and for regional harmonization of navigation specifications.

4.2.2 TERMINAL AREA (SIDs and STARs)

Introduction of RNAV 1 or RNP 1 in International airports will be completed during this period and RNAV 1 or RNP 1 will be expanded to major domestic airports. And, as needed, RNAV 1 or RNP 1 will be mandated within some congested TMAs. Continuous descent operation (CDO) will be expanded to domestic airport as well.

4.2.3 APPROACH

Introduction of APV-Baro will be completed at all airports in Turkey and trial operation of GLS (GBAS Landing System) will be started at the selected airports. During this term, studies will be conducted to review the progress of PBN implementation and to evaluate the need of each ground NAVAID. Thereafter, evaluation results will be announced to public with Turkish AIP and/or NOTAMs.

4.3 LONG TERM OBJECTIVES

(2020-2023)

All RNAV 5 routes in operation will be switched over to RNAV 2 or RNP 2 and Approach procedures using GBAS will be expanded to other airports. VOR routes and RNAV routes will be completely separated at specific altitudes. Ground NAVAIDs on the removal notice will be out of commission gradually from 2021 and conventional routes will be replaced with RNAV routes.

Chapter 5

PLAN COORDINATION

5.1 COORDINATION AND CONSULTATION

Working from the needs and constraints it has identified, the DGCA of Turkey has developed a Master Plan for implementation of PBN operations in Turkey. This plan must allow for the deployment of PBN operations commensurate with Turkey's international commitments and other operational issues.

However, there is a need for the interests of all civil and military aviation stakeholders to be duly taken into consideration through a concerted implementation process. To this purpose, coordination of PBN activities nationally and internationally is proposed as follows.

A PBN Coordinating Committee is set up under DGCA control, to which the following are associated:

- the Military Authority;
- the Airport Authority;
- the Air Navigation Service Provider;
- the representatives of National air operators;
- a representative scope of the international airlines operating in Turkey, whether commercial or non-commercial.
- ICAO Regional Office

Aircraft manufacturers and equipment manufacturers and environment experts will also be invited depending on the subject.

This committee aims to offer a forum, so that the direction taken by the DGCA take into account the various issues. It will annually review the actions (past, present and future) regarding the implementation of PBN operations in Turkey.

5.2 PLAN RESPONSIBILITY

The DGCA of Turkey is the authority having responsibility for the effective and efficient performance of Turkey's PBN implementation plan.

The PBN implementation also places responsibilities on the other organization involved to the process:

- DHMİ is responsible to fulfil the requirements with respect to the integration, installation and maintenance of NAVAIDs, training of ATCOs, providing experts to the airspace core team which is responsible for the design of routes, terminal and approach areas, and also publication of charts.
- The airline operators are responsible to have their aircraft equipped the appropriate avionic systems on board so as to operate with the new procedures and complete training of the pilots.

5.3 PLAN REVIEW

Plan review is a fundamental component of an airspace change. The implementation of PBN is going to introduce new technologies, new procedures or systemic changes that affect aviation operations. Plan review is under the responsibility of PBN coordinating committee led by DGCA of Turkey.

Chapter 6

SAFETY

6.1 PRELIMINARY SAFETY ASSESSMENT

Once the design process has been completed for any PBN implementation, a series of review meetings will be held in order to identify any significant hazards or violation of safety regulations. The review team will be composed of pilots from airlines, flight procedure designers and air traffic controllers. If the team finds any serious defect which results in unacceptable level of safety, then the airspace in question must be redesigned. The team will meet several times to finalize the airspace design that delivers an acceptable level of safety.

Though the airspace is reviewed and is verified of having an acceptable level of safety, a meeting for official safety assessment should be held to see if every corner of operational environment is safe, reflecting changes introduced by the new concept of navigation specification. The meeting will identify any hazards, even those with minor problems, and organize them into a list. Then a risk assessment process will be conducted to list-up the expected risks and rate them according to the guidelines provided by ICAO SMS manual. The members of the safety assessment meeting are composed of pilots from airlines, airspace planners, flight procedure designers, air traffic controllers, NAVAID facility operators, and other experts from related organizations. If the meeting finds risks which require risk mitigation, they will recommend specific remedial actions for risk mitigation. When the level of safety is considered sufficient to meet safety requirements after the above mentioned process, the operation of the PBN airspace can be started.

6.2 IMPLEMENTATION SAFETY ASSESSMENT

It is necessary to analyse flight track data after the implementation of the PBN procedure to see if safety requirements are met. As a source of flight track, the radar track data will be used at the initial stage. Also a system that utilizes ADS-B track data as another source of flight track data will be developed in the near future. The recorded source data for specific months of the year will be collected for deviation analysis. Software for measuring magnitude of deviation from collected flight track will be developed and safety assessment experts will evaluate the level of safety through deviation analysis and collision risk analysis utilizing a Probability Density Function and Collision Risk Model.

APPENDIX 1

PBN Capabilities of Turkish Registered Aircrafts

PBN CAPABILITIES OF TURKISH REGISTERED AIRCRAFTS														
PBN Operation Types / Aircraft Types	RNAV 10	RNAV 5	RNAV 2	RNAV 1	RNP 4	RNP 2	RNP 1	RNP 0.3	RNP 0.1	RNP APCH	RNP APCH (BV)	RNP AR APCH	A-RNP	None
B737	121	211	124	221	121	124	221	198	89	208	168	89	64	
A320	40	140	40	140	36	17	136	123	14	136	125	14	17	
A319	1	1	1	1	1		1	1		1	1			
A321	13	13	13	13	13		13	13		13	13			
ERJ 190/195	12	12	12	12			12	12		12	12	12		
Global-XRS	1	1	1	1	1	1	1	1		1	1	1		
B747	7	7	7	7	7	7	7			7	7			
B777	24	24		24	24		24	24		24	24			
A310	3	3	3	3										
A340	5	5		5	5		5	5		5	5			
Cessna Citation	1	1		1	1			1			1			
A330	62	62	8	62	62		62	54		62	56	12		
TOTAL	290	480	209	480	271	149	472	432	103	469	418	128	81	

APPENDIX 2

ICAO Assembly Resolution A37-11

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 (PBN) Manual (Doc 9613);

Resolves that:

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;

- 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

- 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;

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.

APPENDIX 3

PBN Implementation Plan of Turkey

	<u>ICAO Assembly Resolution A37-11:</u> *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 (PBN) Manuel (Doc 9613).*	**Short Term 2016 - 2018**	**Medium Term 2018 - 2020**	**Long Term 2020 - 2023**
Enroute	Implementation of RNAV and RNP operations (where required)	1) All current ATS routes will be changed to RNAV 5. 2) RNAV 2 and RNP 2 will be introduced to establish unidirectional parallel routes on heavily congested routes with 8NM lateral seperation. 3) Routes to be harmonized with neighbor countries.	1) RNAV 2 or RNP 2 will be applied to new RNAV routes installed during this period.	
Terminal	Implementation of RNAV and RNP operations (where required)	1) Currently utilized RNAV STAR and SID will be switched over to RNAV 1. 2) RNAV 1 SIDs and STARs to be implemented to selected airports. 3) RNP 1 SIDs and STARs to be implemented to selected airports.		
Approach	Implementation of approach procedures with vertical guidance (APV - Baro - VNAV and/or augmented GNSS), including LNAV-only minima, for all instrument runway ends, Implementation of straight-in LNAV- only procedures, as an exception to above.	1) APV-Baro VNAV will be introduced to international and high traffic domestic airports. 2) Instrument Approach Procedures will be re-designed for mixed navigation environment. 3) A study for the introduction of GBAS will be initiated. 4) RNP APCH (LNAV/VNAV) procedures will be implemented to selected airports.		