



**GHANA  
PERFORMANCE  
BASED  
NAVIGATION  
IMPLEMENTATION  
PLAN**

## **FOREWARD**

### **EXECUTIVE SUMMARY**

This plan describes Ghana's PBN implementation strategy for the next 10 years and beyond 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 AFI region, 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.

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

Finally, Ghana 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.

**APPROVAL**

This document has been drafted based on the standards and implementation guidance for PBN in the ICAO Doc 9613 “PBN Manual”.

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All personnel assigned by the GCAA to perform tasks that are addressed in this technical document shall comply with these policies and procedures in the performance of their duties.

The GCAA has authority to amend the manual, as necessary, to conform to the State Safety Program (SSP) and the ICAO global air navigation plan. Therefore, this manual will be treated as a dynamic document.

As a result of amendments to the Ghana Civil Aviation legislation and the progress of aviation safety practices, there will be the need for amendments.

Contribution of meaningful ideas for the improvement of the content of this manual is therefore encouraged and requested from all users.

**Approved by:**

  
SIMON ALLOTEY  
DIRECTOR-GENERAL  
GHANA CIVIL AVIATION AUTHORITY



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**16<sup>TH</sup> JULY, 2018**

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## **GLOSSARY OF DEFINITIONS/ACRONYMS/ABBREVIATIONS**

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

<b>Acronyms/Abbreviation</b>	<b>Definition</b>
ANSP	Air Navigation Service Provider
APCH	Approach
ATM	Air Traffic Management
CNS	Communication, Navigation, Surveillance
GANP	Global Air Navigation Plan
GASP	Global Air Safety Plan
ICAO	International Civil Aviation Organization
NAVAID	Navigation Aid
PBN	Performance-based navigation
RNAV	Area Navigation
RNP	Required Navigation Performance
SARPs	Standards and Recommended Practices
SID	Standard Instrument Departure
STAR	Standard Terminal Arrival

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## **CHAPTER 1 – OVERVIEW**

### **1.1 BACKGROUND**

- 1.1.1 The AFI Regional Performance Based Navigation (PBN) Roadmap details the framework within which the ICAO PBN concept will be implemented in the AFI region for the foreseeable future. The AFI Region Roadmap for PBN is guided by ICAO Doc 9613 and relevant SARPs. The primary driver for this plan is to maintain and increase safety, air traffic demand capacity, services and technology in consultation of with the relevant stakeholders. The AFI Region Roadmap also supports national and international interoperability and global harmonization.
- 1.1.2 The continuing growth of aviation places increasing demand on airspace capacity and emphasizes the need for the optimum utilization of available airspace.
- 1.1.3 Growth in scheduled and general aviation aircraft is expected to increase point-to-point and direct routings. The increasing cost of fuel also presents a significant challenge to all segments of the aviation community. This anticipated growth and higher complexity of the air transport system could result in increased flight delays, schedule disruptions, choke points, inefficient flight operations, and passenger inconvenience, particularly when unpredictable weather and other factors constraint airport capacity. Without improvements in the system efficiency, workforce productivity, the aviation community and cost of operations will continue to increase. Upgrades to the air transportations system must leverage current and evolving capabilities in the near future term, while building the foundation to address the future needs of the aviation community stakeholders. These circumstances can be partially alleviated by efficiencies in airspace and procedures through the implementation of PBN concepts.
- 1.1.4 In setting out requirements for navigation applications on specific routes or within a specific airspace, it is necessary to define requirements in a clear and concise manner. This is to ensure that both flight crew and ATC are aware of the on-board area navigation (RNAV) system capabilities and to ensure that the performance of the RNAV system is appropriate for the specific airspace requirements.
- 1.1.5 The early use of RNAV systems arose in a manner similar to the conventional ground-based routes and procedures. A specific RNAV system was identified and its performance was evaluated through a combination of analysis and flight testing. For domestic operations, the initial systems used VOR and DME for their

position estimation. For the oceanic operations, inertial navigation systems (INS) were employed.

- 1.1.6 The new systems were developed evaluated and certified. Airspace and obstacle clearance criteria were developed on the basis of available equipment performance. Requirements specifications were based on the available capabilities and in some implementations, it was necessary to identify the individual models of equipment that could be operated within the airspace concerned.
- 1.17 Such prescriptive requirements result in delays to the introduction of new RNAV system capabilities and higher cost for maintaining appropriate certification. To avoid such prescriptive specifications of requirements, the PBN concept introduces an alternative method for defining for equipage requirements by specification of the performance requirements. This is termed Performance Based Navigation (PBN)

## **1.2 PURPOSE**

- 1.2.1 This PBN Plan is developed in consultation with the aviation community in Ghana and all stakeholders concerned. It is intended to assist the main stakeholders of the aviation community to plan a gradual transition to the RNAV and RNP concepts. These stakeholders include but not limited to:
- a) Airspace operators and users
  - b) The Air Navigation service provider
  - c) The Ghana Civil Aviation Authority
  - d) National and International organisations
  - e) The Military

## **1.3 THE PBN PLAN**

- 1.3.1 This PBN Plan is intended to assist the main stakeholders of the aviation community plan future transition and their investment strategies. This is to help Airlines and operators use this roadmap to plan future equipage and additional navigation capability investments. The Air navigation service provider can plan a gradual transition for evolving ground infrastructure. The regulating agency will be able to anticipate and plan for criteria that will be needed in the future as well as regulatory workload and associated training requirements for their work force.

## **1.4 GUIDING PRINCIPLE**

- 1.4.1 The guiding principle for this Plan is based on the need to ensure;
- a) The continued application of conventional air navigation procedures during the transition period in order to guarantee the availability to users that are not RNAV and/or RNP equipped
  - b) The development of airspace concepts applying airspace modelling tools as well as real time and accelerated simulations, which identify the navigation applications that are compatible with the aforementioned concept;
  - c) That cost benefit analysis is conducted to justify the implementation of the RNAV and /or RNP concept in a particular airspace;
  - d) The conduction of a pre- and post-implementation safety assessment to ensure the application and maintenance of the established target levels of safety
  - e) That the Plan does not conflict with the regional PBN implementation plan.

## **1.5 STRATEGIC OBJECTIVES**

- 1.5.1 The strategic objectives include;
- a. To achieve efficiency and capacity in the implementation of PBN routes, RNP SIDs, STARs and terminal airspace redesign.
  - b. To achieve a total performance-based area navigation environment with defined ICAO PBN Navigation Specification designator values for all operations and airspaces.
  - c. To address current and forecast airspace capacity and operational efficiency issues through application of the ICAO PBN concept.
  - d. To maximize the use of current and emerging navigation (GBAS and SBAS), air traffic management and aircraft avionics systems.
  - e. To utilize PBN to reduce environmental impact from aviation through more efficient operations that result in a less fuel burn and noise emissions.

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## **CHAPTER 2 – PERFORMANCE-BASED NAVIGATION (PBN)**

### **2.1 PBN CONCEPT**

- 2.1.1 Performance Based Navigation (PBN) is a concept that encompasses both area navigation (RNAV) and required navigation performance (RNP) and revises the current RNP concept. Performance based navigation is increasingly seen as the most practical solution for regulating the expanding domain of navigation systems.
- 2.1.2 Under the traditional approach, each new technology is associated with a range of system specific requirements for obstacle clearance, aircraft separation, operational aspects (e.g., arrival and approach procedure), air crew operational training and training of air traffic controllers. However, this system-specific approach imposes an unnecessary effort and expense on States, airlines and air navigation service providers.
- 2.1.3 The performance based navigation eliminates the need for redundant investment in developing criteria and in operational modification and training. Rather than build an operation around a particular system, under PBN the operation is defined according to the operational goals, and the available systems are then evaluated to determine whether they are supportive.
- 2.1.4 The advantage of this approach is that it provides clear, standardized operational approvals which enable harmonized and predictable flight paths resulting in the more efficient use of existing aircraft capabilities, as well as improved safety, greater airspace capacity, better fuel efficiency, and the resolution of environmental issues.
- 2.1.5 The PBN Concept is based on a shift from sensor-based navigation to performance based. The PBN concept specifies that aircraft area navigation system performance is defined in terms of accuracy, integrity, continuity and functionality. It explains and describes the performance-based RNAV and RNP navigation specifications that can be applied to oceanic, en-route and terminal airspace, to improve safety, efficiency and capacity, as well as reduce the environmental impact. These specifications also detail the navigation sensors and equipment necessary to meet the performance requirement.
- 2.1.6 The application of a PBN specification depends on many factors – the navigation infrastructure, communications capability, surveillance capability, the operational

requirement, the aircraft fleet capability and operational approvals. etc. In determining which PBN specification to apply for each instrument runway, these factors are taken into consideration in consultation with all stakeholders.

- 2.1.7 Under the PBN, generic navigation requirements are defined based on the operational requirements. Operators are then able to evaluate options in respect of available technologies and navigation services that could allow these requirements to be met. The chosen solution could be most cost effective for the operator, rather than a solution being imposed as part of the operational requirements. Technologies can evolve over time without requiring the operations itself to be revised, as long as the requisite performance is provided by the RNAV system. As part of future work of ICAO, it is anticipated that other means for meeting the requirements of the navigation specifications will be evaluated and may be included in the applicable navigation specifications as appropriate.
- 2.1.8 ICAO's performance based navigation (PBN) concept aims to ensure global standardization of RNAV and RNP specifications and to limit the proliferation of navigation specifications use worldwide. It is a new concept based on the use of Area Navigation (RNAV) systems. Significantly, it is a move from a limited statement of required performance accuracy to more extensive statements for required navigation performance in terms of accuracy, integrity, continuity, and availability, together with descriptions of how this performance is to be achieved in terms of aircraft and flight crew requirements.

## **2.2 CURRENT IMPLEMENTATION STATUS**

- 2.2.0 Ghana has completed implementation of PBN procedures at all major airports and terminal areas in the country.

### **2.2.1 Oceanic, Remote and Continental En-route**

The oceanic area of the Accra FIR south of latitude 4°N is a random routing area with RNAV 10 required as the navigation specification and this provides airline operators with the direct tracks resulting in efficiency and fuel saving as a direct impact of reduced track miles. This also addresses a major issue of reduced carbon emission and brings direct benefit to the environment.

### **2.2.2 Terminal Areas (SIDs and STARs)**

All terminal areas of the four major airports, DGAA, DGSI, DGLE, and the military airport of DGTK are served by SIDs and STARs except DGSN which has no SID/STAR. The implementation commenced in 2013. Currently, planned review



of the instrument flight procedures is being considered to ensure the integrity of data and the safety of flight.

### **2.2.3 Approach**

100% of instrument Runways are served by RNAV/GNSS procedures with BARO-VNAV for vertical guidance.

### **2.2.4 Helicopter Operations**

The increases in off shore operations require the need for the development and publication of an RNP 2 route system to address safety, efficiency and environmental concerns. Approval for this has been obtained and published.

### **2.2.5 Military Operations**

The current fleet of the Ghana Air Force is RNAV/GNSS equipped. The operations of these however are mixed with civilian operations and therefore flight crews are going through the same process of training and certification for PBN operations.

## **2.3 PBN APPROACHES WITH AND WITHOUT VERTICAL GUIDANCE**

2.3.1 PBN facilitates the implementation of instrument approaches with vertical guidance (APV) to all runway ends. This has a significant safety impact, as non-precision approaches (dive and drive) with no vertical guidance can be removed. It has been proven that approach procedures with vertical guidance are 25% safer than procedures with no vertical guidance. Furthermore, PBN facilitates the design and implementation of APV to runways that do not currently have an approach capability, thus improving airport accessibility and flight operations efficiency.

2.3.2 Therefore, Ghana, in collaboration with the airspace users places a high priority on the design and implementation of PBN approach procedures with vertical guidance in concert with Assembly Resolution A37-11, to improve both safety and efficiency.

## **2.4 AIRCRAFT FLEET CAPABILITIES**

- 2.4.1 Currently 85% of all aircraft operating within the Accra FIR are RNAV equipped;
- i. 80% are RNAV approved
  - ii. 85% are GNSS equipped
  - iii. 5% Non GNSS equipped

- 2.4.2 The current situation is however improving and it is envisaged that by 2020 95% of all aircraft operating in the Accra FIR will be RNAV/GNSS approved.

## **2.5 CNS/ATM CAPABILITIES**

- 2.5.1 Ghana's PBN implementation is based on basic GPS GNSS operations with vertical guidance provided by BARO-VNAV
- 2.5.2 ATM infrastructure include
- a) Secondary Surveillance Radar for the continental airspace
  - b) ADS-C/CPDLC for the oceanic airspace
  - c) VHF/HF radios for voice communication
  - d) Planned ADS-B infrastructure to serve both the continental and oceanic areas

## **2.6 BENEFITS OF PBN AND GLOBAL HARMONIZATION**

- 2.6.1 PBN offers a number of advantages over the sensor-specific method of developing airspace and obstacle clearance criteria. For example:
- a) It reduces the need to maintain sensor-specific routes and procedures and their associated costs (e.g. VOR, NDB, DME);
  - b) Enhances safety by allowing for straight-in approach procedures with vertical guidance as a primary approach or back up to existing precision approach procedures;
  - c) Improves airport accessibility under all weather conditions;
  - d) Allows for more efficient use of airspace, thus increasing capacity;
  - e) Improves operational efficiency through user preferred routings, reduced delays and holds, and enables continuous descent and continuous climb operations;
  - f) Lessens the environmental impact by contributing to reduced aircraft fuel burn and noise emissions
  - g) Clarifies the way in which RNAV systems are used
  - h) Facilitates the operational approval process by providing a limited set of navigation specifications intended for global use
- 2.6.2 For Ghana the main focus is on using RNAV and RNP specifications to facilitate more efficient design of airspace and procedures, which collectively result in improved safety, access, capacity, predictability, operational efficiency, and environmental effects. Specifically, RNAV and RNP may;

- a Increase safety by using three dimensional (3D) approach operations with course guidance to the runway, which reduces the risk of controlled flight into terrain;
  - b Improve airport and airspace access in all weather conditions and the ability to meet environmental and obstacle clearance constraints
  - c Enhance reliability and reduce delays by defining more precise terminal area procedures that feature parallel routes and environmentally optimized airspace corridors. Flight management systems will then be programmed to save time and money by managing climb, descent and engine management profiles efficiently.
  - d Improve efficiency and flexibility by increasing use of operator-preferred trajectories airspace wide at all altitudes. This will be particularly useful in maintaining schedule integrity when convective weather arises
  - e Reduce workload and improve productivity of air traffic controllers
- 2.6.3 Performance based navigation ~~will~~ enables the needed operational improvements by leveraging current and evolving aircraft capabilities in the near term that can be expanded to address future needs of aviation stakeholders and service providers.

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## **CHAPTER 3 – IMPLEMENTATION CHALLENGES**

### **3.1 SAFETY**

- 3.1.1 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;
- a. Integration into the ATM system including enhanced software to support PBN
  - b. Safety monitoring of ATM system
  - c. Mixed fleet/system operations
  - d. Maintenance of the Target Level of Safety (TLS)
  - e. Continued evolution of PBN navigation specifications and their deployment in the ATM system
  - f. Development of supporting rule set
  - g. Education and training of stakeholders
  - h. Approach naming and charting conventions
  - i. Vertical Advisory versus Vertical Guidance
  - j. Data base integrity and control
  - k. GNSS system performance and prediction of the availability of continuous service
  - l. Scale of change for ATC and Aircrew
  - m. Multiple airspace designs if conventional routes are kept as the back-up network.

### **3.2 AIRCRAFT FLEET EQUIPMENT AND INFRASTRUCTURE**

- 3.2.1 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 the existing network of terrestrial navigation aids in Ghana is of sufficient density to support PBN navigation specifications. Therefore, PBN implementation in Ghana is supported by self-contained aircraft navigations systems (inertial and/or GNSS based).
- 3.2.2 Ghana 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.

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

### **3.3 EFFICIENCY AND CAPACITY**

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

3.3.2 The PBN coordinating committee consists of the 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)**

3.4.1 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<sub>2</sub>

### **3.5 REGULATORY**

3.5.1 To achieve the targets of implementation that is consistent with the requirements of Ghana Civil Aviation Directives and in line with the goals set out in the Global Air Navigation Plan.

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## **CHAPTER 4 – IMPLEMENTATION**

### **4.1 GENERAL**

- 4.1.1 This plan provides a high-level strategy for the evolution of navigation capabilities to be implemented in three timeframes: Near Term (2008-2013), mid-term (2013-2016) and long term (2017 and beyond). The strategy rests on two key navigational concepts: Area Navigation (RNAV) and Required Navigation Performance (RNP). It also encompasses instrument approaches, Standard Instrument Departure (SID) and Standard Terminal Arrival (STAR) operations, as well as en-route continental, oceanic and remote operations. The section on long term initiative discusses integrated navigation, communication and surveillance and automation strategies.
- 4.1.2 To avoid proliferation of new navigation standards, Ghana and other aviation stakeholders in the AFI region communicates any new operational requirements with ICAO HQ, so that it can be taken into account by the ICAO study group in charge of PBN.

### **4.2 SHORT TERM (2008-2013)**

- 4.2.0 The key tasks involved in the transition to performance based navigation are:
- a) Establish navigation service needs through the Long term that will guide the infrastructure decisions and specify needs for navigation system infrastructure, and ensure funding for managing and transitioning these systems.
  - b) Define and adopt a national policy enabling additional benefits based on RNP and RNAV
  - c) Identify operational and integration issues between navigation and surveillance, air ground communication and automation tools that maximize the benefits of RNP
  - d) Support mixed operations throughout the term of this roadmap, in particular considering navigation system variations during the near term until appropriate standards are developed and implemented
  - e) To support Civil/Military coordination and develop policies need to accommodate the unique missions and capabilities of military aircraft operating in civil airspace

- f) Harmonize the evolution of capabilities for interoperability across airspace operations
- g) Increase emphasis on human factors, especially on training and procedures as operations increase reliance on appropriate use of flight deck systems
- h) Facilitate and advance environmental analysis efforts required to support the development of RNAV and RNP procedures
- i) Maintain consistent and harmonized global standards for RNAV and RNP operations

To this end Ghana has achieved the following milestones;

#### **4.2.1 Oceanic, Remote and Continental En-route**

- 4.2.1.1 RNAV 10 free routing system in the oceanic region south of Latitude 4°N.
- 4.2.1.2 To promote global harmonization, Ghana continues to work closely with its international partners in implementing RNAV-10 and where operationally required RNP-4 by 2020. Safety assessment has been conducted to evaluate reduced oceanic and remote longitudinal/lateral separation minima between aircraft approved for RNAV -10 and RNP-4 operations
- 4.2.1.3 For oceanic and remote areas where high density of traffic operations occurs, a review of the airspace concept will be undertaken to convert to Continental En-route Operation where sufficient surveillance is available so as to allow RNAV-5 operations.
- 4.2.1.4 For airspace and corridors requiring structured routes for flow management, Ghana will review existing conventional and RNAV routes to transition to PBN RNAV-5 or where operationally required RNAV-2/1.

#### **4.2.2 Terminal Areas (SIDs and STARs)**

- 4.1.2.1 RNAV reduces conflict between traffic flows by consolidating flight tracks. RNAV-1/Basic RNP-1 SIDs and STARs improve safety, capacity and flight efficiency and also lower communication errors.
- 4.1.2.2 Ghana has implemented SIDs and STARs in all the terminal areas at the four major airports including the DGTK and DGLE (these have mixed civil/military operations).

#### **4.2.3 Approach**

- 4.2.3.1 RNP (RNAV/GNSS) approaches to all instrument runways with BARO-VNAV for vertical guidance has been implemented

#### **4.2.4 Helicopter Operations**

- 4.1.4.1 RNP 2 routing system for offshore operations has been developed and a review of this procedure is planned for the last quarter of 2019 due to the increase in offshore operations.

### **4.3 MEDIUM TERM (2017-2020)**

- 4.3.1 In the medium term increasing demand for air travel will continue to challenge the efficiencies of the air traffic management system.
- 4.3.2 While the hub-and-spoke system will remain largely the same for major airline operations, the demand for more point to point service will create new markets and spur increase in low cost carriers, air taxi system operations and on-demand services. Additionally, the emergence of Very Light Jets (VLJs) is expected to create new markets in the general and business aviation sectors for personal, air taxi and point to point passenger operations. Many airports will thus experience increase in unscheduled traffic. In addition, many destination airports that support scheduled air carriers are forecast to grow and to experience congestion or delays if efforts to increase capacity fall short. As a result, additional airspace flexibility will be necessary to accommodate not only the increasing growth, but also the increasing air traffic complexity.
- 4.3.3 The medium term will leverage these increasing flight capabilities based on RNAV and RNP, with commensurate increase in benefits such as fuel efficient flight profiles, better access to airspace and airports, greater capacity, and reduced delays. These incentives, which should provide an advantage over non-RNP operations, will expedite propagation and equipage and the use of RNP procedures.
- 4.3.4 To achieve efficiency and capacity gains partially enabled by RNAV and RNP, Ghana and the aviation industry is pursuing the use of data communications (e.g. Controller Pilot communication) and enhanced surveillance functionality e.g. ADS-Broadcast (ADS-B). Data communications will make it possible to issue complex clearances easily with minimal errors. ADS-B will expand or augment surveillance coverage so that track spacing and longitudinal separation can be optimized where needed (e.g. non radar airspace). Initial capabilities for flights to receive and confirm 3D clearances and time of arrival control based on RNP will be demonstrated in the mid-term. With data-link implemented, flights will begin to transmit 4D trajectories (set of points defined by, latitude, longitude, altitude and time). Stakeholders must therefore develop concepts that will leverage this capability.



**4.3.5 Oceanic, Remote and Continental En-route**

In the medium term Ghana will endeavour to work with international air traffic service providers to promote the application of RNP-10 and RNP-4 in additional sub-regions of the oceanic environment.

**4.3.5.1 Implementation**

By the end of the mid-term, other benefits would have been enabled, such as flexible procedures to manage the mix of faster and slower aircraft in congested airspace and use of less conservative PBN requirements

**4.3.6 Automation for RNAV and RNP Operations**

4.3.6.1 By the end of the mid-term, enhanced en-route automation will allow the assignment of RNAV and RNP routes based upon specific knowledge of and aircrafts RNP capabilities. En-route automation will use collaborative routing tools to assign aircraft priority, since the automation system can rely on the aircraft's ability to change a flight path and fly safely around problem areas. This functionality will enable the controller to recognize aircraft capability and to match the aircraft to dynamic routes or procedures, thereby helping appropriately equipped operators to maximize the predictability of their schedules.

4.3.6.2 Conflict prediction and resolution in most en-route airspace must improve as the airspace usage increases. Path repeatability achieved by RNAV and RNP operations will assist in achieving this goal. Mid-term automation tools will facilitate the introduction of RNP offsets and other forms of dynamic tracks for maximizing the capacity of the airspace. By the end of the mid-term, en-route automation will have evolved to incorporate more accurate and frequent surveillance reports through ADS-B, and to execute problem prediction and conformance checks that enable offset manoeuvres and closer route spacing (e.g. for passing other aircraft and manoeuvring around weather).

**4.3.7 Terminal Areas (SIDs and STARs)**

4.3.7.1 During this period, either Basic RNP-1 or RNAV-1 will become a required capability for flights arriving and departing major airports based upon the needs of the airspace, such as the volume of traffic and complexity of operations. This will ensure the necessary throughput and access, as well as reduced controller workload, while maintaining safety standards.

4.3.7.2 With RNAV-1 operations as the predominant form of navigation in terminal areas by the end of the mid-term, Ghana will have the option of removing conventional terminal procedures that are no longer expected to be used.

#### **4.3.8 Terminal Automation**

4.3.8.1 Terminal automation will be enhanced with tactical controller tools to manage complex merges in busy terminal areas. As data communications become available, the controller will apply the knowledge of flights estimates of time of arrival at upcoming waypoints, and altitude and speed constraints, to create efficient manoeuvres for optimal throughput.

4.3.8.2 Terminal automation will also sequence flights departing busy airports more efficiently than today. This capability will be enabled as a result of PBN and flow management tools. Flights arriving and departing busy terminal areas will follow automation assigned PBN routes.

#### **4.3.9 Approach**

In the Medium term, implementation priorities for instrument approaches will be based on RNP APCH and full implementation is expected at the end of this term. The introduction of the application of landing capability, using GBAS/SBAS (currently non PBN) is expected.

#### **4.3.10 Helicopter Operations**

Ghana will introduce appropriate procedures to integrate helicopter operations. Helicopter procedures are planned for development to all heliports and pads at the various aerodromes with a target completion date of 2020.

#### **4.3.11 Medium Term Strategy Summary**

Airspace	Nav. Specification	Nav. Spec where operationally required
En-route Oceanic	RNAV-10	RNP-4
En-route Remote Continental	RNAV-10	RNP-4
En-route Continental	RNAV-2, RNAV-5	RNAV-1
TMA-Arrival	Expand RNAV-1 application	
Approach	Expand RNP APCH with (BARO-VNAV) and APV	

##### **4.3.11.1 Implementation Targets;**

- a) RNP APCH (with BARO-VNAV) or APV in 100% instrument runways; Completed
- b) Expand RNAV-1 SID/STAR for 100% international airports; Completed
- c) RNAV-1 SID/STAR for busy domestic airports where there are operational benefits; Completed

- 4.3.11.2 En-route structure will be reviewed to achieve optimization of the route network in terms of reduction of route lengths/flight times and this will entail;
- a) change of existing RNAV routes to PBN routes where operational requirements is identified;
  - b) change of the existing RNAV routes without PBN Navigation Specification requirements to routes with PBN Navigation requirements
  - c) development of an ATS route network structure characterized by minimized city pair lengths.
- 4.3.11.3 The following implementation on the en-route network is envisaged/foreseen through CDM process
- a) ATS routes within the Ghana (Accra FIR)
  - b) RNAV-5 Continental routes (where there is surveillance)
  - c) RNAV-10 remote continental and oceanic airspace (depending on the structure of the FIR concerned)
- 4.3.11.4 A full implementation plan will be developed in coordination with the PBN Task Force route network development work group and proposed for amendment of the AFI Air Navigation Plan (ANP).

#### **4.4 LONG TERM OBJECTIVES (2020-2027)**

- 4.4.1 The long term environment will be characterized by continued growth in air travel and increased air traffic complexity.
- 4.4.2 No one solution or simple combination of solutions will address the inefficiencies, delays, and congestion anticipated to result from the growing demand for air transportation. Therefore, Ghana and key stakeholders need an operational concept that exploits the full capability of the aircraft in this time frame.

##### **4.4.3 Long term key Strategies (2020 and beyond)**

- 4.4.1.1 Airspace operations in the long term will make maximum use of advanced flight deck automation that integrates CNS capabilities. RNP, RCP and RSP standards will define these operations. Separation assurance will remain the principal task of air traffic management in this time frame. This task is expected to leverage a combination of the aircraft and ground based tools. Tools for conflict detection and resolution, and for flow management, will be enhanced significantly to handle increasing traffic levels and complexity in an efficient and strategic manner.

- 4.4.1.2 Strategic problem detection and resolution will result from better knowledge of aircraft position and intent, coupled with automated, ground based problem resolution. In addition, pilot and air traffic controller workload will be lowered by substantially reducing voice communications for clearance to flight deck. Workload will also decrease as the result of automated confirmation (via data communication) of flight intent from the flight deck to ground automation.
- 4.4.1.3 With the necessary aircraft capabilities, procedures, and training in place, it will become possible in certain situations to delegate separation tasks to pilots and to flight deck systems that depict traffic and conflict resolution. Procedures for airborne separation assurance will reduce reliance on ground infrastructure and minimize controller workload. As an example, in IMC an aircraft could be instructed to follow a leading aircraft, keeping a certain distance. Once the pilot agreed, ATC would transfer responsibility for maintaining spacing (as is now done with visual approaches)
- 4.4.1.4 Performance based operations will exploit aircraft capabilities ‘for electronic’ visual acquisition of external environment in low visibility conditions, which may potentially increase runway capacity and decrease runway occupancy times.
- 4.4.1.5 Improved wake prediction and notification technologies may also assist in achieving increased runway capacity by reducing reliance on wake separation buffers.
- 4.4.1.6 System-wide information exchange will enable real-time data sharing of National Airspace System constraints, airport and airspace capacity, and aircraft performance. Electronic data communication between ATC automation and aircraft achieved through data link will become widespread-possibly even mandated in the busiest airspace and airports. The direct exchange of data between ATC automation and aircraft FMS will permit better strategic and tactical management of flight operations.
- 4.4.1.7 Aircraft will downlink to ground-based system their position and intent data, as well as speed, weight, climb and descent rates, and wind and turbulence reports. The ATC automation will uplink clearances and other types of information, for example weather, metering, choke points and airspace use restrictions.
- 4.4.1.8 To ensure predictability and integrity of aircraft flight path, RNP will be mandated in busy en-route and terminal airspace. RNAV operations will be required in other airspaces (except oceanic). Achieving standardized FMS functionalities and consistent levels of crew operation of FMS is integral to the success of this Long-term strategy.

- 4.4.1.9 The most capable aircraft will meet requirements for low values of RNP (RNP-0.3 or lower en-route). Flights by such aircraft are expected to benefit in terms of airport access, shortest routes during IMC or convective weather, and the ability to transit to avoid constrained airspace, resulting in greater efficiencies and fewer delays operating into and out of the busiest airports.
- 4.4.1.10 Enhanced ground-based automation and use of real-time flight intent will make time-based metering to terminal airspace a key feature of future flow management initiatives. This will improve the sequencing and spacing of flights and efficiency of terminal operations.
- 4.4.1.11 Uniform use of RNP for arrivals and departures at busy airports will optimize management of traffic and merging streams. ATC will continue to maintain control over sequencing and separation; however, aircraft arriving and departing the busiest airports will require little controller intervention. Controllers will spend more time monitoring the flows and will intervene only as needed, primarily when conflict prediction algorithms indicate potential problem.
- 4.4.1.12 More detailed knowledge of meteorological conditions will enable better flight path conformance, including time of arrival control at key merge points. RNP will also improve management of terminal arrival and departure with seamless routing from the en-route and transition segments to runway threshold. Enhanced tools for surface movement will provide management capabilities that synchronize aircraft movement on the ground; for example, to coordinate taxiing aircraft across active runways and to improve the delivery of aircraft from the parking area to the main taxiways.

#### **4.4.2 Oceanic, Remote and Continental En-route**

To achieve RNAV-1 and/or RNP-2/4 routing systems that take advantage of aircraft capabilities and ATC automation and therefore increase airspace capacity to accommodate the increasing levels of traffic and complexity (2025)

#### **4.4.3 Terminal Areas (SIDs and STARs)**

Implement RNP-1 through a review of the existing systems and procedure to enhance efficiency and flow management while reducing delays and addressing environmental concerns through reduced tracks within the terminal areas resulting in less fuel burn and carbon emissions. (2025)

#### **4.4.4 Approach**

Achieve an RNP-0.3 or less through the implementation of SBAS/GBAS leading to increased safety in all-weather operations, reduced spacing and increased capacity, reduced delays and improve efficiency of planning by operators and the ANSP. (2030)

#### **4.4.5 Helicopter Operations**

Develop and implement RNAV and RNP procedures for helicopters to be integrated into the general traffic system for efficient management (2020)

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## **CHAPTER 5 – PLAN COORDINATION**

### **5.1 COORDINATION AND CONSULTATION**

- 5.1.1 The Ghana Civil Aviation has developed a Master Plan for implementation of PBN operations in Ghana. This plan must allow for the deployment of PBN operations commensurate with Ghana's international commitments and other operational issues.
- 5.1.2 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 as follows.
- 5.1.3 A PBN Coordinating Committee is set up by The Director General of the Ghana Civil Aviation Authority and consists of the following:
- a) Military Authority;
  - b) The Regulator (GCAA);
  - c) Ghana Airports Company Ltd;
  - d) Air Navigation Service Provider;
  - e) The representatives of National air operators (IATA);
  - f) ICAO Regional Office (WACAF), environment experts and other stakeholders are invited depending on the subject.
- 5.1.4 This committee aims to offer a forum, so that the direction taken by the GCAA takes into account the various issues. It will periodically review the actions (past, present and future) regarding the implementation of PBN operations in Ghana.

### **5.2 PLAN RESPONSIBILITY**

- 5.2.1 The Director General of the Ghana Civil Aviation Authority has responsibility for the effective and efficient performance of Ghana's PBN implementation plan.
- 5.2.2 The PBN implementation also places responsibilities on;
- a) The Director of Air Traffic Services, who is responsible for the fulfilment of 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.

- b) 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 Director General of the Ghana Civil Aviation Authority.



## **CHAPTER 6 – SAFETY**

### **6.1 PRELIMINARY SAFETY ASSESSMENT AND RISK ANALYSIS**

- 6.1.1 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.
- 6.1.2 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 OF SAFETY ASSESSMENT**

- 6.2.1 It is necessary to analyse flight track data as part of the post implementation review of 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.

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## **APPENDIX A**

### **Assembly Resolution (A37-11)**

#### **PERFORMANCE BASED NAVIGATION GLOBAL GOALS**

Note: Resolution A37-11 is a result of the 11th Air Navigation Conference recommendations on area navigation implementation and Resolution A33-16 that requested Council to develop a program to encourage States to implement approach procedures with vertical guidance. The main points of Resolution A37-11 are as follows:

The Assembly

1. Urges all States to implement RNAV and RNP air traffic services (ATS) routes and approach procedures in accordance with ICAO PBN concept laid down in the Performance-based Navigation (PBN) Manual (DOC 9613);
2. Resolves that:
  - a) States complete a PBN implementation plan as a matter of urgency to achieve:
    - 1) Implementation of RNAV and RNP operations (where required) for en route and terminal areas according to established timelines and intermediate milestones;
    - 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% by 2010, 70% 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 and where there are no aircraft suitably equipped for APV operations with a maximum certificated take-off mass of 5700 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;
3. Urges that States include in their PBN implementation plan provisions for implementation of approach procedures with vertical guidance (APV) to all

runway ends serving aircraft with a maximum certificated take-off mass of 5700kg or more, according to established timelines and intermediate milestones;

4. Instructs the Council to provide a progress report on PBN implementation to the next ordinary session of the Assembly, as necessary;
5. Requests the Planning and Implementation Regional Groups (PIRGs) to include in their work programme, the review of status of implementation of PBNB by States according to the defined implementation plans and report annually to ICAO any deficiencies that may occur; and
6. Declare that this resolution supersedes Resolution A36-23.

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## **APPENDIX B**

### **PBN Implementation Schedule for En-route, Terminal and Approach Procedures**

<b>PBN Specification</b>	<b>En-route(Oceanic, Remote, Continental)</b>	<b>Terminal Airspace (SIDs.STARs)</b>	<b>Approach Procedures</b>
RNAV 10			
RNAV 5	Planned uni-directional routes (2022)		
RNAV 2			
RNAV 1		Completed: all major airports	
RNP 4	Oceanic and continental (2022)		
RNP 2	Offshore helicopter routes (2020)		
RNP 1			All instrument runways completed
RNP APCH			GNSS/RNAV with BARO-VNAV APP to all instrument runways completed. Planned review (2018)
RNP AR APCH			
RNP 0.3			With SBAS/GBAS planned implementation (2024)

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## **APPENDIX C**

### **References**

The following table summarizes the documents referenced in this document.

<b>Document Name</b>	<b>Description</b>	<b>Location</b>
Performance Based Navigation Manual	Doc 9613	Icao.int.net
Procedures for Air Navigation Service, Air Traffic Management (PANS-ATM)	Doc 4444	Icao.int.net
Procedures For Air Navigation Services, Operations (PANS-OPS)	Doc 8168	Icao.int.net
Quality Assurance Manual for Procedure Design	Doc 9906	Icao.int.net
The Turkish PBN Implementation Plan	Version 1	
ICAO, State PBN Implementation Plan template	Version 1	Icao.int.net

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