CAA BOTSWANA

BOTSWANA

Performance Based Navigation (PBN) Implementation Plan

JANUARY 2010

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1.0 Introduction

1.1 The Botswana Performance Based Navigation (PBN) Roadmap details the framework within which the ICAO PBN concept will be implemented in Botswana for the foreseeable future. Botswana 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 and capacity, services and technology in consultation with relevant stakeholders. The Botswana Roadmap also supports national and international interoperability and global harmonization.

2. 0 Background

2.1 The continuing growth of aviation places increasing demands on airspace capacity and emphasizes the need for the optimum utilization of the available airspace.

2.2 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 transportation system could result in increased flight delays, schedule disruptions, choke points, inefficient flight operations, and passenger inconvenience, particularly when unpredictable weather and other factors constrain airport capacity. Without improvements in system efficiency and workforce productivity, the aviation community and cost of operations will continue to increase. Upgrades to the air transportation system must leverage current and evolving capabilities in the near 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.

2.3 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.

2.4 The early use of RNAV systems arose in a manner similar to 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 oceanic operations, inertial navigation systems (INS) were employed.

2.5 These '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 upon available capabilities and, in some implementations, it was necessary to identify the individual models of equipment that could be operated within the airspace concerned.

2.6 Such prescriptive requirements result in delays to the introduction of new RNAV system capabilities and higher costs for maintaining appropriate certification. To avoid such prescriptive specifications of requirements, the PBN concept introduces an alternative method for defining equipage requirements by specification of the performance requirements. This is termed Performance Based Navigation (PBN).

3.0 Performance Based Navigation (PBN)

3.1 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.

3.2 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 procedures), aircrew 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 services (ANS) providers.

3.3 Performance based navigation eliminates the need for redundant investment in developing criteria and in operational modifications and training. Rather than build an operation around a particular system, under performance based navigation the operation is defined according to the operational goals, and the available systems are then evaluated to determine whether they are supportive.

3.4 The advantage of this approach is that it provides clear, standardized operational approvals which enables harmonized and predictable flight paths which result in more efficient use of existing aircraft capabilities, as well as improved safety, greater airspace capacity, better fuel efficiency, and resolution of environmental issues.

3.5 The PBN concept specifies aircraft RNAV system performance requirements in terms of accuracy, integrity, availability, continuity and functionality needed for the proposed operations in the context of a particular Airspace Concept. The PBN concept represents a shift from sensor-based to performance-based navigation. Performance requirements are identified in navigation specifications, which also identify the choice of navigation sensors and equipment that may be used to meet the performance requirements. These navigation specifications are defined at a sufficient level of detail to facilitate global harmonization by providing specific implementation guidance for States and operators.

3.6 Under 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 would be the 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 operation itself to be revisited, as long as the requisite performance is provided by the RNAV system. As part of the future work of the 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.

3.7 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 in 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 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.

3.8 RNAV Current status in Botswana

3.8.1 Currently, an RNAV operation in Botswana is employed by Airliners and high fliers operating in RNAV/RNP airspace, which is established in the form of ATS routes.

3.8.2 Although GNSS approaches are published for two airports; these procedures are hardly used by local operators, however international operators use them.

1.8.2 RNAV, ATS routes, SIDs, STARs and approaches

3.8.2.1 A couple of ATS routes in the upper airspace are designated RNAV/ RNP routes. GNSS based SIDs and STARs are established for two airports at both Sir Seretse Khama and Maun Airports.

3.8.3 Fleet equipage

3.8.3.1 Very few Botswana registered aircraft are fitted with approved GNSS receivers.

4.0 Benefits of PBN and global harmonization

4.1 PBN offers a number of advantages over the sensor-specific method of developing airspace and obstacle clearance criteria. These include:

4.1.1 Reduces need to maintain sensor-specific routes and procedures, and their associated costs. For example, moving a single VOR ground facility can impact dozens of procedures, as that VOR can be used on routes, VOR approaches, as part of missed approaches, etc. Adding new sensor specific procedures will compound this cost, and the rapid growth in available navigation systems would soon make system-specific routes and procedures unaffordable.

4.1.2 Avoids need for development of sensor-specific operations with each new evolution of navigation systems, which would be cost-prohibitive.

4.1.3 Allows more efficient use of airspace (route placement, fuel efficiency, noise abatement).

4.1.4 Clarifies the way in which RNAV systems are used.

4.1.5 Facilitates the operational approval process for operators by providing a limited set of navigation specifications intended for global use.

4.2 RNAV and RNP specifications 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:

4.2.1 Increase safety by using three-dimensional (3D) approach operations with course guidance to the runway, which reduce the risk of controlled flight into terrain.

4.2.2 Improve airport and airspace access in all weather conditions, and the ability to meet environmental and obstacle clearance constraints.

4.2.3 Enhance reliability and reduce delays by defining more precise terminal area procedures that feature parallel routes and environmentally optimized airspace corridors. Flight management systems (FMS) will then be poised to save operators time and money by managing climb, descent, and engine performance profiles more efficiently.

4.2.4 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.

4.2.5 Reduce workload and improve productivity of air traffic controllers.

4.3 Performance-based navigation will enable the needed operational improvements by leveraging current and evolving aircraft capabilities in the near term that can be expanded to address the future needs of aviation stakeholders and service providers.

5.0 Stakeholders

5.1 Coordination is critical with the aviation community through collaborative forums. This will assist aviation stakeholders in understanding operational goals, determining requirements, and considering future investment strategies. This, in turn, enables the aviation stakeholders to focus on addressing future efficiency and capacity needs while maintaining or improving the safety of flight operations by leveraging advances in navigation capabilities on the flight deck. RNAV and RNP have reached a sufficient level of maturity and definition to be included in key plans and strategies, such as this Botswana PBN plan.

5.2 The stakeholders who will benefit from the concepts in this Botswana PBN plan include airspace operators, air traffic service providers, regulators, and standards organizations. As driven by business needs, airlines and operators can use the Botswana PBN roadmap to plan future equipage and capability investments. Similarly, air traffic service providers can determine requirements for future automation systems, and more smoothly modernize ground infrastructure. Finally, regulators and standards organizations can anticipate and develop the key enabling criteria needed for implementation.

5.3 This Botswana PBN plan is a work in progress and will be amended through collaborative AFI Region States and International Organisations, industry efforts and consultations that establish a joint aviation community/government/industry strategy for implementing performance-based navigation. Critical initiative strategies are required to accommodate the expected growth and complexity over the next two decades.
These strategies have five key features:

5.3.1 Expediting the development of performance-based navigation criteria and standards.

5.3.2 Introducing airspace and procedure improvements in the near term. capabilities.

5.3.3 Providing benefits to operators who have invested in existing and upcoming

5.3.4 Establishing target dates for the introduction of navigation mandates for selected Procedures and airspace, with an understanding that any mandate must be rationalized on the basis of benefits and costs.

5.3.5 Defining new concepts and applications of performance-based navigation for the mid term and Long term and building synergy and integration among other capabilities toward the realization of the AFI Regional PBN goals.

6 Challenges

6.1 The challenge faced by the CAAB is to meet the PBN implementation strategy outlined in 7.1 below in accordance with the set timelines. Increasing demand by international air traffic as opposed to local demand will be constrained by financial resources necessary for aircraft equipage, airspace re-organisation and personnel training.

6.2 Continental En route

6.2.1 Most of the ATS routes in the upper airspace accommodate RNAV/RNP operations and it is feasible to meet the requirements for RNAV-5 subject to the constraints outlined above.

6.3 Terminal Areas (Departures and Arrivals)

6.3.1 PBN implementation in the Terminal areas to meet RNAV-1 and or Basic RNP-1 will only be possible at Sir Seretse Khama and Maun airports during the envisaged period.

6.4 Approach

6.4.1 PBN implementation in the Approach phase to meet RNP APCH with Baro-VNAV will only be possible at Sir Seretse Khama and Maun airports during the envisaged period.

7. Implementation strategy

7.1 This plan provides a high-level strategy for the evolution of navigation capabilities to be implemented in three time frames: near term (2008-2012), mid term (2013-2016), and Long term (2017 and Beyond). The strategy rests upon two key navigation 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 initiatives discusses integrated navigation, communication, surveillance and automation strategies.

7.2 To avoid proliferation of new navigation standards, Botswana and other aviation stakeholders in the AFI region should communicate any new operational requirements with ICAO HQ, so that it can be taken into account by the ICAO Study Group in charge of PBN.

8. Near Term (2008-2012) Mid Term (2013-2016) and Long Term (2017 and Beyond) Key Tasks

8.1 The key tasks involved in the transition to performance-based navigation are:

8.1.1 Establish navigation service needs through the Long term that will guide infrastructure decisions and specify needs for navigation system infrastructure, and ensure funding for managing and transitioning these systems.

8.1.2 Define and adopt a national policy enabling additional benefits based on RNP and RNAV.

8.1.3 Identify operational and integration issues between navigation and surveillance, air- ground communications and automation tools that maximize the benefits of RNP.

8.1.4 Support mixed operations throughout the term of this Roadmap, in particular considering navigation system variations during the near term until appropriate standards re developed and implemented.

8.1.5 To support Civil/Military coordination and develop the policies needed to accommodate the unique missions and capabilities of military aircraft operating in civil airspace.

8.1.6 Harmonize the evolution of capabilities for interoperability across airspace operations.

8.1.7 Increase emphasis on human factors, especially on training and procedures as operations increase reliance on appropriate use of flight deck systems.

8.1.8 Facilitate and advance environmental analysis efforts required to support the development of RNAV and RNP procedures.

8.1.9 Maintain consistent and harmonized global standards for RNAV and RNP operations.

9 Near term strategy (2008-2012)

9.1 In the near-term, initiatives focus on investments by operators in current and new aircraft acquisitions, in satellite-based navigation and conventional navigation infrastructure as well as Botswana investments. Key components include wide-scale RNAV implementation and the introduction of RNP for en route, terminal, and approach procedures.

9.2 The near-term strategy will also focus on expediting the implementation and proliferation of RNAV and RNP procedures. As demand for air travel continues at healthy levels, choke points will develop and delays at the major airports will continue to climb. RNAV and RNP procedures will help alleviate those problems.

9.3 Continued introduction of RNAV and RNP procedures will not only provide benefits and savings to the operators but also encourage further equipage.

9.4 Civil Aviation Authority of Botswana will as a matter of urgency adapt new flight plan procedures to accommodate PBN operations. This particularly addresses fields 10 and 18.

9.5 Operators will need to plan to obtain operational approvals for the planned Navigation Specifications for this period. Operators shall also review Regional PBN Implementation Plans from other Regions to assess if there is a necessity for additional Operational approvals.

10 Continental Enroute

10.1 For airspace and corridors requiring structured routes for flow management, Botswana will review existing conventional and RNAV routes to transition to PBN RNAV-5 or where operationally required RNAV-2/1.

10.2 Terminal Areas (Departures and Arrivals)

10.2.1 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.

10.2.2 Botswana will continue to plan, develop and implement RNAV-1 SIDs and STARs, at major airports and make associated changes in airspace design. In addition, Botswana will implement Basic RNP-1 SIDs and STARs. RNAV-1 will be implemented in airspace where there is sufficient surveillance coverage and Basic RNP-1 where there is no such coverage.

10.2.3 Where operationally feasible, Botswana should develop operational concepts and requirements for continuous descent arrivals (CDAs) based on FMS Vertical Guidance and for applying time of arrival control based on RNAV and RNP procedures. This would reduce workload for pilots and controllers as well as increase fuel efficiency.

10.2.4 PBN SIDs and STARS would allow the following:

- Reduction in controller-pilot communications;
- Reduction of route lengths to meet environmental and fuel efficiency requirements;
- Seamless transition from and to en-route entry/exit points;
- Sequence departures to maximize benefits of RNAV and identify automation requirements for traffic flow management, sequencing tools, flight plan processing, and tower data entry activities.

10.3 **Approach Operations**

10.3.1 The application of RNP APCH is expected to be implemented in the maximum possible number of aerodromes. To facilitate a transitional period, conventional approach procedures and conventional navigation aids should be maintained for non PBN equipped aircraft during this term.

10.3.2 Botswana should promote the use of APV Operations (Baro-VNAV or SBAS) to enhance safety of RNP Approaches and accessibility of runways (Sir Seretse Khama & Maun airports).

10.3.3 The application of RNP AR Approach should be limited to selected runways where obvious operational benefits can be obtained due to the existence of significant obstacles.

10.3.4 RNP approaches include:

10.3.4.1 APV implemented at all instrument runways at major regional airports (see above) and all non-Instrument runways serving aircraft weighing greater than 5,700kg.

11 Summary of near term strategy-2008-2012

Airspace	**Nav. Specifications**	**Nav. Specifications where operationally required**
En-Route/Remote Continental	RNAV-10	RNP-4
En-Route Continental	RNAV-5	RNAV-1
TMA Arrival/Departure	RNAV-1 in a surveillance environment Basic RNP-1 in non-surveillance environment	
Approach	RNP APCH with Baro-VNAV or RNP AR APCH if required	

12 Implementation Targets

12.1 RNP APCH (with Baro-VNAV) in 30% of instrument runways by 2010 and 50% by 2012 and priority given to airports with operational benefits

12.2 RNAV-1 SID/STAR for 30% of international airports by 2010 and 50% by 2012 and priority given to airports with RNP Approach

12.3 Review existing conventional and RNAV routes to transition to PBN RNAV-5 or where operationally required RNAV-2/1 by 2012.

13 Medium term strategy (2013-2016)

13.1 In the mid term, increasing demand for air travel will continue to challenge the efficiencies of the air traffic management system.

13.2 While the hub-and-spoke system will remain largely the same as today for major airline operations, the demand for more point-to-point service will create new markets and spur increases in low-cost carriers, air taxi operations, and on-demand services. Additionally, the emergence of 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 significant increases in unscheduled traffic. In addition, many destination airports that support scheduled air carrier traffic are forecast to grow and to experience congestion or delays if efforts to increase their 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.

13.3 The mid term will leverage these increasing flight capabilities based on RNAV and RNP, with a commensurate increase in benefits such as fuel-efficient flight profiles, better access to airspace and airports, greater capacity, and reduced delay. These incentives, which should provide an advantage over non-RNP operations, will expedite propagation of equipage and the use of RNP procedures.

13.4 To achieve efficiency and capacity gains partially enabled by RNAV and RNP, Botswana and the aviation industry will pursue use of data communications (e.g. for controller-pilot communications) and enhanced surveillance functionality, e.g. ADS-Broadcast (ADS-B). Data communications will make it possible to issue complex clearances easily and 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. in 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 (a set of points defined by latitude, longitude, altitude, and time.) Stakeholders must therefore develop concepts that leverage this capability.

13.5 **Continental**

The review of en-route airspace will be completed by 2016.

14 Implementation

14.1 By the end of the mid term other benefits of PBN will 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.

14.2 Automation for RNAV and RNP Operations

14.2.1 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 an aircraft's RNP capabilities. En route automation will use collaborative routing tools to assign aircraft priority, since the automation system can rely upon 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.

14.2.2 Conflict prediction and resolution in most en route airspace must improve as 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 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).

14.3 Terminal Areas (Departures and Arrivals)

14.3.1 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.

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

14.4 Terminal Evolution

14.4.1 During this period, 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.

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

14.5 Terminal Automation

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

14.5.2 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.

14.6 Approach Evolution

In the mid term, implementation priorities for instrument approaches will still be based on RNP APCH and RNP AR APCH and full implementation is expected at the end of this term.

The introduction of the application of landing capability, using GBAS (currently non PBN) is expected to guarantee a smooth transition towards high performance approach and landing capability.

14.7 Mid-term Implementation Targets

a) RNP APCH (WITH Baro-VNAV) or APV in 100% of instrument runways by 2016
b) RNAV-1 or RNP-1 SID/STAR for 100% of international airports by 2016
c) RNAV-1 or RNP-1 sid/star for 70% of busy domestic airport where there are operational benefits
a) Implementation of ditional RNAV/RNP routes as required.

14.8 Medium term strategy summary

Airspace	**Nav. Specifications**	**Nav. Specifications where operationally required**
En-Route/Remote Continental	RNAV-10,	RNP-4
En-Route Continental	RNAV-2, RNAV-5	RNAV-1
TMA Arrival/Departure	Expand RNAV-1, or basic RNP-1 application Mandate RNAV-1, or basic RNP-1	
Approach	Expand RNP APCH with (Baro-VNAV) and APV Expand RNP AR APCH where there are operational benefits	

15.0 Long term strategy (2017 and beyond)

15.1 The Long-term environment will be characterized by continued growth in air travel and increased air traffic complexity.

15.2 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, Botswana and key Stakeholders need an operational concept that exploits the full capability of the aircraft in this time frame.

15.3 Long Term Key Strategies (2017 and Beyond)

15.3.1 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 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.

15.3.2 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 communication of clearances, and furthermore using data communications for clearances to the flight deck. Workload will also decrease as the result of automated confirmation (via data communications) of flight intent from the flight deck to the ground automation.

15.3.3 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 resolutions. 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).

15.3.4 Performance-based operations will exploit aircraft capabilities for "electronic" visual acquisition of the external environment in low-visibility conditions, which may potentially increase runway capacity and decrease runway occupancy times.

15.3.5 Improved wake prediction and notification technologies may also assist in achieving increased runway capacity by reducing reliance on wake separation buffers.

15.3.6 System-wide information exchange will enable real-time data sharing of NAS constraints, airport and airspace capacity, and aircraft performance. Electronic data communications between the 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 the ATC automation and the aircraft FMS will permit better strategic and tactical management of flight operations.

15.3.7 Aircraft will downlink to the ground-based system their position and intent data, as well as speed, weight, climb and descent rates, and wind or turbulence reports. The ATC automation will uplink clearances and other types of information, for example, weather, metering, choke points, and airspace use restrictions.

15.3.8 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 all other airspace (except oceanic). Achieving standardized FMS functionalities and consistent levels of crew operation of the FMS is integral to the success of this Long-term strategy.

15.3.9 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 or avoid constrained airspace, resulting in greater efficiencies and fewer delays operating into and out of the busiest airports.

15.3.10 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 the efficiency of terminal operations.

15.3.11 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 flows and will intervene only as needed, primarily when conflict prediction algorithms indicate a potential problem.

15.3.12 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 the 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 areas to the main taxiways.

15.4 Summary of Long Term Key Strategies (2017 and Beyond)

15.4.1 The key strategies for instituting performance-based operations employ an integrated set of solutions.

15.4.2 Airspace operations will take advantage of aircraft capabilities, i.e. Aircraft equipped with data communications, integrated displays, and FMS.

15.4.3 Aircraft position and intent information directed to automated, ground-based ATM systems, strategic and tactical flight deck-based separation assurance in selected situations (problem detection and resolution).

15.4.4 Strategic and tactical flow management will improve through use of integrated airborne and ground information exchange.

15.4.5 Ground-based system knowledge of real-time aircraft intent with accurate aircraft position and trajectory information available through data link to ground automation.

15.4.6 Real-time sharing of National Air Space (NAS) flight demand and other information achieved via ground-based and air-ground communication between air traffic management and operations planning and dispatch.

15.4.7 Overall system responsiveness achieved through flexible routing and well-informed, distributed decision-making.

15.4.8 Systems ability to adapt rapidly to changing meteorological and airspace conditions.

15.4.9 System leverages through advanced navigation capabilities such as fixed radius transitions, RF legs, and RNP offsets.

15.4.10 Increased use of operator-preferred routing and dynamic airspace.

15.4.11 Increased collaboration between service providers and operators.

15.4.12 Operations at the busiest airports will be optimized through an integrated set of capabilities for managing pre-departure planning information, ground-based automation, and surface movement.

15.4.13 RNP-based arrival and departure structure for greater predictability.

15.4.14 Ground-based tactical merging capabilities in terminal airspace.

15.4.15 Integrated capabilities for surface movement optimization to synchronize aircraft movement on the ground. Improved meteorological and aircraft intent information shared via data link.

16 Key Research Areas

16.1 The aviation community must address several key research issues to apply these strategies effectively. These issues fall into several categories:

16.2 Navigation

16.2.1 To what extent can lower RNP values be achieved and how can these be leveraged for increased flight efficiency and access benefits?

16.2.2 Under what circumstances RNAV should be mandated for arriving/departing satellite airports to enable conflict-free flows and optimal throughput in busy terminal areas?

16.3 Flight Deck Automation

16.3.1 What FMS capabilities are required to enable the future concepts and applications?

16.3.2 How can performance-based communication and surveillance be leveraged in the flight deck to enable Long-term strategies such as real-time exchange of flight deck data?

16.4 Automation

16.4.1 To what extent can lateral or longitudinal separation assurance be fully automated, in particular on final approach during parallel operations?

16.4.2 To what extent can surface movement be automated, and what are the cost-benefit trade-offs associated with different levels of automation?

16.4.3 To what extent can conflict detection and resolution be automated for terminal ATC operations?

16.5 Procedures

16.5.1 How can time of arrival control be applied effectively to maximize capacity of arrival or departure operations, in particular during challenging wind conditions?

16.5.2 In what situations is delegation of separation to the flight crews appropriate?

16.5.3 What level of onboard functionality is required for flight crews to accept separation responsibility within a manageable workload level?

16.6 Airspace

16.6.1 To what extent can airspace be configured dynamically on the basis of predicted traffic demand and other factors?

16.6.2 What separation standards and procedures are needed to enable smoother transition between en route and terminal operations?

16.6.3 How can fuel-efficient procedures such as CDAs be accomplished in busy airspace?

16.7 Policy

- How is information security ensured as information exchange increases?
- What are the policy and procedure implications for increased use of collaborative decision-making processes between service providers and the operator?

16.7.1 The answers to these and other research questions are critical to achieving a PBN system. Lessons learned from the near-term and mid-term implementation of the roadmap will help answer some of these questions. The aviation community will address others through further concept development, analysis, modeling, simulation and field trials. As concepts mature and key solutions emerge, the community will develop more detailed implementation strategies .

17 Periodic review of implementation activities

17.1 Procedures to modify the regional plan

17.1.1 Whenever a need is identified for a change to this document, the request for change (RFC) form (to be developed) should be completed and submitted to the ICAO Regional Offices. The Regional Offices will collate RFCs for consideration by the PBN Task Force (ATM/SAR/AIS Sub-group of APIRG).

17.1.2 When an amendment has been agreed by a meeting of the PBN Task Force, a new version of the PBN Regional Plan will be prepared, with the changes marked by an " in the margin, and an endnote indicating the relevant RFC, to enable a reader to note the origin of the change. If the change is in a table cell, the outside edges of the tables will be highlighted. Final approval for publication of an amendment to the PBN Regional Plan will be the responsibility of APIRG.

Glossary

3D	Three- dimensional
4D	Four- dimensional
ADS-B	Automatic Dependent Surveillance- Broadcast
ADS-C	Automatic Dependent Surveillance- Contract
ATC	Air Traffic Control
CDA	Continuous Descent Arrival
CNS	Communications, Navigation, Surveillance
EFVS	Enhanced Flight Visibility System
GA	General Aviation
GBAS	Ground-Based Augmentation System
GLS	GNSS (Global Navigation Satellite System) Landing System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
ICAO	International Civil Aviation Organization

IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
LNAV	Lateral Navigation
LPV	Localizer Performance with Vertical Guidance
NAS	National Airspace System
NAVAID	Navigation Aid
NM	Nautical Miles
PBN	Performance Based Navigation
RCP	Required Communications Performance
RF	Radius-to-Fix
RNAV	Area Navigation
RNP	Required Navigation Performance
RNPSORSG	Required Navigation Performance and Special Operational Requirements Study Group

RSP	Required Surveillance Performance
SAAAR	Special Aircraft and Aircrew Authorization Required
SID	Standard Instrument Departure
STAR	Standard Instrument Arrival
VLJ	Very Light Jet
VNAV	Vertical Navigation
WAAS	Wide Area Augmentation System