Liberia Civil Aviation Authority
Office of the Director General
CAA16/DG/A4-002

April 6, 2016

Mr. Mam Sait Jallow
Regional Director
ICAO West and Center African Office (WACAF)

RE: Submission of Liberia PBN Implementation Plan

Dear Mr. Jallow:

I present my compliments and in keeping with the procedures established for the Performance Based Navigation (PBN) Implementation Plan, hereby submit to your office the approved Liberia National PBN Implementation Plan.

Please accept the assurances of my highest esteem and consideration.

Sincerely,

Richelieu A. Williams
Director General

P. O Box 68, Harbel Margibi County, Republic of Liberia
Tel: 231-77273689 eFax: +1(347) 402-4352
E-mail: liberiacaa@liberiacaa.com / www.liberiacaa.com

PBN IMPLEMENTATION PLAN LIBERIA

Liberia Civil Aviation Authority

JANUARY 2016

Approved by: ____________________
DIRECTOR GENERAL

EXECUTIVE SUMMARY

This plan covers PBN implementation in all flight phases in Roberts FIR including the arrival, departure phases in the lower airspace of Liberia.

In order to ensure a safe and efficient performance of the global Air Navigation System, ICAO has urged 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 PBN Manual (ICAO Doc 9613) vol. 1. This is to be done by developing a Performance Based Navigation (PBN) Implementation Plan to ensure the implementation of RNAV and RNP operations (where required) for en-route and terminal areas, and implementation of instrument approach procedures with vertical guidance (APV) including LNAV only minima for all instrument runway ends either as primary approach or as a back-up for precision approaches by the end of 2016.

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1. Background

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

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.

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 more recently Required Navigation Performance (RNP) to ensure that the performance of the RNAV system is appropriate for the specific airspace requirements.

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.

These 'new' systems were developed, evaluated and certified. Airspace and obstacle clearance criteria were developed on the basis of available equipment performance. Requirements and specifications were based upon available capabilities and, in some implementation, it was necessary to identify the individual models of equipment that could be operated within the airspace concerned.

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 equipment requirements by specification of the performance requirements. This is termed Performance Based Navigation (PBN).

2. Area Navigation (RNAV)

Area navigation (RNAV) is a method of instrument flight rules (IFR) navigation that allows an aircraft to choose any course within a network of navigation beacons, rather than navigate directly to and from the beacons. This can conserve flight distance, reduce congestion, and allow flights into airports without beacons.

RNAV and RNP systems are fundamentally similar. The key difference between them is the requirement for on-board performance monitoring and alerting. A navigation specification that includes a requirement for on-board navigation performance monitoring and alerting is 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.

2.1 Capabilities

Area Navigation (RNAV) is capable of permitting aircraft operation on any desired course within the coverage of station-referenced navigation signals or within the limits of a self-contained system capability, or a combination of these.

RNAV was developed to provide more lateral freedom and thus more complete use of available airspace. This method of navigation does not require a track directly to or from any specific radio navigation aid, and has three principal applications:

1. A route structure can be organized between any given departure and arrival point to reduce flight distance and traffic separation.
2. Aircraft can be flown into terminal areas on varied pre-programmed arrival (STAR) and departure (SID) paths to expedite traffic flow.
3. Instrument approaches can be developed and certified at certain airports, without local instrument landing aids at that airport.

Navigation systems which provide RNAV capability include VOR/DME, DME/DME.

2.1.1 RNAV Specifications

RNAV specifications do not require on board navigation performance monitoring and alerting.

RNAV tracks (e.g.: RNAV 5, RNAV 2, RNAV 1) will normally require monitoring by ATC surveillance systems to achieve desired performance and separation safety standards. This requirement implies near universal surveillance coverage for RNAV specifications:

a) RNAV 10: intended for use in continental airspace
b) RNAV 1: intended for use in Terminal airspace

In oceanic airspace this surveillance is provided by ADS-C and in domestic airspace by a network of radar systems (PSR & SSR). The surveillance of domestic airspace will also include WAM (Wide Area Multilateration) and ADS-B when these systems are approved and operational.

2.2 Current status of RNAV operations in Liberia

RNAV approach procedures were implemented in Liberia during 2013, at the Roberts International Airport for arrival and approach phases of flight.

3. Benefits of RNAV and Global Harmonization

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

- 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.

- Avoids need for development of sensor-specific operations with each new evolution of navigation systems, which would be cost-prohibitive.
- Allows more efficient use of airspace (route placement, fuel efficiency, noise abatement).
- Clarifies the way in which RNAV systems are used.
- Facilitates the operational approval process for operators by providing a limited set of navigation specifications intended for global use.

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:

- Increase safety by using three-dimensional (3D) trajectory operations with course guidance to the runway, which reduce the risk of Controlled Flight Into Terrain (CFIT).
- Improve airport and airspace access in all weather conditions, and the ability to meet environmental and obstacle clearance constraints.
- 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.
- 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.
- Reduce workload and improve productivity of air traffic controllers.

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.

4. Challenges

In order to cope with forecasted increase in air traffic, the airspace capacity must be increased whilst at the same time keep the controller workload at a justifiable level. Because RNAV allows a more flexible route system, a more efficient airspace organisation can be established and thus contribute to fulfill the above requirements. The current RNAV procedures that have been introduced for enroute, terminal and approach use only part of the full navigation and functional capabilities of many RNAV equipped aircraft and provide only part of the potential benefits.

RNAV operating procedures need to be drawn up, and routes making use of the advanced navigation performance of modern aircraft should be established so that more benefits can be provided from the RNAV procedures. Aircraft that do not meet the requirements for the new RNAV procedures are expected to continue flying, so there will be a period during which aircraft that meet the new requirements must coexist with aircraft that do not (mixed operations).

Confronted with a mix of equipped and non-equipped aircraft, there will be a need to figure out how to move to a "best equipped, best served" policy.

4.1 Increasing Demands

There is increasing demand for the implementation of PBN considering the increase in international operations (scheduled and non-scheduled flights), increases in general aviation operations, development of new aerodromes, complexity involved with civil & military operations etc.

4.1.1 En route

Airspace design enroute must be based on a strategic ATS-route system along main traffic flows enabling optimum connections to the SID/STAR systems, coordinated connections to neighbouring states, flexible use of airspace and fulfilling the capacity demand.

- Roberts FIR plans to meet the migration targeted date from AIS to AIM by 2018.
- Roberts FIR introduced GNSS Procedure in Guinea 2012 and Liberia 2013 with plans to do the same in Sierra Leone in 2016 and to fine tune it to provide links to join the international routes based on RNAV 5 and RNAV 1 Specifications where required.
- Roberts FIR plans to design the PBN RNAV Routes based on RNAV 5 and where operationally required.

4.1.2 Terminal Areas (Departures and Arrivals)

Airspace design of TMAs must be based upon a strategic SID/STAR system enabling continuous climb operations (CCO) for departures and continuous descent operations (CDO) for arrivals and which serve the declared airport capacity.

The requirement of SID/STARs in Liberia necessitates cost/benefit analysis to decide upon supporting navigation infrastructure (DVOR/DME and/or GNSS). Upon the design of appropriate SIDS/STARS based on RNAV 1 and Basic RNP 1, the following will be realized:

- Increase operations to a single runway. This awaits WGS-84 re-survey in 2016.
- Air traffic controller workload will be further reduced.
- Air traffic controller/Pilot communication will be minimized.
- The numbers of internal routes will be increased (with reduced separation) by creating parallel routes between cities within its national airspace.

4.1.3 Approach

Utilizing RNP APCH and RNP AR APCH operations will enable Liberia to achieve the following:

- Increasing operations on a single runway by use of better GNSS/PBN SIDs/STARs based on RNP APCH with Baro-VNAV or RNP AR APCH (in mountainous areas).

- Reducing Air traffic controller workload by using appropriate designed PBN procedures (SIDS/STARS) based navigation specification RNP APCH with Baro-VNAV or RNP AR APCH (in mountainous areas).
- Introducing GNSS procedure design for its domestic airports by 2017.
- Improving the link from the TMA along existing airways using STARs and those to be established in the future by augmenting SIDs to supplement them by 2017.

4.2 Efficient Operations

Aviation being the fastest mode of transport the world over; passengers and cargo have increased tremendously in an upward trend. This has resulted in the increase of aircraft that fly in the sky and a subsequent scramble for airspace during all phases of flight.

There is need therefore for a very efficient mode of operations in the airspaces. The only system that can provide such operation is the Performance Based Navigation (PBN) which ensures efficient operations in the approach phase, terminal areas, enroute and the continental navigation of aircraft.

4.2.1 En route

ATS-routes based upon RNAV 5/RNP 2 specifications will result in the following benefits to stakeholders:

- Facilitate operators to save fuel by providing more direct route based on the use of well-designed RNAV 5/RNP 2 routes.
- Reduce carbon emission by using shorter routes and CDOs procedure based on RNAV 5/ RNP 2 routes.
- Maximise airspace usage by creating more routes including a parallel routes with reduced separation, which is operable based on RNAV 5/RNP 2 procedure designs.
- Maintain current NAVAIDs to be used by conventionally equipped aircraft and as a fall-back position when aircraft loses their equipment.

4.2.2 Terminal Areas

There is an on-going process of implementing RNAV 1 SIDs to augment the STARs at Roberts International Airport in Liberia; supported either by GNSS and/or DVOR/DME.

Upon implementation of RNAV 1/RNP 1 SIDs and STARs the below will be achieved:

- Fuel and time will be saved by using improved and shorter approaches to the end of the runway with a good procedure design based on RNAV 1/Basic RNP 1.
- Improved and simpler method shall be applied to avoid and simplify issues of airspace restrictions with a good procedure design based on RNAV 1/Basic RNP 1.
- Increase capacity by maximising the use of airspace by use of reduced separation and better PBN Procedure designs based on RNAV 1/Basic RNP 1.

- Landing is expedited by avoiding the unnecessary holding of aircraft in the holding stacks by using improved PBN Procedures.

4.2.3 Approach

Implementation of RNP APCH (with Baro-VNAV) or RNP AR APCH procedures to all instrument runway ends will accomplish the following:

- Time and fuel is saved by the use of short approaches to the runway ends. This can be attained by using the PBN procedure design based on RNP APCH (with Baro-VNAV) or RNP AR APCH (where applicable).
- Separation standards can be reduced while maintaining efficiency by requiring better aircraft equipment, GBAS and well-designed PBN procedures.
- Continuous Climb Operation (CCO) profile shall be maintained by well-designed PBN procedures that are executed by aircraft with the right equipment.
- Incidences/near misses/air misses or even delays can be reduced by the operators adhering to the laid down PBN procedures while flying aircraft with correct equipment.
- Air navigation service providers shall also provide the right training to the controllers and other stakeholders.

4.3 Environment

The implementation of RNAV is geared towards protecting the environment against:

- Sound/noise,
- carbon dioxide emissions,
- the protection of published restricted areas.

The above can be achieved by using modern aircraft with better fuel efficiency. The aircraft has to be flown in a well-designed PBN procedures based on the navigation specifications applicable to the airspace concerned. The PBN procedures will be designed by well trained personnel.

5. Implementation

The intent of this chapter is to give an overview of the planned PBN implementation for all flight phases. The following PBN implementation strategy is the basis for the roadmap.

This plan provides a high-level strategy for the evolution of navigation capabilities to be implemented in two phases; medium (2013-2016), 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 Departures (SID) and Standard Terminal Arrivals (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.

To avoid proliferation of new navigation standards, Liberia 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.

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

- To 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.
- To develop and adopt a national policy enabling additional benefits based on RNP and RNAV.
- To identify operational and integration issues between navigation and surveillance, air-ground communications, and automation tools that maximize the benefits of RNP.
- To 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.
- To support Civil/Military coordination and develop the policies needed to accommodate the unique missions and capabilities of military aircraft operating in civil airspace.
- To harmonize the evolution of capabilities for interoperability across airspace operations.
- To increase emphasis on human factors, especially on training and procedures as operations increase reliance on appropriate use of flight deck systems.
- To facilitate and advance environmental analysis efforts required to support the development of RNAV and RNP procedures.
- To maintain consistent and harmonized global standards for RNAV and RNP operations.

5.1 Medium term strategy (2013-2016)

Phase one:

In the medium term, initiatives will focus on investments by operators in current and new aircraft acquisitions, in satellite-based navigation and conventional navigation infrastructure as well as investments by LCAA. Key components include wide-scale RNAV implementation and the introduction of RNP for en route (Roberts FIR), terminal (Roberts FIR/LCAA), and for approach (LCAA).

The medium 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 in alleviate those problems.

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

The Liberia Civil Aviation Authority as a matter of urgency shall ensure that Aeronautical Information Management (AIM) adheres to the new ICAO Flight Plan procedures to accommodate PBN operations. This particularly addresses fields 10 and 18.

Operators will need to plan to obtain operational approvals from the LCAA 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.

5.1.1 En route

ATS-routes in Liberia will be based upon continued use of RNAV 5 supported as necessary by ADS-B service. RNP 1 routes will be considered at the end of the period.

5.1.1.1 Oceanic and remote continental

Not applicable at the present time

5.1.1.2 Continental

For airspace and corridors requiring structured routes for flow management, Roberts FIR will review existing conventional and RNAV routes to transition to PBN RNAV 5 or where operationally required RNAV 2.

5.1.2 Terminal Areas (Departures and Arrivals)

RNAV reduces conflict between traffic by consolidating flight tracks. RNAV 1/Basic RNP 1 SIDs and STARs improve safety, capacity, and flight efficiency, environmental issues and also lower communication errors.

Liberia plans to develop and implement RNAV 1 SIDs and STARs, at major airports and make associated changes in airspace design. In addition, Liberia will also complete the implementation of 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.

Where operationally feasible, Liberia will develop operational concepts and requirements for Continuous Climb Operation (CCO) based on FMS Vertical Guidance and for applying time of arrival control based on RNAV and RNP procedures. This will reduce workload for pilots and controllers as well as increase fuel efficiency.

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 lower data entry activities.

5.1.3 Approach

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

Liberia will promote the use of APV Operations (Baro-VNAV or SBAS) to enhance safety of RNP Approaches and accessibility of runways.

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.

5.1.4 Helicopter Operations

Apart from a contingency of military helicopters, there are very few helicopters for civil operations. The PBN operations for helicopters shall then be developed for civil operations as and when the time permits.

5.1.5 Summary of phase one medium term strategy

Airspace	Navigation Specifications	Navigation Specifications Where operationally required
En-route Oceanic	RNAV 10	RNP 4
En-Route Remote Continental	N/A	N/A
En-Route Continental	RNAV 5	RNP 2
TMA Arrival/Departure	-RNAV 1/RNAV 2 in a surveillance environment (GLRB) -Basic RNP 1/RNP 2 in non-surveillance environment.	
Approach	RNP APCH with Baro-VNAV(ROB GLRB)	RNP AR APCH

5.1.6 Implementation Targets (Effective dates are subject to changes)

	Navigation Specifications	Where applicable	Effective date	100% Application
APPROACH	RNP APCH (with Baro-VNAV/LNAV)	UB614 UB600 UG852 UG433	September 2013 GNSS	Dec. 2016
	RNP AR APCH	N/A	N/A	N/A
TERMINAL (SID/STARS)	RNP 1	GLRB	September 2013	Dec. 2016
	RNAV 1	GLRB	September 2013	Dec. 2016
ENROUTE	RNAV 5	Continental	April 2016	Dec. 2016
	RNP 2	Domestic	N/A	N/A

Phase two

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

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 Very Light Jets 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.

The medium 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 equipment and the use of RNP procedures.

To achieve efficiency and capacity gains partially enabled by RNAV and RNP, Liberia and its 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 trajectories and time of arrival control based on RNP will be demonstrated in the medium 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.

5.2.1 En route

ATS-routes in Liberia will be based upon continued use of RNAV 5/RNAV 2 supported as necessary by ADS-B/ADS-C services.

5.2.1.1 Oceanic and remote continental

Not applicable at the present time

5.2.1.2 Continental

The review of en-route airspace will be completed by 2017.

Implementation

By the end of the medium 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.

Automation for RNAV and RNP Operations

By the end of the medium 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

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Automation for RNAV and RNP Operations

By the end of the medium 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.

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. Medium 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 medium 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).

5.2.2 Terminal Areas (Departures and Arrivals)

During this period, either Basic RNP 1 or RNAV 1 will become a required capability for all 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.

With RNAV-1 operations as the predominant form of navigation in terminal areas by the end of the medium term, Liberia will maintain the conventional terminal procedures that are expected to be used.

Terminal Automation

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 manoeuvres for optimal throughput.

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.

5.2.3 Approach

In the medium 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.

5.2.4 Helicopter operations

Apart from a contingency of military helicopters, there are very few helicopters operated for civil operations. The operations for helicopters shall then be developed for civil operations as and when the time comes.

5.2.5 Medium term Phase two strategy summary

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.

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).

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.

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

System-wide information exchange will enable real-time data sharing of National Airspace System (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.

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.

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.

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.

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.

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.

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.

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

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

- Airspace operations will take advantage of aircraft capabilities, i.e. aircraft equipped with data communications, integrated displays, and FMS.
- 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).
- Strategic and tactical flow management will improve through use of integrated airborne and ground information exchange.
- Ground-based system knowledge of real-time aircraft intent with accurate aircraft position and trajectory information available through data link to ground automation.
- 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.
- Overall system responsiveness achieved through flexible routing and well-informed, distributed decision-making.
- Systems ability to adapt rapidly to changing meteorological and airspace conditions.
- System leverages through advanced navigation capabilities such as fixed radius transitions, RF legs, and RNP offsets.
- Increased use of operator-preferred routing and dynamic airspace.
- Increased collaboration between service providers and operators.

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.

- RNP-based arrival and departure structure for greater predictability.
- Ground-based tactical merging capabilities in terminal airspace.
- Integrated capabilities for surface movement optimization to synchronize aircraft movement on the ground.
- Improved meteorological and aircraft intent information shared via data link.

5.3.3 Key Research Areas

The aviation community must address several key research issues to apply these strategies effectively.

These issues fall into several categories:

Navigation

- To what extent can lower RNP values be achieved and how can these be leveraged for increased flight efficiency and access benefits?
- Under what circumstances RNAV should be mandated for arriving/departing satellite airports to enable conflict-free flows and optimal throughput in busy terminal areas?

Flight Deck Automation

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

Automation

- To what extent can lateral or longitudinal separation assurance be fully automated, in particular on final approach during parallel operations?
- To what extent can surface movement be automated, and what are the cost-benefit trade-offs associated with different levels of automation?
- To what extent can conflict detection and resolution be automated for terminal ATC operations?

Procedures

- How can time of arrival control be applied effectively to maximize capacity of arrival or departure operations, in particular during challenging wind conditions?
- In what situations is delegation of separation to the flight crews appropriate?
- What level of on-board functionality is required for flight crews to accept separation responsibility within a manageable workload level?

Airspace

- To what extent can airspace be configured dynamically on the basis of predicted traffic demand and other factors?
- What separation standards and procedures are needed to enable smoother transition between en route and terminal operations?
- How can fuel-efficient procedures such as CDAs be accomplished in busy airspace?

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Glossary

3D	Three-Dimensional
4D	Four-Dimensional
ADS-B	Automatic Dependent Surveillance-Broadcast
ADS-C	Automatic Dependent Surveillance-Contract
ATC	Air Traffic Control
CCO	Continuous Climb Opération
CDO	Continuous Descent Opération
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	Meteorological Conditions
LNAV	Lateral Navigation
LPV Guidance	Localizer Performance with Vertical
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