SUDAN CIVIL AVIATION AUTHORITY
AIR NAVIGATION SERVICES
AIR TRAFFIC MANAGEMENT
PBN PLAN 2013-2022

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Sudan Civil Aviation Authority

PERFORMANCE BASED NAVIGATION (PBN)

IMPLEMENTATION PLAN

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RECORD OF AMENDMENTS

Record the incorporation of an amendment, the date of inserting the amendment and signature as indicated below

No.	Page	Amendment Date	Incorporated by	Date

About the Plan

The Sudan performance based navigation (PBN) implementation plan has been developed to harmonized PBN implementation in MID/AFI regions and to addresses the strategic objectives of PBN based on clearly established operational requirements, avoiding equipage of multiple on-board or ground based equipment, avoidance of multiple airworthiness and operational approvals and explains contents relating to potential navigation applications.

The plan was prepared in accordance with ICAO provisions related to PBN, the Global Air Navigation Plan, Aviation System Block Upgrades (ASBU) methodology, MID/AFI regions Air Navigation Plan and the MID/AFI Regions Air Navigation Strategies. In addition to the Assembly Resolutions and the twelfth Air Navigation Conference (AN-Conf/12) recommendations related to PBN.

Requirement for PBN Plan

1.1 ICAO Assembly Resolution A36-23 calls for each State to develop a national PBN implementation plan by December 2009. By elaborating this plan, **Sudan** wants to meet the intent of the resolution and to show his engagement (commitment) for the implementation of PBN.

Why is a PBN implementation plan needed?

1.2 With RVSM implementation, the main tool to optimize the airspace structure is the implementation of performance-based navigation (PBN), which will foster the necessary conditions for the utilization of RNAV and RNP capabilities by a significant portion of airspace users in the Regions and States.

1.3 Current planning by the Regional Planning and Implementation Groups is based on the Air navigation plans and the Regional CNS/ATM Plans. Currently, these plans are mostly made up of tables that do not contain the necessary details for the implementation of each of the CNS and ATM elements. For this reason, the Regions will be developing Regional PBN implementation plans. The aim of this national implementation PBN plan is to implement the MID regional plan at the State level and address PBN implementation strategy at the national level.

1.4 The national PBN implementation plan wants also to provide proper guidance and direction to the air navigation service provider(s), airspace operators and users, regulating agency, as well as foreign operators who operate or plan to operate in **Sudan**. This plan will address the planned evolution of navigation, as one of the key systems supporting air traffic management, and describe the RNAV and RNP navigation applications that will be implemented in at least the short and medium term, in **Sudan**.

What are the objectives of the PBN Implementation Plan or Roadmap?

1.5 The PBN implementation plan should meet the following strategic objectives:

a) Provide a high-level strategy for the evolution of the navigation applications to be implemented in the **Sudan** in the short and medium term (2013-2022).

This strategy is based on the concepts of PBN, Area Navigation (RNAV) and Required Navigation Performance (RNP), will be applied to aircraft operations involving instrument approaches, standard departure (SID) routes, standard arrival (STAR) routes, and ATS routes in accordance with the implementation goals in the Assembly resolution;

b) Ensure that the implementation of the navigation portion of the CNS/ATM system is based on clearly established operational requirements;
c) Avoid unnecessarily imposing the mandate for multiple equipment on board or multiple systems on the ground;
d) Avoid the need for multiple airworthiness and operational approvals for intra- and inter-regional operations;
e) Prevent commercial interests from outdoing ATM operational requirements, generating unnecessary costs for **Sudan** as well as for airspace users.

What is the intent of the PBN Implementation Plan or Roadmap?

1.6 The PBN Implementation Plan should be developed by the Sudan Civil Aviation Authority together with the stakeholders concerned and is intended to assist the main stakeholders of the aviation community plan a gradual transition to the RNAV and RNP concepts. The main stakeholders of the aviation community that benefit from this roadmap and should therefore be included in the development process are:

- Airlines and operators
- Air navigation service providers
- Regulating agencies
- National and international organizations
- Military

The PBN Implementation Plan is intended to assist those stakeholders of the aviation community plan a gradual transition to the RNAV and RNP concepts and their investment strategies.
Airlines and operators will use this roadmap to plan future equipage and additional navigation capability investments;
Air navigation service providers will plan a gradual transition for the evolving ground infrastructure.
The **Sudan Civil Aviation Authority** will anticipate and plan for the criteria that will be needed in the future as well as the future regulatory workload and associated training requirements for their work force.

What principles should be applied in development of the PBN Implementation Plan?

The implementation of PBN in Sudan is based on the following principles:
a) Continued application of conventional air navigation procedures during the transition period, to guarantee availability by users that are not RNAV- and/or RNP-equipped;
b) Development of airspace concepts, applying airspace modeling tools as well as real time and accelerated simulations, which identify the navigation applications that are compatible with the aforementioned concept;
c) Conduct of cost-benefit analyses to justify the implementation of the RNAV and/or RNP concepts in each particular airspace;
d) Conduct of pre- and post-implementation safety assessments to ensure the application and maintenance of the established target levels of safety.
e) Conduct of environmental assessment to the ATS routes by considering the ICAO requirements for the environment (fuel consumption, CO2 emission …………).
f) Must not conflict with the MID/AFI regional PBN implementation plan.

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1. Introduction

2. Background

The continuing growth of aviation places increasing demands 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 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 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. 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. Performance Based Navigation (PBN)

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.

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.

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.

The advantage of this approach is that it provides clear, standardized, operational approvals which enable 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.

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.

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.

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.

3.1. RNAV Current status in Sudan (routes)

The following RNV routes are established within Khartoum Airspace:

Route UM863 as RNV 10 linking the Gulf with West Africa

Route UT124 as RNV 10 linking East Africa with Europe

Routes UQ584 as RNV 10 linking the Gulf with West Africa down South America

Route UT535 linking Juba with East Africa.

Route UT139 as RNAV 10 linking east Africa with West Africa.

Route UT142 linking East Africa with the North West Africa.

Note:

- The navigation specification in the above routes will be upgrade to **RNAV-5** because Sudan Airspace was covered with ATS surveillance Systems.
- Sudan Civil Aviation Authority plan for major changes to the airspace redesign by applying RNAV routes for the upper airspace (unidirectional routes and direct routes), these changes will be conducted during 2016 and therefore all the above routes may be amended to cope with new design and to cover ICAO requirement.
- The main aim of the new design is to provide an appropriate and relevant respond to the future traffic demand by considering the PBN concept, which recommended by ICAO.
- According to Sudan Strategic Plan South Sudan will be involved in the above scenario, South Sudan airspace will be covered with RNAV routes, also ADS-C and CPDLC will be implemented.
- The conventional Navaid infrastructure will be maintained to support non-equipped aircraft during a transition period until at least 2017.

3.1.1 RNAV, ATS routes, SIDs, STARs and approaches

- RNAV 5 based on GNSS will be applying to all RNAV routes in SUDAN and South Sudan Airspaces.
- By **June 2016** RNAV SIDs and STARs will be applying for **7** airports (Khartoum , el fasher , El obied , el genana , Nyala, port Sudan , Marawai)
- By the end of **2016** RNAV SIDs and STARs will be applying for **4** airports (El damazin, Kadugli, Kasala and Dongola).
- By the end of **2017** RNAV SIDs and STARs will be applying for **2** airports (Eldaien and Zalengi).
- SIDs and STARs within **Khartoum TMA** will apply **RNAV 1 based on GNSS**.
- SIDs and STARs within other **SUDAN airports** will apply **RNP 1** (BASIC RNP1) based on GNSS.
- Khartom, Portsudan, Nyala and El obied are certified as international airports.
- Kasala and El genana will be under the process of certifications during 2016, and expected to be certified as international airports by the end of 2017.
- Baro-VNAV will be designed for Khartoum, Portsudan and Marawai by June 2016.
- Baro-VNAV will be designed for El fasher, El obied, Elgenana, Kasala, Eldamazin, Kadugli, Nyala and Dongola by the end of 2016.
- Baro-VNAV will be designed for Zalengi and El daien by the end of 2017**.**

RNAV GNSS APPROACH IN SUDAN

- GNSS approach is part of the GPS service and is established at **Khartoum airport**, since **2010** therefore, acquisition of such service could only be done by means of flying towards a number of waypoints which are prevailed along the approach phases within The Sudan TMA after which it will guide the A/C to the final approach phase of the landing runway.
- On **2012** SUDAN signed a contract with CGX AERO (France) for designing IAPs, SIDs, and STARs for 13 airports and according to that Sudan established a unit for procedure design to follow with the CGX the designing task for these airports.

3.1.2 Fleet equipage in Sudan airspace

- Aircrafts registered in **Sudan To be Developed**
- Aircrafts landing in **Sudan to be completed**

3.2 Benefits of PBN 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) approach operations with course guidance to the runway, which reduce the risk of controlled flight into terrain.
- 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.

3.3 Stakeholders

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 State PBN plan.

The stakeholders who will benefit from the concepts in this State PBN plan include airspace operators, air traffic service providers, regulators, military and standards organizations. As driven by business needs, airlines and operators can use the State 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.

This plan is a work in progress and will be amended through collaborative MID/AFI Region States, 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:

- Expediting the development of performance-based navigation criteria and standards.
- Introducing airspace and procedure improvements in the near term.
- Providing benefits to operators who have invested in existing and upcoming capabilities.
- 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.
- 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 MID Region PBN goals.

4. Challenges

4.1 Increasing Demands

- Sudan CAA adapted Open sky policy.
- Growing volume of air traffic in Sudan create the needs to increase airspace and airport capacities to accommodate the increasing numbers of traffic, this will be through the restructure of the Sudan airspace which will increase efficiency, flight predictability and airspace capacity, while reducing fuel burn, emissions and controller-pilot communications, thereby enhance safety, and make Sudan airspace routes harmonize with MID/AFI routes.
- Khartoum new airport is under construction which also has positive impact in increasing the airport capacities, reduce delays and environmental benefits.
- **GNSS** will be used as primary means of navigation within SUDAN; proper backup system must be kept in place to support a healthy aviation system and continuous services.

4.1.1 En route

- The present route network in **Sudan** is ground-based navigation aids such as VOR and RNAV routes. These mixed routes could create complexity for ATC and increased controller workload at specific points. The ATC complexity caused by the mixed operation must be removed to increase the numbers of aircraft handled by each controller, and to reduce controller workload.

- Measures must be introduced to increase both airspace capacity and the number of aircraft that can be handled by individual controllers without increasing workload through:
    1. Re-structuring of airspace,
    2. Improve air traffic management.
    3. Introducing tools to assist air traffic controllers that can increase the number of aircraft handled by a controller without increasing their workload.

4.1.1.2 Continental

RNAV-5 will be applying**.**

4.1.2 Terminal Areas (Departures and Arrivals)

- RNAV departure and arrival routes can be made shorter than routes that use ground-based navigation aids. Analysis and coordination for the establishment of RNAV departure and arrival routes has initiated so the benefits from RNAV operations can be provided to operators as soon as possible.
- Arrival routes will be connected directly to the approach phase. To minimize fuel consumption, the routes will be designed so that an optimized profile descent can be made using the aircraft's FMS. For airports without Airport Surveillance Radar, RNAV could be very effective in shortening routes. For the approach phase.
- **Apply RNAV-1** in surveillance environment and with adequate navigation infrastructure.

4.1.3 Approach

- Apply RNAV GNSS approach LNAV for 11 instruments R/W by the end of Mar 2016.
- Apply LNAV/VNAV (Baro-VNAV) for 7 instruments R/W by the end of June 2016.
- Apply LNAV/VNAV (Baro-VNAV) for 4 instruments R/W by the end of 2016.
- Apply LNAV/VNAV (Baro-VNAV) for the other 2 airports by the end of 2017.

4.2 Efficient Operations

4.2.1 En route (continental)

- Sudan new airspace design will concentrate on the direct and unidirectional PBN routes on the upper airspace as much as possible.

4.2.2 Terminal Areas (Departures and Arrivals)

- Provides an efficient link to the TMA and en-route structure.
- Provide for increase operations in a single runway environment.
- Reduced ATC controller workload.
- Apply CCO and CDO operations.

4.2.3 Approach

- Provides an efficient link to the TMA and en-route structure.
- Provide for increase operations in a single runway environment.
- Reduced ATC controller workload.
- Better Aerodrome operating minim
- Redundancy to landing navigation aids

4.3 Environment

- Sudan has submitted his state action plan to the ICAO office and this study concentrates on the measures to be done during all phases of flights within Sudan airports and the airspace.
- Also Sudan new airspace design will be followed by environmental study which will covered all ICAO requirements for environment.

5. Implementation strategy

This plan provides a high-level strategy for the evolution of navigation capabilities to be implemented in two timeframes: short- term (2013-2017), and medium term (2018-2022). 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 and remote operations. The section on Long-term initiatives discusses integrated navigation, communication, surveillance and automation strategies.
To avoid proliferation of new navigation standards, [**SUDAN CAA**] and other aviation stakeholders in the MID/AFI regions 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.

Short Term (2013-2017) and Medium Term (2018-2022) Key Tasks

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

- Establish navigation service needs through the terms that will guide infrastructure decisions and specify needs for navigation system infrastructure, and ensure funding for managing and transitioning these systems.
- Define and adopt a national policy enabling additional benefits based on RNP and RNAV.
- Identify operational and integration issues between navigation and surveillance, air-ground communications, and automation tools that maximize the benefits of RNP.
- 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.
- Harmonize the evolution of capabilities for interoperability across airspace operations.
- Increase emphasis on human factors, especially on training and procedures as operations increase reliance on appropriate use of flight deck systems.

- Facilitate and advance environmental analysis efforts required to support the development of RNAV and RNP procedures.
- Maintain consistent and harmonized global standards for RNAV and RNP operations.

5.1 En route

5.1.1 Oceanic and Remote Continental

N/A

5.1.2 Continental

For upper airspace and corridors requiring structured routes for flow management, [SUDAN] will review existing conventional, RNAV routes, SIDs and STARs through the new design of the Sudan airspace and transition to PBN RNAV-5 or where operationally required RNAV-2/1.

5.2 Terminal Areas (Departures and Arrivals)

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.
[SUDAN] will continue to plan, develop and implement **RNAV-1 SIDS and STARs**, at major airports and will make associated changes in airspace design. In addition, [SUDAN] will implement **RNP-1**(**Basic RNP-1) SIDs and STARs**.
RNAV-1 will be implemented in airspace where there is sufficient surveillance coverage and **RNP-1(Basic RNP-1**) where there is no such coverage.
CCO and CDO operations will be implemented within Khartoum TMA during this period; this will increase efficiency, flight predictability and airspace capacity, while reducing fuel burn, emissions and controller-pilot communications, thereby enhancing safety.

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.

5.2.1 Approach

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 (2013-2017).
[SUDAN] should promote the use of **APV** (BARO-VNAV) Operations (LNAV/VNAV) to enhance safety of RNP Approaches and accessibility of runways (**2016-2017**).

Precision approach capability using GPS and its ground based augmentation systems in **SUDAN** will start **after 2018** if the business case proves an operational and economic benefit for all concerned stakeholders.

Implementation Targets

- RNP APCH (with Baro-VNAV) in **100%** of instrument runways by the end of **2017** and priority given to airports with operational benefits
- RNAV-1 or RNP-1 SID/STAR for **100%** of international airports by the end of **2016**.
- **CCO** and **CDO** will be implementing by the end of **2016**.
- Review existing conventional and RNAV routes to transition to PBN RNAV-5 by the end of 2016 through the new airspace design.

5.3 SUDAN Medium term strategy (2018-20122)

Use of ADS-C and data link communications (**CPDLC**) in remote areas, in South Sudan and where there is difficulty in VHF communications. Stakeholders must therefore develop their fleets so as to be leverage to this concepts capability.

5.3.1 En route

5.3.1.1 Oceanic and Remote Continental

N/A

5.3.1.2 Continental

The new design of Sudan airspace represents a challenging work carried by SCAA and the main tool for optimizing the airspace structure is implementation of PBN, so during the MID-term SCAA will cover all ICAO requirements for ASBU BLOCK 0 and BLOCK 1.

Implementation

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.

Automation for RNAV and RNP Operations

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.

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 man oeuvres and closer route spacing (e.g., for passing other aircraft and maneuvering around weather).

5.3.2 Terminal Areas (Departures and Arrivals)

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.
With RNAV-1 operations as the predominant form of navigation in terminal areas by the end of the mid-term, [**SUDAN**] will have the option of removing conventional terminal procedures that are no longer 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 maneuvres 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.

5.3.3 Approach

In the mid- term, implementation priorities for instrument approaches will still be based on RNP APCH and full implementation is expected before the end of this term.
RNAV 1, A-RNP 1 will be implemented in all TMAs by the end of this term.
The introduction of the application of landing capability, using GLS will be considered during the mid-term at Khartoum new airport so as to enhance reliability and predictability of approaches to runways and this will increase safety, accessibility, and efficiency.

5.3.4 Helicopter operations

NOT YET

5.4 Long term strategy (2023 and beyond)

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

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, [**SUDAN**] and key Stakeholders need an operational concept that exploits the full capability of the aircraft in this time frame.

5.4.1 Long Term Key Strategies (20123 and Beyond)

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.

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.

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 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 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. 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.

5.4.2 Summary of Long Term Key Strategies (2023 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.

5.4.3 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 trades-offs associated with different levels of automation?
- To what extent can conflict detection and resolution be automated for terminal ATC operations?
- How can time of arrival control be applying 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 onboard 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?

References

The below ICAO Documents provide Guidance related to the PBN implementation:

• PANS-ATM (Doc 4444)
• PANS-Ops (Doc 8168)
• PBN Manual (Doc 9613)
• GNSS Manual (Doc 9849)
• RNP AR Procedure Design Manual (Doc 9905)
• CDO Manual (Doc 9931)
• Manual on Use of PBN in Airspace Design (Doc 9992)
• CCO Manual (Doc 9993)
• Procedure QA Manual (Doc 9906)
• PBN Ops Approval Manual (Doc 9997)

Publication

The AIP should clearly indicate the navigation application is PBN. The routes should identify minimum segment altitude requirements. The navigation data published in the State AIP for the routes and supporting navigation aids must meet the requirements of Annex 15 — Aeronautical Information Services. All routes must be based upon WGS-84 coordinates Navigation Specifications and the Approval process

A Navigation Specification found in this Manual does not in itself constitute regulatory guidance material against which either the aircraft or the operator will be assessed and approved. Aircraft are certified by their State of manufacture. Operators are approved in accordance with their National Operating Rules.

The Navigation Specification provides the technical and operational criteria, and does not imply a need for recertification. Therefore, with RNAV 2/ RNAV 1, for example, there is still a need to have an approval process. This could be either through a dedicated approval document or through recognition that existing regional RNAV implementation certification documents (TGL No. 10 and AC 90-100) can be applying with the necessary differences, to satisfy the objectives set out in the PBN Navigation Specification.

Compliance should be determined against each relevant Navigation Specification. Compliance with one Navigation Specification does not automatically imply compliance with another.

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 Syste