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

Aviation System Block Upgrades - ASBUs (Edition March 2013)

http://www.icao.int/sustainability/Pages/ASBU-Framework.aspx
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<th>Block 0</th>
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<tr>
<td><strong>B0-APTA</strong>&lt;br&gt;Optimization of Approach Procedures including vertical guidance&lt;br&gt;This is the first step toward universal implementation of GNSS-based approaches.</td>
<td><strong>B1-APTA</strong>&lt;br&gt;Optimised Airport Accessibility&lt;br&gt;This is the next step in the universal implementation of GNSS-based approaches.</td>
<td><strong>B2-WAKE</strong>&lt;br&gt;Advanced Wake Turbulence Separation (Time-based)&lt;br&gt;The application of time-based aircraft-to-aircraft wake separation minima and changes to the procedures the ANSP uses to apply the wake separation minima.</td>
<td><strong>B3-RSEQ</strong>&lt;br&gt;Integrated AMAN/DMAN/SMAN&lt;br&gt;Fully synchronized network management between departure airport and arrival airports for all aircraft in the air traffic system at any given point in time.</td>
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<td><strong>B0-WAKE</strong>&lt;br&gt;Increased Runway Throughput through Optimized Wake Turbulence Separation&lt;br&gt;Improved throughput on departure and arrival runways through the revision of current ICAO wake vortex separation minima and procedures.</td>
<td><strong>B1-WAKE</strong>&lt;br&gt;Increased Runway Throughput through Dynamic Wake Turbulence Separation&lt;br&gt;Improved throughput on departure and arrival runways through the dynamic management of wake vortex separation minima based on the real-time identification of wake vortex hazards.</td>
<td><strong>B2-SURF</strong>&lt;br&gt;Optimized Surface Routing and Safety Benefits (A-SMGCS Level 3-4 and SVS)&lt;br&gt;Taxi routing and guidance evolving to trajectory based with ground / cockpit monitoring and data link delivery of clearances and information. Cockpit synthetic visualisation systems.</td>
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<td><strong>B0-RSEQ</strong>&lt;br&gt;Improved Traffic Flow through Sequencing (AMAN/DMAN)&lt;br&gt;Time-based metering to sequence departing and arriving flights.</td>
<td><strong>B1-RSEQ</strong>&lt;br&gt;Improved Airport operations through Departure, Surface and Arrival Management&lt;br&gt;Extended arrival metering, integration of surface management with departure sequencing bringing robustness to runways management and increase airport performances and flight efficiency.</td>
<td><strong>B2-SURF</strong>&lt;br&gt;Enhanced Safety and Efficiency of Surface Operations- SURF, SURF IA and Enhanced Vision Systems (EVS)&lt;br&gt;Airport surface surveillance for ANSP and flight crews with safety logic, cockpit moving map displays and visual systems for taxi operations.</td>
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<td><strong>B0-SURF</strong>&lt;br&gt;Safety and Efficiency of Surface Operations (A-SMGCS Level 1-2)&lt;br&gt;Airport surface surveillance for ANSP.</td>
<td><strong>B1-SURF</strong>&lt;br&gt;Enhanced Safety and Efficiency of Surface Operations- SURF, SURF IA and Enhanced Vision Systems (EVS)&lt;br&gt;Airport surface surveillance for ANSP and flight crews with safety logic, cockpit moving map displays and visual systems for taxi operations.</td>
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<td><strong>B0-ACDM</strong>&lt;br&gt;Improved Airport Operations through Airport-CDM&lt;br&gt;Airport operational improvements through the way operational partners at airports work together.</td>
<td><strong>B1-ACDM</strong>&lt;br&gt;Optimized Airport Operations through Airport-CDM&lt;br&gt;Airport operational improvements through the way operational partners at airports work together.</td>
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<td><strong>B1-RATS</strong>&lt;br&gt;Remotely Operated Aerodrome Control&lt;br&gt;Remotely operated Aerodrome Control Tower contingency and remote provision of ATS to aerodromes through visualisation systems and tools.</td>
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### Performance Improvement Area 4: Flight Trajectory-based Operations

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<td><strong>B8-CDO</strong>&lt;br&gt;Improved Flexibility and Efficiency in Descent Profiles (CDO)&lt;br&gt;Deployment of performance-based airspace and arrival procedures that allow the aircraft to fly their optimum aircraft profile taking account of airspace and traffic complexity with continuous descent operations (CDOs)</td>
<td><strong>B1-CDO</strong>&lt;br&gt;Improved Flexibility and Efficiency in Descent Profiles (CDOs) using VNAV&lt;br&gt;Deployment of performance-based airspace and arrival procedures that allow the aircraft to fly their optimum aircraft profile taking account of airspace and traffic complexity with Optimised Profile Descents (OPDs).</td>
<td><strong>B2-CDO</strong>&lt;br&gt;Improved Flexibility and Efficiency in Descent Profiles (CDOs) using VNAV, required speed and time at arrival&lt;br&gt;Deployment of performance based airspace and arrival procedures that optimise the aircraft profile taking account of airspace and traffic complexity including Optimised Profile Descents (OPDs), supported by Trajectory-Based Operations and self-separation.</td>
<td><strong>B3-TBO</strong>&lt;br&gt;Full 4D Trajectory-based Operations&lt;br&gt;Trajectory-based operations deploy an accurate four-dimensional trajectory that is shared among all of the aviation system users at the cores of the system. This provides consistent and up-to-date information system-wide which is integrated into decision support tools facilitating global ATM decision-making.</td>
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- **B8-TBO**<br>Improved Safety and Efficiency through the initial application of Data Link En-Route<br>Implementation of an initial set of data link applications for surveillance and communications in ATC.

- **B8-CCO**<br>Improved Flexibility and Efficiency in Departure Profiles - Continuous Climb Operations (CCO)<br>Deployment of departure procedures that allow the aircraft to fly their optimum aircraft profile taking account of airspace and traffic complexity with continuous climb operations (CCO).

- **B1-RPAS**<br>Initial Integration of Remotely Piloted Aircraft (RPA) Systems into non-segregated airspace<br>Implementation of basic procedures for operating RPA in non-segregated airspace including detect and avoid.

- **B2-RPAS**<br>RPA Integration in Traffic<br>Implements refined operational procedures that cover lost link (including a unique squawk code for lost link) as well as enhanced detect and avoid technology.

- **B3-RPAS**<br>RPA Transparent Management<br>RPA operate on the aerodrome surface and in non-segregated airspace just like any other aircraft.
PBN implementation involves many different stakeholders and processes from airborne equipment to airspace infrastructure development.
PBN sets clear performance requirements for flight operations. PBN involves a major shift from conventional ground-based navigation and procedures to satellite-based navigation and area navigation procedures. PBN is more accurate and allows for shorter more direct routes, as well as more efficient take-offs and landings. This reduces fuel burn, airport and airspace congestion, and aircraft emissions.
PBN:

- Improves Safety
  - Reduces CFIT
  - Consistent predictable flight paths
  - Stabilized approach paths

- Improves Operating Returns
  - Reduces fuel costs
  - Reduces investment in ground based systems
  - Reduces time in flight through more direct routes

- Increases Airspace Capacity
  - More efficient direct routes
  - Reduces airspace conflicts

- Is Environmentally Friendly
PERFORMANCE-BASED NAVIGATION

Benefits in terms of ATC
- Safety culture
- Fewer radio transmissions
- Less chance of readback/hearback errors
- Greater predictability
- Airspace Containment
- Fewer go-arounds
- Less transit occupancy time in airspace
- Changing Roles and Responsibilities
- Best practices involving stakeholders in design
PERFORMANCE-BASED NAVIGATION

PBN Documents:

*advance copies restricted to States on ICAO-net

http://www.icao.int/safety/pbn/Pages/default.aspx
PBN Overview
Area navigation based on performance requirements for aircraft operating along an ATS route, on an instrument approach procedure or in a designated airspace. (ICAO Doc 9613)
PERFORMANCE-BASED NAVIGATION CONCEPT

PBN specifies **SYSTEM PERFORMANCE REQUIREMENT** for aircraft operating on air traffic routes or instrument approach procedures, in a designated airspace.

The performance requirements are defined in term of accuracy, integrity, continuity and availability.

And **ALSO** in term of **FUNCTIONALITIES**
- Display
- ARINC 424 legé
COMPONENTS OF PBN CONCEPT

1. NAVAID INFRASTRUCTURE
2. NAVIGATION SPECIFICATION
3. NAVIGATION APPLICATION

PBN
NAVIGATION APPLICATION

NAVIGATION APPLICATION is the application of a NAVIGATION SPECIFICATION and associated NAVAID INFRASTRUCTURE to ATS routes, instrument approach procedures and/or defined airspace volume in accordance with the Airspace Concept.

Example in Terminal area

Navigation Specification : RNAV1 (1 Nm of accuracy)
Navaid infrastructure: GNSS or DME/DME

Reference : PBN Manual vol I § 1.4
FLIGHT MANAGEMENT SYSTEM

- FMS capabilities are integral part of PBN
- Enables aircraft to fly RNAV or RNP procedures
RNAV stands for Area Navigation

RNAV: Capability to fly any desired flight path, defined by waypoints such as geographic fixes (LAT/LONG) and not necessarily by ground navaids.

RNAV capability is linked to aircraft on-board equipments (RNAV systems).

RNAV is a method of navigation allowing for the definition of more direct routes.
RNAV-SOME CLARIFICATIONS

- The RNAV navigation concept is not new
  - This method of navigation has been in use for many years
  - Most of the aircraft are RNAV capable

- An RNAV route can be flown using different navigation sensors:
  - IRS
  - VOR-DME
  - DME-DME
  - GNSS (GPS)

All Performance Based Navigation (PBN) is based on RNAV
WHY PBN

Conventional Route Following VORs
WHY PBN

PBN Route Using Waypoints
PBN APPROACH - FLEXIBILITY IN DESIGN
NAVI GATION SPECIFICATION

---

**Defined path**

- **a)** PBN: linear lateral performance requirements, e.g. RNP and RNAV specifications
- **b)** non-PBN: angular lateral performance requirements, e.g. APV I and APV II

---

ICAO 9613 figure I-A-1-2
Performance described in terms of accuracy value.

RNAV[x] or RNP[x] where [x] is the accuracy value in nm.

Examples:

Å RNAV 5  = 5nm either side of centerline
Å RNP 1   = 1nm either side of centerline
Å RNP 0.3 = 0.3nm either side of centerline
Two types of navigation specifications exist:

- **RNAV (Without Performance Monitoring and Alerting System)**
- **RNP (With Performance Monitoring and Alerting System)**

The relationship is explained as:

**RNP = RNAV + OPMA** (On-board Performance Monitoring and Alerting)
RNAV and RNP

RNAV 1

RNP 1
Alert to Pilot

1 Nautical Mile 95% of flight time

1 Nautical Mile 95% of flight time

RNP is not different from RNAV: it is more than RNAV

The Key Extra Ingredient:
On-Board Performance Monitoring and Alerting
ROLE OF OPMA

Allows flight crew to determine whether the airborne system meets the navigation performance required.

Relates to lateral and longitudinal performance but not vertical.

Provides greater assurance of lateral track keeping.
RNP is RNAV with the additional requirement of On Board Performance Monitoring and Alerting.
RNP AR stands for Authorization Required (ICAO wording), equivalent to RNP SAAAR (ex-FAA wording)

An RNP AR procedure has one of the following characteristics:

- Reduced RNP values lower than 0.3 in approach (down to 0.1 NM) or lower than 1 NM in missed approach and/or departure;

- Curved flight path after FAF (RF legs);

- Reduced obstacle protections, at 2xRNP, without buffers
PBN REQUIREMENTS: LEVELS OF QUALIFICATION

- **EQUIPMENT LEVEL APPROVAL**
  - NAVIGATOR BOX e.g. GPS of type ABC
  - GPS could be a sensor in multi-sensor system or a self-contained and stand-alone navigator;

- **AIRCRAFT LEVEL APPROVAL**
  - INSTALLATION APPROVAL
  - NAVIGATOR BOX e.g. GPS installed in aircraft
  - Installation approval on aircraft against an EASA AMC or FAA AC which includes an operational context e.g. RNAV 5;

- **OPERATOR LEVEL APPROVAL**
  - NAVIGATOR BOX e.g. GPS installed in aircraft
  - For the aircraft installation to be used by pilot, operational approval needed.
  - Operational Approval is concerned with training, flight crew procedures, quality, database management, etc.
The latest edition of the PBN Manual, ICAO Doc 9613 contains navigation specifications that cover:

- **En-route Oceanic/Remote**: RNAV 10, RNP 4, RNP 2, Advanced RNP
- **En-route Continental**: RNAV 5, RNAV 2, RNAV 1, RNP 2, Advanced RNP, RNP 0.3 (for helicopters only)
- **Terminal Arrivals**: RNAV 5, RNAV 2, RNAV 1, Advanced RNP, RNP 1, and RNP 0.3 (for helicopters only)
- **Terminal Departures**: RNAV 2, RNAV 1, Advanced RNP, RNP 1, and RNP 0.3 (for helicopters only)
- **Approaches**: RNP APCH (LNAV), RNP APCH (LNAV/VNAV), RNP APCH (LPV) and RNP AR APCH

1. Only applies once 50m (40m Cat H) obstacle clearance has been achieved after the start of climb.
2. RNAV 5 is an en-route navigation specification which may be used for the initial part of a STAR outside 30 NM and above MSA.
3. The RNP 1 specification is limited to use on STARs, SIDs, the initial and intermediate segments of instrument approach procedures and the missed approach after the initial climb phase; beyond 30 NM from the airport reference point (ARP), the accuracy value for alerting becomes 2 NM.
4. Advanced RNP also permits a range of scalable RNP lateral navigation accuracies – see the PBN Manual, Vol. II., Part C, Chapter 4, paragraph 4.3.3.3.4.
5. Optional – requires higher continuity.
6. There are two sections to the RNP APCH specification; Part A is enabled by GNSS and Baro VNAV, Part B is enabled by SBAS.
7. RNP 0.3 is applicable to RNP APCH Part A. Different angular performance requirements are applicable to RNP APCH Part B only.
8. The RNP 0.3 specification is primarily intended for helicopter operations.
ICAO State Letter SP 65/4-13/24

Proposes amendments to:
• PANS-OPS, Volume I
• PAN-OPS Volume II
• Annex 4
• Annex 6, Parts I, II and III
• Annex 14, Volume II
• Annex 15
• PANS-ABC

Applicable on 13 November 2014
PBN ï ADVANCED RNP

A-RNP + options

A-RNP

Optional Performance/Functionality
- RNP Scalability
- RNP 2 oceanic/remote
- Fixed Radius Transition (FRT)
- Time of Arrival Control
- Barometric VNAV

RF legs
Parallel offset
RNAV holding

RNAV 5
RNAV 2
RNAV 1

RNP APCH

RNP 1

RNP 2
Final approach: RNP 0.3

RNP 10

RNP 4
PBN ENABLES THE AIRSPACE CONCEPT

Airspace Concept

COM
NAV
SUR
ATM

NAVIGATION APPLICATION

PBN

NAVIGATION SPECIFICATION

NAVAID INFRASTRUCTURE
NAVIGATION SPECIFICATION BY FLIGHT PHASE

OCEANIC / Enroute Remote (nonSUR)
RNAV 10, RNP 4, RNP 2, Advanced RNP 2

RNAV 1/2 & RNP 1 SIDs
ARNP 1 SIDs

RNAV 5/2/1 RNP 2
Advanced RNP 2 or 1 Enroute Continental

RNAV 1/2 & RNP 1 STARs
ARNP 1 STARs

RNP Approach RNP-AR Approach
Performance-based Navigation

Executives

Regulator

ANSP

A/C Operator

Manufacturer
The Assembly:

1. Urges 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 (Doc 9613).
2. Resolves that:
   a) States and planning implementation regional groups (PIRGs) **complete a PBN implementation plan by 2009** to achieve:
      1) Implementation of RNAV and RNP operations (where required) for en route and terminal areas according to established timelines and intermediate milestones; and
      2) Implementation of Approach Procedures with Vertical guidance (APV) (Baro-VNAV and/or augmented GNSS) for all instrument runway ends; either as a primary approach or as a back-up for precision approaches **by 2016** with intermediate milestones as follows: **30 percent by 2010, 70 percent by 2014**; and
   b) ICAO develop a coordinated action plan to assist states in implementation of PBN...
The Assembly:

1. Urges 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 (Doc 9613).

2. Resolves that:
   a) States complete a PBN implementation plan as a matter of urgency to achieve:
      1) Implementation of RNAV and RNP operations (where required) for en route and terminal areas according to established timelines and intermediate milestones;
      2) Implementation of Approach Procedures with Vertical guidance (APV) (Baro-VNAV and/or augmented GNSS), including LNAV (Lateral Navigation) only minima, for all instrument runway ends; either as a primary approach or as a back-up for precision approaches by 2016 with intermediate milestones as follows: 30 percent by 2010, 70 percent by 2014; and
      3) Implementation of straight-in LNAV-only procedures, as an exception to 2) above, for instrument runways at aerodromes where there is no local altimeter setting available and where there are no aircraft suitably equipped for APV operations with a maximum certificated take-off mass of 5 700 kg or more
   b) ICAO develop a coordinated action plan to assist states in implementation of PBN.
ICAO has established five Strategic Objectives for 2014-2016:

1. SAFETY
2. AIR NAVIGATION CAPACITY AND EFFICIENCY
3. SECURITY AND FACILITATION
4. ECONOMIC DEVELOPMENT OF AIR TRANSPORT
5. ENVIRONMENTAL PROTECTION
WORLDWIDE FLIGHT ROUTES
Why is the PBN Implementation Plan or Roadmap needed?

- To implement the regional PBN plans at the State level and address PBN implementation strategy at the national level

- To provide proper guidance and direction to the domestic air navigation service provider(s), airspace operators and users, regulating agency, as well as foreign operators who operate or plan to operate in the State
  - Assist the main stakeholders plan a gradual transition to the RNAV and RNP concepts
  - Assist the stakeholders in planning their investment strategies during the future transition

- *The benefits of PBN only come with implementation*
This PBN Implementation Workshop is intended to assist States/Administrations in enhancing their PBN Implementation Plans and move forward with actual PBN executions.

The Workshop will also provide updated information regarding global PBN activities and how PBN can be an enabler for enhancing ATM operations.

END
Advanced RNP

A-RNP is based upon GNSS

ANSPs should ensure operators relying on GNSS are required to have the means to predict the availability of GNSS fault detection (e.g. ABAS RAIM)

Operator procedures, maintenance, dispatch and other operations processes that satisfy the A-RNP criteria will be considered acceptable for RNAV 1, RNAV 2, RNAV 5, RNP 2, RNP 1 and RNP APCH Part A.

An A-RNP aircraft qualification can be more broadly applicable to multiple navigation specifications without the need for re-examination of aircraft eligibility. This enables an operator’s approved procedures, training, etc to be common to multiple navigation applications.

The RNP system should provide the ability to intercept the final approach at or before the final approach fix. This functional capability must provide the pilot with the ability to rejoin the published final approach track following a period when the aircraft has been flown manually, or in AFCS Heading mode, following ATC vectors to support Final Approach Sequencing.