(ICAO Doc 9992)

Manual On The Use of Performance Based Navigation (PBN) in Airspace Design

Overview

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MANUAL ON THE USE OF PERFORMANCE-BASED NAVIGATION (PBN) IN AIRSPACE DESIGN

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Airspace Concept

Assumption: CNS/ATM/RWY/Traffic/MET

Inter-facility Letters of Agreement
Sector Interaction
Traffic assignment (including regulation)
Special techniques (CCO, CDO, etc.)
Flexible Use of Airspace
Airspace Classification

Airspace Design:
Routes, Volumes, Sectors.
PBN Implementation Processes

- PLAN
- DESIGN
- VALIDATE
- IMPLEMENT
Airspace Concept Activity Overview

**PLAN**

- **Activity 1**: Agree on Operational Requirements
- **Activity 2**: Create Airspace Design Team
- **Activity 3**: Agree on Objectives, Scope, & Timeline
- **Activity 4**: Analyze Reference Scenario
- **Activity 5**: Select Safety Criteria, Safety Policy, & Performance Criteria
- **Activity 6**: Agree on CNS/ATM Assumptions, Enablers, & Constraints

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**DESIGN**

- **Activity 7**: Airspace Routes and Holds
- **Activity 8**: Initial Procedure Design
- **Activity 9**: Airspace Volumes and Sectors
- **Activity 10**: Confirm ICAO Navigation Specification

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**VALIDATE**

- **Activity 11**: Airspace Concept Validation
- **Activity 12**: Finalization of Procedure Design
- **Activity 13**: Procedure Validation

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**IMPLEMENT**

- **Activity 14**: ATC System Integration
- **Activity 15**: Awareness and Training Material
- **Activity 16**: Implementation
- **Activity 17**: Post Implementation Review
Activity 1

1 - Agree on Operational Requirements

- Safety
- Capacity
- Efficiency
- Environment
- Accessibility
**Objectives ➔ Implementation Example**

**Safety**
- Reduce Controlled Flight Into Terrain via lateral & vertical course guidance to runway

**Capacity**
- Increase number of air traffic routes to reduce congestion; accommodate projected growth

**Efficiency**
- Reduce delays that result from excessive “levelling off” flight profiles by implementing CCO/CDO

**Environment**
- Reduce noise over sensitive area

**Access**
- Improve airport and airspace access in all weather conditions

- RNP approach (LNAV/VNAV) to replace circling approach
- Parallel RNAV-2 ATS routes between cities
- RNAV-1 SID that allows continuous climb to enroute
- Use of RF in intermediate or missed approach segment
- RNP approach allowing lower minima
Who develops an Airspace Concept?

- A *team effort* by representatives of various organizations and technical specialties

- Composition of the team depends on the scale and nature of the project
  - A simple airspace concept (e.g. a SID, STAR and IAP) would have experts from
    - ANSP (including PANS OPS procedure designer)
    - civil aviation regulator
    - airport operator
    - operators’ representative
  - A more extensive Airspace Concept (e.g. new runway, plan for terminal and enroute airspace) could also include
    - safety management system experts
    - simulation studies experts
    - additional operator representatives
    - environmental personnel

- **Team lead** - usually an airspace planner or knowledgeable ANSP air traffic manager - *Not a hard and fast rule*. The fundamental requirement is for a knowledgeable, proactive and dedicated individual with a sound understanding of air traffic management and airspace organization.
Activity 2

2 – Create Airspace Design Team

- Lead by ATM/airspace specialist
- ATC (Approach and Area controllers)
- ATM & CNS specialist
- Procedure designers
- Technical pilots

Airspace Design Team expanded on an as needed basis

Airspace Planners,
Procedure Designers,
Air Traffic Controllers (both en-route and terminal),
ATM Operations Manager,
Airline Operators, (Regulator)
Activity 3

3 – Project objectives, scope and timescales

- Objective derived from Ops requirements
- Scope !! (sets the limit of the project)
  - Time
  - Resources
- Timescales
Activity 3

3 – Project objectives

Safety? | Capacity | Efficiency | Environment | Access?

- Improve SID/STAR design to accommodate projected traffic growth
- Provide shorter and more predictable routes to/from Kapitali
- Reduce noise over sensitive areas

Airspace Concept
**Example:**

Although GNSS is associated primarily with navigation, GNSS is also the backbone of ADS-B surveillance applications.

As such, GNSS positioning and track-keeping functions are no longer “confined” to being a navigation enabler to an airspace concept. GNSS, in this case, is also an ATS surveillance enabler.

The same is true of data-link communications: data are used by an ATS surveillance system (for example, in ADS-B and navigation).
What is needed to develop an Airspace Concept?

- **TIME** – to explore the needs of the various stakeholders, reach agreement on goals, identify current ground and airborne equipment limitations, conduct traffic flow analyses, etc.

- **RESOURCES** – Costs may include (but are not limited to):
  - education and training (regulators, operators, ATC, procedure designers, etc),
  - establishment and sustainment of robust airworthiness, operations approvals, data quality techniques,
  - changes to ATC automation, flight validation, possibly new NAVAIDS (DMEs), etc

- **TOOLS** - design and modeling tools to support the design, validation and assessment of the present (“reference scenario”) and planned Airspace Concept.
Activity 3

3 – Project objectives, scope and timescales

$ Implementation Date(s)
$ Phases of Work?

$ Which Human Resources?
$ What about the budget?

Beware of Project Creep!
Activity 3

3 – Project timescales

To find out time available to complete a project – calculate backward from Implementation date
# Example Project Plan

**Activity**

<table>
<thead>
<tr>
<th>Plan</th>
<th>Activity</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Agree on Operational Requirements</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>Create Airspace Design Team</td>
<td>5</td>
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<tr>
<td>3</td>
<td>Agree on Objectives, Scope &amp; Timeline</td>
<td>15</td>
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<tr>
<td>4</td>
<td>Analyze Reference Scenario</td>
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<td>5</td>
<td>Select Safety Criteria, Safety Policy, &amp; Performance Criteria</td>
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<td>6</td>
<td>Agree on CBS/ATM Assumptions</td>
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<tr>
<td>7</td>
<td>Design Airspace Routes and Holds</td>
<td>14</td>
</tr>
<tr>
<td>8</td>
<td>Initial Procedure Design</td>
<td>20</td>
</tr>
<tr>
<td>9</td>
<td>Design Airspace Volumes and Sectors</td>
<td>20</td>
</tr>
<tr>
<td>10</td>
<td>Confirm ICAO Navigation Specification</td>
<td>5</td>
</tr>
<tr>
<td>11</td>
<td>Airspace Concept Validation</td>
<td>20</td>
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<tr>
<td>12</td>
<td>Finalize Procedure Design</td>
<td>22</td>
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<td>13</td>
<td>Procedure Validation</td>
<td>20</td>
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<td>14</td>
<td>ATC System Integration</td>
<td>30</td>
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<td>15</td>
<td>Awareness and Training Material</td>
<td>30</td>
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<td>16</td>
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<tr>
<td>17</td>
<td>Post Implementation Review</td>
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**Total Days Required**: 279
# Example Project Plan

<table>
<thead>
<tr>
<th>Activity</th>
<th>Timeline Number of WorkDays</th>
<th>Parallel Days</th>
<th>Total Work Days</th>
<th>Start Date</th>
<th>Completion Date</th>
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<td><strong>PLAN</strong></td>
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<td>9-Feb-2013</td>
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<td>5</td>
<td>22-Feb-2013</td>
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<td>12</td>
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<td>14-May-2013</td>
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<td>5</td>
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<td>11 Airspace Concept Validation</td>
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<td>22</td>
<td>2-Sep-2013</td>
<td>2-Oct-2013</td>
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<tr>
<td>13 Procedure Validation</td>
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<td>0</td>
<td>20</td>
<td>2-Oct-2013</td>
<td>30-Oct-2013</td>
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<td><strong>IMPLEMENT</strong></td>
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<td>14 ATC System Integration</td>
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<td>16-Oct-2013</td>
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<td>15 Awareness and Training Material</td>
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<td>0</td>
<td>30</td>
<td>28-Nov-2013</td>
<td>9-Jan-2014</td>
</tr>
</tbody>
</table>

**Timeline Days Required:** 239

**Total Workdays:** 279

**End Date:** 9-Jan-2014

*Note: Uses WORKDAY function to exclude weekend and holiday days*
Activity 4

4 – Analysis of the reference scenario

✈ Assessment of present operations
✈ Identification of positive and negative benchmark
✈ Avoids repeats of design flaws
Activity 4

4 – Analysis of the reference scenario

Reference Scenario
- Routes, Airspace, Volume, Sectorisation
- Assumptions, Enablers, Constraints

New Scenario
- Routes, Airspace, Volume, Sectorisation
- Assumptions, Enablers, Constraints

System Performance

Compare

Translate the text to natural language.
Activity 5

5 – Select Safety Criteria, Safety Policy and Performance Criteria

Select Safety Management system

Select Safety Assessment Methodology

What evidence is needed to prove safety of design

Set success criteria
### Activity 6

#### 6 – Agree on ATM/CNS assumptions

<table>
<thead>
<tr>
<th>ATM/CNS ASSUMPTIONS (current and future)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Traffic Analysis</strong></td>
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<tr>
<td>Representative Traffic Sample</td>
</tr>
<tr>
<td>Distribution - Time/Geography</td>
</tr>
<tr>
<td>Cross check adjacent facility traffic</td>
</tr>
<tr>
<td>IFR/VFR mix</td>
</tr>
<tr>
<td>Civil/Military mix</td>
</tr>
<tr>
<td>Acft performance mix (jet/prop/helo)</td>
</tr>
<tr>
<td><strong>Runway in use (primary/secondary)</strong></td>
</tr>
<tr>
<td>Available runways/length</td>
</tr>
<tr>
<td>Meteorological assumptions</td>
</tr>
<tr>
<td>Landing Aids</td>
</tr>
<tr>
<td>Greenfield Site? Orientation choice?</td>
</tr>
<tr>
<td>Runway usage statistics</td>
</tr>
<tr>
<td><strong>ATC System</strong></td>
</tr>
<tr>
<td>Sectors/Personnel/Equipment</td>
</tr>
<tr>
<td>Traffic Sequencing and Management</td>
</tr>
<tr>
<td><strong>Surveillance Means/Coverage</strong></td>
</tr>
<tr>
<td><strong>Communications Means/Coverage</strong></td>
</tr>
</tbody>
</table>
Activity 6

6 – Agree on ATM/CNS assumptions

A = Arrival flow
D = Departure flow

20% 15% 10% 40% 30% 15% 40% 30%
Activity 7

7 – Design the Airspace, Routes and Holds

1st Design Routes

2nd Initial Procedure Design

3rd Define the airspace volumes and sectorise these, if needed

Iterations necessary!
Activity 7

7 – Design the Airspace

✈ Arrivals
✈ Departures
✈ Transit
✈ VFR
✈ Military

AVOID trying to fit the routes into the existing airspace volumes
Activity 8

8 – Initial Procedural Design

↗️ Capability/functionality needed?

↗️ Fleet capability/functionality available?

↗️ Coverage provided by available Navaid infrastructure?

↗️ Design according to ICAO Doc 8168 and Doc 9905
  - Initiation
  - Collect & Validate Data
  - Create Conceptual Design
  - Review by Stakeholders
Activity 9

9- Design Airspace Volumes and Sectors

- Sectorisation
- Airspace volume
- Iterations possible
Activity 10

10 – Confirm ICAO Navigation specification

- Review NAV specs
- Identify appropriate spec
- Go to Validation and Implementation
- If no appropriate spec
  - Apply Trade off
Activity 11

11 – Airspace Concept Validation

- Prove ATM operability & validity
- Assess objectives
- Identify possible weak points
- Provide evidence and proof to support Safety Assessment
CONCEPT VALIDATION

MORE

COST / ACCURACY / TIME / SAMPLES

LESS

Airspace Modelling

Fast Time Simulation

Real Time Simulation

Types of Validation

COST

ACCURACY

TIME

Number of Traffic samples / Test cases

VALIDATE

IATA
Activity 12

12- Finalisation of procedure design

- Design according to ICAO Doc 8168 and Doc 9905
  - Apply Criteria
  - Document and Store
  - Support Safety Assessment

- Output:
  - Draft procedure layouts
  - Calculation outputs
  - Textual description of procedure
Activity 13

13-Procedure validation

- Verification of terrain, obstacle and aeronautical data used to support design
- Validate intended use of procedure (match to conceptual design)
- Validate correct application of criteria
- Validate flyability and human factors (charting)
- Flight Inspection (if required)
Activity 14

14- ATC System Integration

_changes to ATC system interfaces and displays to ensure controllers have the necessary information on aircraft capabilities and the appropriate displays to support the new routings. Such system changes could include modifications to:

- Air Traffic Flight Data Processor (FDP)
- Air Traffic Radar Data Processor (RDP)
- ATC situation display
- ATC support tools
The introduction of PBN can involve considerable investment in terms of training, education and awareness material for both flight crew and controllers.

- Printed training packages
- Computer based training
- NOTAMS
- ICAO provides additional training material and seminars.
Activity 16

16 – Implementation

✓ Have the Safety and Performance Criteria been satisfied;
✓ Have the required changes been made to the ATM system;
✓ Have the required changes been made to the ground navigation systems;
✓ Do the assumptions and conditions upon which the Airspace Concept has been developed still pertain. (are traffic flows as forecast, is the fleet suitably equipped and approved etc);
✓ Are the critical enablers all in place.;
✓ Have the pilots and controllers received appropriate training.
Activity 16

START IMPLEMENTATION and REVIEW PROCESS

Design re-Validation

Design Modification

Review Implementation Criteria (decided during Project Planning)

Pre-Implementation Review

Assumptions still valid
Safety criteria satisfied
Performance criteria satisfied
Resources available

GO / No-Go

Implementation Planning

Performance Metrics
Schedule
Training Complete
Procedures Published
(allow time for AIRAC cycle)
Transition Plan
Coordination Complete
Internal/External
Risk Mitigation
Fallback Procedures
Logistics Support
Set Implementation Date

 IMPLEMENT

Post Implementation Review
Activity 16

- Monitor the implementation process;

- Support the Centre supervisor/Approach Chief or Operational Manager should it become necessary to use redundancy or contingency procedures;

- Provide support and information to operational controllers and pilots;

- Maintain a record of implementation-related difficulties for use in future project planning;
Activity 17

- Post Implementation Review
- Keep LOG
- Assess if objectives are met
- Measure!
- System safety assessment – collect evidence
Lessons Learned

RNAV implementation in some regions over past 15 years has highlighted some issues.

The following slides list a few of those issues.
RNAV 5 implementation en-route airspace

- Selecting the right Nav Spec can be a challenge... sometimes there are more older aircraft than expected.
- Roll out airspace changes over time: avoid multiple airspace changes at the same time as the PBN switch on date.
- ‘Switch on’ PBN in the Terminal Airspace should be matched by ‘switch on’ in continental en route...
RNAV 1 and 2 implementation

- Aircraft populations may not make ‘cleaner’ turns because of PBN ... watch turn angles in design
- Co-ordination with stakeholders is a pre-requisite for success
- The number of SIDs/STARs at some major airports increased significantly which caused problems for operators with limited data base storage space.
- Education needed on RNAV and RNP
THANK YOU