PBN Airspace & Procedures
Design/Database/Charting Aspects

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Topics

- Evolution of Procedure Design Criteria: Role of NavData;
- ARINC 424 Standard: PBNs coding short-considerations;
- RNAV/RNP design/coding/charting overview;
- RNP AR APCH;
- ARINC 424 Transition Identifier Concept;
- Continuous Descent Operations Concept (CDO);
- Future Navigation: GBAS;
Evolution of Procedure Design criteria

**Ground-Navaid, Complicated, Rigid paths, Non-standard, Manually flow:**
Analogue World

**Satellite, Simple, Flexible paths, Standard shape, database-driven:**
Digital World
ARINC 424
Procedure Coding Process

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[Map and diagrams related to ARINC 424 procedure]
ARINC 424
Worldwide Standard

- September 1973: First ARINC 424 Meeting
- July 1975: First “Gray Cover” published
- July 1976: ARINC 424-1
- ARINC 424-3: First "Air Mass" Application
- ARINC 424-4: Added Simulator Capability
- ARINC 424-5: Added Computer FPL
- ARINC 424-16: Added Path Point Record
- ARINC 424-17: Adopted April 30, 2004
- ARINC 424-18: Ready for Adoption consideration Dec 2004
- ARINC 424-19: Published Dec 19, 2008
- ARINC 424-20: Published Dec 5, 2011
Database Structure: Hierarchy Concept

ARINC Area

Country

En-route Comm

En-route

Airways

En-route Waypoints

En-route Holdings

Terminal

Controlled Airspace

Restrictive Airspace

ILS DME

Markers

SIDs / STARs / Approaches

Terminal Waypoints

Terminal NDBs

Terminal Holdings

Gates

MSA

Communications
ARINC 424 type of records

- Primary Record
- Continuation Record
- Simulation Continuation Record
- Flight Planning Continuation Record
- Jeppesen Supplemental Record

Length 132 characters
ARINC Files can be composed of the ‘Standard’ records or ‘Standard’ and ‘Tailored’ records (list below not complete).

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</table>
‘Path/ Terminator’ Concept (23) permits coding of Terminal Procedures (no en-route segments) and includes a two-character codes and data associated.

1. **Path** – logically describes how the aircraft gets thru air to the Terminator (track, course, heading);

2. **Terminator** – is the event or condition (fix, altitude, distance, manual) that causes the system to switch to the next leg;

- Twelve (12) P/T acceptable for RNAV procedure design

- Smaller sub-set of four (4) used for RNP AR applications i.e. IF, TF, RF and HM

**Note:** P/T leg behavior heavily dependent on the specific FMS implementation!
RF leg (Constant Radius Arc)

- When procedure type designed with RF leg capability as a design criteria;

- Does NOT require a ground navaid as the arc origin, but centre fix required.

- Single RF turn limited to turns between 2° and 358°.
RNAV Path & Terminator (short-considerations)

TF leg (Track to Fix)

- Preferred leg for RNAV (GNSS) approaches;
- Easiest to implement, database requirements are minimal;
RNAV Path & Terminator (short-considerations)

**DF leg (Direct to Fix)**
- Its construction is essentially similar to the TF leg;
- Over-fly flag required for CF/DF, DF/DF and TF/DF combination;

**XA legs (Fix/Heading/Course to Altitude)**
- Altitude Termination is always ‘AT or ABOVE’;
- Terminator is still at an undefined position as dependent of acft performance;
RNAV Path & Terminator
(short-considerations)

HM leg (Manual Termination)

Requires pilot’s manual intervention:
‘Go to ABC and hold, don’t know how long your going to hold’

Remark: HM leg is holding, not reversal!

[Map and chart with flight path and waypoints]
Fly-by and Fly-Over

- Fly-By = Turn prior to fix, Fly-over = Initiate turn after the fix;

- Standard FMS behavior is to anticipate the turn and FB turn are key characteristic of an PBN flight path;

**Design/Coding basic rules:**

- All approach procedure fixes should be designed as Fly-By
- MAPt shall be defined as Fly-Over waypoint
- Fixes on straight lines are fly-by fixes
Turn Direction/ Turn Direction Valid

ARINC 424 Rules:

✓ **TD** must always be indicated whenever a turn of 90° or more exists between two consecutive legs; the indication is carried on the leg being turned to;

✓ **TD** is always required when RF leg is coded;

✓ **TD** and **TDV** are used in combination to force a particular turn direction whenever the track/heading change exceeds 135°;
Altitude at Missed Approach Point (MAP) is a computed value based on the following ‘design MAPt’ possible locations:

- Published MAPt prior to the runway threshold, fix altitude must be an ‘at’ altitude equal to the computed altitude at the MAPt.

- Published MAPt at the runway threshold, fix altitude must be an ‘at’ altitude equal to the runway threshold plus the published TCH (default 50ft).

- Published MAPt beyond the runway threshold, lateral coding must insert an LTP or FEP; altitude must be an ‘at’ altitude equal to the runway threshold plus the published TCH (default 50ft).

All RNAV approach procedure MAP must be **at or prior to** a runway threshold. MDA and DA are NOT part of the approach coding solution!
## Approach Coding Structure

### Fixes associated with approach coding

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* FACF (ARINC) = IF (PANS-OPS)

**Final Approach Transition:** As a minimum, the coding of final segment must include a fix for the FAF and MAP. A third fix called FACF has to be always included when ‘design’ IF is published.
Approach Coding Structure

Description: a) Approach Transition (Route Type ‘A’);
b) Final Approach Transition (Route Type ‘R’ = APV, ‘H’ = RNP AR, ‘J’ = GLS)
c) Missed Approach Transition (Route Type ‘Z’);
ARINC 424 Transitions Concept

- SID Runway Transitions Route type 1
- SID Common Body Route type 2
- En-route Transitions Route type 3
- En-route Transitions Route type 1
- STAR Common Body Route type 2
- STAR Runway Transitions Route type 2
- Approach Transitions Route type ‘A’
- Approach Common Body Route type varies
- Missed Approach Route type ‘Z’
- RNAV Route type ‘A’
- RNAV Route type varies
RNP AR APCH operations are classified as approach procedures with vertical guidance (APVs). This type of operation requires a vertical navigation (VNAV) guidance system for the final (Baro-VNAV).

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| GNSS   | Doc. 9905 ‘RNP AR PD Manual’ (No SDFs!) | Special Authorization Required  
Accuracy published (RNP 0.x) | RF leg  
and/or  
RNP ≤ 0.3 (final)  
and/or  
RNP ≤ 1 (missed approach) | RNP 0.x value |
Coding of speed restrictions

- Speed/Altitude restrictions applied at the waypoint: general situation like ‘Below FL100/IAS 250KT’ has no procedure coding solution;

- Speed limitation depicted ‘somewhere’ during a turn shall be associated with a waypoint.
Altitude constraints have to be clearly associated to a fix; no appropriate coding solution for minimum segment altitude or MEA's.

‘Expect’, “Tactical” or “Recommended” not appropriately code-able;
Multiple Indicator i.e. suffix letter used when:

1. Two or more aids of same type support different approaches to same runway;

2. Two or more MA’s are associated with a common approach;

3. Different approaches of same type provided for different aircraft Category (e.g. A/B and C/D)

Database Identifier:

The procedure designer should take some factors into considerations to ensure an unambiguous translation of the design intention into NavData.

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PBN Procedures to be validated should be contained in the suitable navigation system i.e. FMS. The procedure may be on a “pre-production” tailored NavData DB:

1. Custom navigation database (preferred method) – most desirable because it will contain a normal operational DB & new official source coded procedures;

2. Electronic media – some PD tools output ARINC 424 coding of the final designed procedure that can be input (CRC driven) to commercial FMS;

3. Entered manually – method should be used sparingly and limited to LNAV procedures only. As soon as available, coded procedure provided by an official DB supplier should be used to confirm appropriate coding prior to public use
Continuous Descent Operations
(ICAO Doc. 9931)

There are two methods for the design of CDO i.e. ‘closed path’ & ‘open path’ designs.

Closed path: is whereby the lateral flight track is predefined up to and including FAF/FAP i.e. STAR is terminating at a point that defines a part of an Instrument Approach Procedure (IAP).

Closed path permits very precise distance planning allowing FMS to automate optimized descents.
Continuous Descent Operations

Sample ‘Closed Path’

Database Coding: TF legs & fly-by waypoints; RF leg is encouraged (where fleet capable)
Continuous Descent Operations

**Open Path:** where the procedures finishes before FAF/FAP.

There are two main options for Open path design:

1. **Open CDO to downwind** i.e. combination of fixed route with vectoring segment.

2. **Vectored CDO** i.e. aircraft is entirely vectored and the pilot is given an estimate of distance to go to runway. Descent is at pilot discretion.
Continuous Descent Operations

Sample ‘Open to Downwind’ STAR

‘Trombone’ concept i.e. more DTWs (Istanbul Apt). Coded as common transition to BA881 and VM leg to Apt as Waypoint ID field.
Continuous Descent Operations

Sample ‘Open Vectored’ STARs

Database Coding: After Termination WPT an FM leg should be coded; if ATC requires a defined path, VM leg can be used instead.
Continuous Descent Operations

‘Point Merge’ Sequencing Method

With this technique, aircraft follow an RNAV routing including a level arc segment until receiving a ‘Direct To’ vector to a Merge Point:
GBAS has the potential to support precision approach ops down to Categories II and III and some surface movement operations (future Precision GBAS Landing System).

Landing aircraft receive signals directly from GPS satellites as well as from VDB with the avionics inserting the correction factor.

Position accuracy better than 1m horizontal/vertical directions.
GBAS key benefits include:

- Selectable glide path angles with displaced thresholds;
- Guidance for missed approach;
- The ability to provide approaches to nearby airports that are within the range of the VDB radio signals:
  
  - According to ICAO, a single GBAS ground installation may provide guidance for up to 48 precision approaches serving several runway ends or multiple approaches with different parameters to the same runway end.
  - GBAS removes the restriction that taxiing a/c remain farther from runway to avoid possible interference with ILS components;
GBAS International Efforts

Rio De Janeiro, Brazil

Agana, Guam

Malaga, Spain

Sydney, Australia

Frankfurt, Germany