Development and Validation of Procedures

Overview

From Procedure design to Database -The steps needed to ensure RNAV/RNP systems follow the procedure correctly

Learning Objectives

- The translation of procedure from origination into a data base
- Taking account of RNAV/RNP limitations if the procedure is to be followed correctly
- The validation of procedures

Note: The term RNAV is used throughout to mean both RNAV and RNP Systems

RNAV Procedure Description

- Instrument Flight Procedures
  - Published in AIP
  - Defined as textual descriptions supported by charts
  - The charts are used by the pilots and ATC
  - Database providers require clear and unambiguous procedure descriptions and use the charts to validate/check

Coding the Procedure

Procedure coding

- Translates textual description of route or a terminal procedure into a format useable in RNAV systems.

Two steps:

- Translation from AIP text/chart into ARINC 424 alphanumeric code
- Translation from ARINC 424 into avionic specific binary code (known as 'packing')

Successful translation into ARINC 424 depends upon a clear and unambiguous description of the route/procedure.

ARINC 424

- Industry standard for the transmission of data
- Navigation element uniquely defined and stored
- Can be accessed for any intended navigation purpose
- Developed to allow RNAV to be used on conventional procedures
- ICAO PANS-OPS references ARINC 424 rules and methodologies

Note: ARINC 424 not developed for design of flight procedures,

BUT: understanding of ARINC 424 enables procedure designers to perform their tasks so that misinterpretations and errors are significantly reduced

ARINC 424 Records

VHF Navaids
NDB Navaids
Waypoints
Holding
Airports
SID/STAR/APP
Localiser and Glide Slope/MLS/GLS
Company Route
Localiser Marker
Path Points
Airport Communications
MSA
Airways Marker
Cruising Tables
FIR/UIR
GRID MORA
En-route Airways
En-route Airways Restrictive
En-route Communications
Preferred Routes
Controlled Airspace

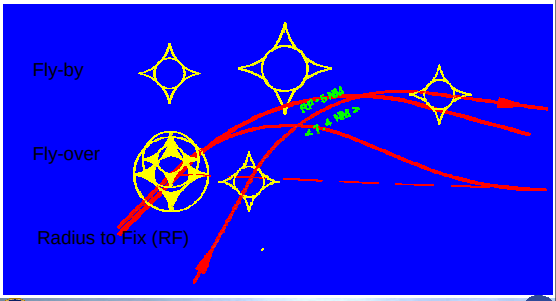
En-Route Coding

- Individual airway legs defined by waypoint and altitude constraints
- En-route holds not associated with any aerodrome and identified as ‘ENRT’

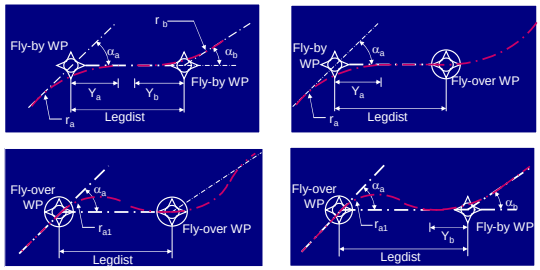
Terminal Coding

- Procedure identified as SID, STAR or APCH
- Only one STAR allowed per route
- ENRT Transitions used to link STARs to APCHs.
- RWY Transitions used to link RWYs to SIDs
- Individual legs defined by heading, waypoint, waypoint transition, path terminator, speed constraint, altitude constraint as appropriate

Waypoint Transitions



Track Distances Between Turns



RNAV – Path Terminator Leg Type

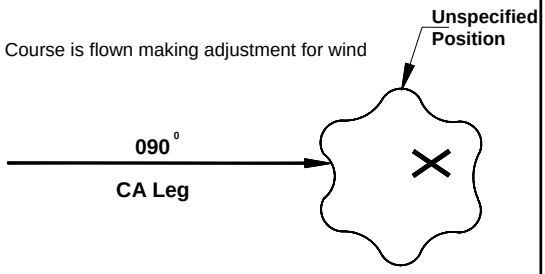
Path		Terminator	
Constant DME arc	A	A	Altitude
Course to	C	C	Distance
Direct Track	D	D	DME distance
Course from a fix to	F	F	Fix
Holding pattern	H	I	Next leg
Initial	I	M	Manual termination
Constant radius	R	R	Radial termination
Track between	T		
Heading to	V		

Path Terminators
14 RNAV Types

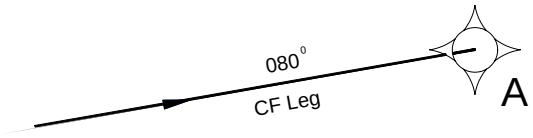
- **Course to an Altitude** - **CA**
- **Course to a Fix** - **CF**
- **Direct to a Fix** - **DF**
- **Fix to an Altitude** - **FA**
- **Fix to a Manual Termination** - **FM**
- **Racetrack Course Reversal (Alt Term)** - **HA**
- **Racetrack (Single Circuit - Fix Term)** - **HF**
- **Racetrack (Manual Termination)** - **HM**
- **Initial Fix** - **IF**
- **Track to a Fix** - **TF**
- **Constant Radius Arc** - **RF**
- **Heading to an Altitude** - **VA**
- **Heading to an Intercept** - **VI**
- **Heading to a Manual Termination** - **VM**

Course to an Altitude

Course is flown making adjustment for wind

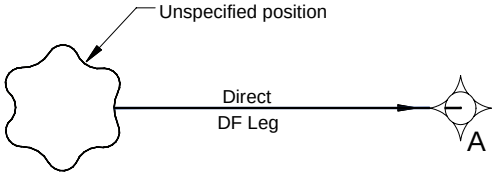


Course to Fix



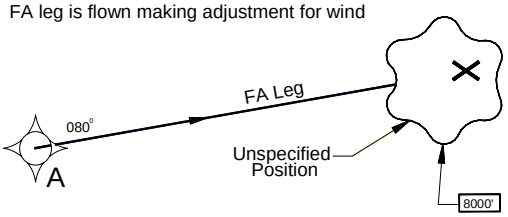
Course is flown making adjustment for wind

Direct to Fix



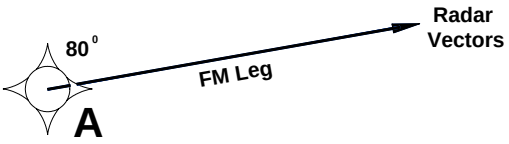
Fix to Altitude

FA leg is flown making adjustment for wind



From a Fix to a Manual Termination

FM leg is flown making adjustment for wind

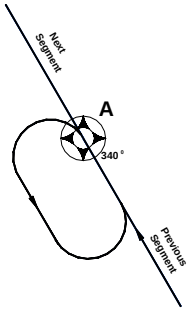


Racetrack

HA - Terminates at an altitude

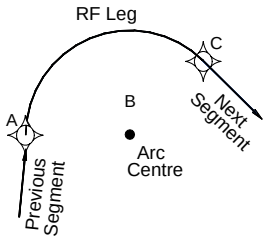
HF - Terminates at the fix after one orbit

HM - Manually terminated

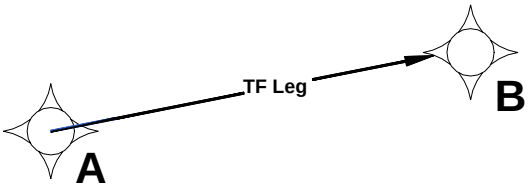


Initial Fix

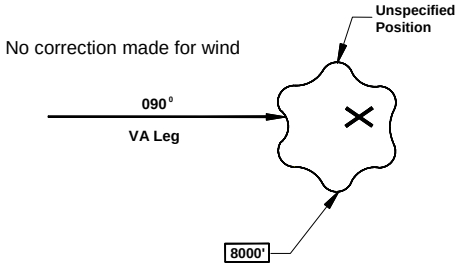
Radius to Fix



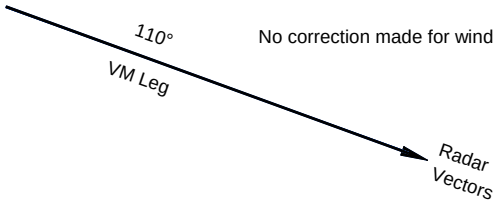
Track to a Fix



Heading to an Altitude



Heading to Manual Termination



Use Of Path Terminators

- Available Path Terminators are defined in PBN Manual Nav Specifications
  - If the RNAV system does not have leg type demanded by procedure, the data packers have to select one (or combination of) available leg types to give best approximation
  - Risk incorrect execution!

Aircraft Types you cater for

Local fast regionals

Occasional older visitors
– lack of functionality

Heavy slow long-hauls

RNAV Procedure Description

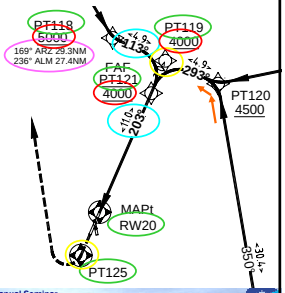
- RNAV procedures defined by:
  - Sequence of waypoints
    - Identifier
    - Co-ordinates
    - Fly-over/fly-by/fixed radius
  - Path Terminators - ARINC 424
  - Altitude restrictions
  - Speed restrictions
  - Direction of turn
  - Required navaid

What Pilots Need to Know

- Waypoint names and sequence
- Fly-over/fly-by/fixed radius
- Turn direction
- Speed restrictions
- Altitude restrictions
- Required navaid
- Leg distance and magnetic track for error checks
- Fixes at certain waypoints for gross error checks

Procedure Description for Pilots

Waypoint sequence
Fly-over/fly-by/fixed radius
Speed/Altitude Restrictions
Leg distance & magnetic track
Fix information
Turn direction



Speed and Altitude Constraints

- Speed constraints allow tighter turns and can assist airspace design and operation
- Altitude constraints can provide separation from obstacles and other traffic - minimum climb gradients must still be published

Procedure Description for Database Providers

- Textual description provide formal statement of procedure
  - Often open to interpretation
- RNAV procedures require more specific details including path terminators
  - Can result in lengthy descriptions
  - Alternative descriptive methods have been developed by IFPP (OCP) and adopted by ICAO
    - Tabular layout
    - Formalised textual description
    - Formalised short-hand description

Tabular Description

RNAV Approach

Path Terminator	Waypoint Name	Fly Over	Course/Track/ Heading °M (°T)	Turn Direction	Altitude Constraint	Speed Constraint	Required Navaid	Bearing/ Range to Navaid	VPA/ TCH
IF	SUSER	-	-	-	+5000	250	-	LOM 262/29	-
TF	CV023	-	-	-	4000	-	-	-	-
CF	CV024	-	348° (347.8°)	-	2680	150	OKE	-	-
TF	RW35L	Y	-	-	370	-	-	-	-3°/50
FA	RW35L	-	348° (347.8°)	L	770	-	OKE	-	-
DF	SUSER	Y	-	-	5000	-	-	-	-

RNAV SID

Path Terminator	Waypoint Name	Fly Over	Course/Track/ Heading °M (°T)	Turn Direction	Altitude Constraint	Speed Constraint	Required Navaid	Bearing/ Range to Navaid	Vertical Path Angle
FA	RW20	-	201° (203.3°)	R	400	-	-	-	-
DF	FOKSI	-	-	-	-	250	-	-	-
TF	PF213	Y	345° (346.8°)	-	+5000	250	-	OKE 330/30	-

Formalised Description

Climb on track 047° M, at or above 800ft, turn right	[A800+; M047; R]-	FA
Direct to ARDAG at 3000ft	→ARDAG[A3000]-	DF
To PF035 at or below 5000ft, turn left	-PF035[A5000-;L]-	TF (Fly-over)
To OTR on course 090°M at 210kts	-OTR[M090; K210]-	CF
From STO at or above FL100, turn	STO[F100+; L]-	TF (Fly-over)
left direct to WW039 at or above	→WW039[F070+]-	DF
FL070, to WW038 at 5000ft	WW038[A5000]	TF

Waypoint Identification

- Significant points
  - Identified by co-located navaid or by unique five-letter pronounceable “name-code” (5LNC)
- Some waypoints in the terminal area used for vectoring for sequencing and must be easy to enter in an RNAV system
  - 5LNCs not appropriate for this
  - Proceed direct ALECS (or ALEKX, ALECS, ALECX, ALLEX, ALIKS, ALIKX, ALICX, ALLIX, ALYKS, ALYKX, ALYCS, ALYCX, ALLYX)
- Concept of strategic and tactical waypoints

Charting Altitude Restrictions

An altitude window :	FL220 10,000
An “at or above” altitude:	7000
A “hard” altitude :	3000
An “at or below” altitude :	5000

Where Are We?

Having designed an RNAV procedure to meet operational requirements we have:

- Considered the need to translate to a Nav DB
- Reviewed the ARINC 424 leg types
- Introduced means for describing the procedure in an unambiguous manner

Now:

- How to ensure that the procedure is correct and will be flown correctly

Validation Activities

- Ground Validation
  - Obstacle clearance
  - Charting
  - Coding
  - Flyability
- Flight Validation
  - Obstacle verification (optional)
  - Flyability (workload, charting, manoeuvring)
  - Infrastructure
- Database Validation

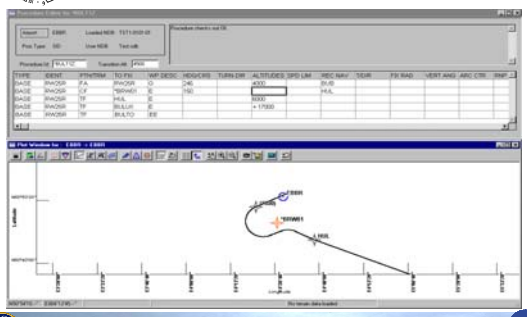
Ground Validation

- Obstacle clearance
  - Independent review by procedure designer
- Charting
  - Independent review

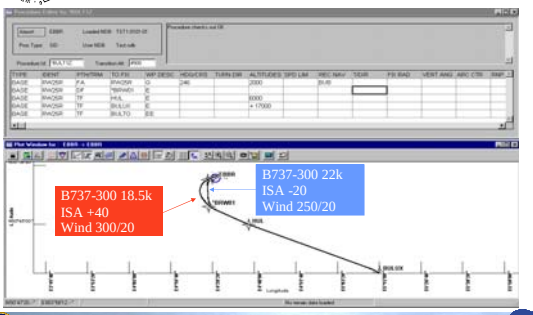
Independent review – can be part of same organisation

- Coding
  - Software tool (e.g. Smiths PDT) or
  - Expert review
- Flyability – software tools (from PC-based to full flight simulator)
  - Not necessarily an issue with standard procedures (e.g. 'T' approaches), but critical for some aircraft types
  - Range of aircraft and meteo conditions

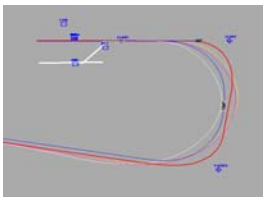
Validate the Procedure Flyabilty



Validate Again with Different Conditions



Different Aircraft and Different Conditions



CA 500ft agl; DF LL001; TF FARKS; TF…

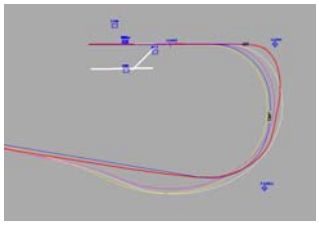
No wind

B737/400

B747/400

A340/300

Wind Effect



CA 500ft agl; DF LL001; TF FARKS; TF…

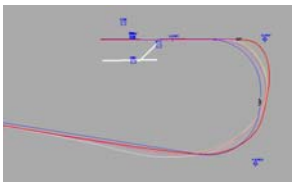
ICAO wind from 045°

B737/400

B747/400

A340/300

Countered by Speed Restriction



CA 500ft agl; DF LL001; TF FARKS [210kts]; TF…

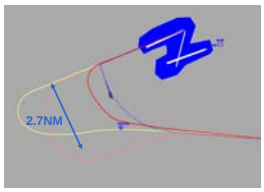
ICAO wind from 045°

B737/400

B747/400

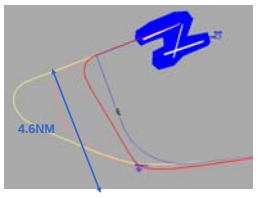
A340/300

Leg Length Too Short



CA 2000ft agl; DF
BRW02
No wind
ATR42
B 747-400
A340-300

Leg Length Acceptable



CA 2000ft agl; DF
BRW02
No wind
ATR42
B 747-400
A340-300

Flight Validation

- Obstacle verification
  - Necessary where full obstacle survey cannot be assured
- Flyability
  - Detailed workload and charting assessments, but
  - High level qualitative assessment of manoeuvring only (rely mainly on Ground Validation)
- Infrastructure assessment
  - Runway markings, lighting, communications, navigation etc

Flight Inspection

- Flight Inspection addresses:
  - **Navaid performance** for DME/DME RNAV
  - **Unintentional interference** for GNSS

DME Tasks

- Need to confirm valid DME pairs
  - Expected coverage and field strength
    - ➢If gaps are present, need to know exact area
  - Range accuracy within Annex 10
- Need to identify DME's that degrade the navigation solution
  - Propagation distortions
    - ➢ Either effect can be removed (small local reflector) or
    - ➢ Pilot needs to deselect

RNAV DME Flight Inspection Planning

Infrastructure Assessment preparation to make inspection efficient

Identify:

- Candidate DME pairs and associated coverage
  - ➢Including expected gaps in coverage, if any
- Candidates for exclusion:
  - ➢Propagation path near horizon or significant terrain
  - ➢Second DME on same channel within line of sight
  - ➢ILS/DME facilities (offset bias?)
- Minimum/maximum height profile for Nav aid coverage validation

PANS-OPS, ATC Operations, Engineering and Flight Inspection Organization jointly plan inspection flight

Database Validation

- RNAV procedures coded using ARINC 424 path terminators to define specific nominal tracks
- Coded procedures not available in operational databases until effective date
  - Recommend implementation date 3 to 10 days after effective date
- Test databases may be provided for flight validation
- Flight does not validate integrity of procedure subsequently coded in operational database
- State must find other means of validating the operational database

Data Origination

ICAO Documents
Annex 15 SARPS
Doc 8071 *Flight Inspection Manual*

EUROCONTROL Guidance Material
Integrity of Aeronautical Information
- Aeronautical Data Origination
AFN/NAV/DAT/ORG/DOC001-150404
Survey and procedure Design Requirements
Navigation Infrastructure assessment Document

FAA Guidance Material
- FAA Specification 405 *Standards for Aeronautical Surveys and Related Products*
- FAA Order 8260.19 *Flight Procedures and Airspace*

Requirements Addressed in Documents

- Survey –WGS84
- Training for designers
- Software Tool Qualification
- Data management
- Quality Assurance
- Verification of Procedure Designs
- Publication
- Validation tests
  - Flyability – under range of wind conditions for appropriate aircraft types
  - Navigation aid coverage

Summary

- Waypoint transitions
- ARINC 424 Path terminators
- Procedure Coding
- Charting Issues
- Validation:
  - Flyability
  - Flight Inspection

Audience Response System Questions