What is Area Navigation?

Module 1

European Airspace Concept Workshops for PBN Implementation

Objectives

By the end of this presentation you will be:

- Aware of the evolution of navigation systems
- Understand the concept of area navigation
- Identify the main components required to perform area navigation

Navigation - The Beginning

IFR

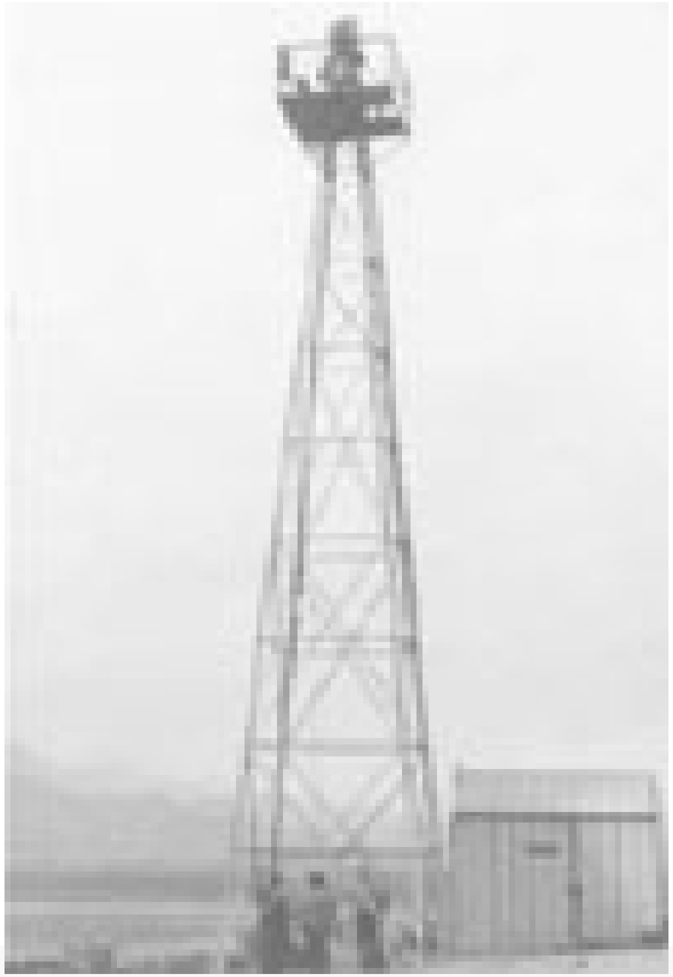
- I Follow Roads!

- And Rivers
- And Railroads
- And Buildings
- And Telephone Lines
- And Whatever Else I Can See

The Early Days

Night and Weather!

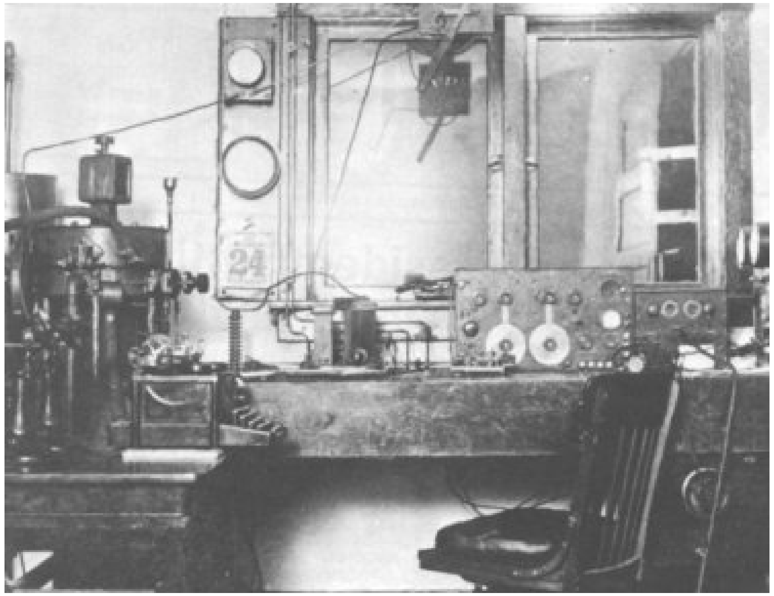
- 1910s
  - First Bonfires and Beacons
- Early 1920s
  - Lighted airport boundaries
  - Spot-lit windsocks
  - Rotating lighted beacons on towers
  - Lighted Airways
    - 1923 Dayton to Columbus, Ohio (USA) – 72 km



Late 1920s - 1930s

Radio!

- Radio for Two-Way Communications
  - Weather Updates
  - Request Help With Navigation
- Radio for Navigation
  - Radio Marker Beacons
  - 4-Course Radio Range System
- Pilots Listen for Navigation Signals



1930s - 1940s

VOR!

- Static-Free VHF Omni-directional Radio Range
  - Pilots Navigate by Instrument
- VOR (with improvements) becomes a primary NAVAID for decades
  - Defines Routes
  - Supports Approach Procedures

VOR
Has Done a Great Job
For Decades

1940s - 1950s

ILS!

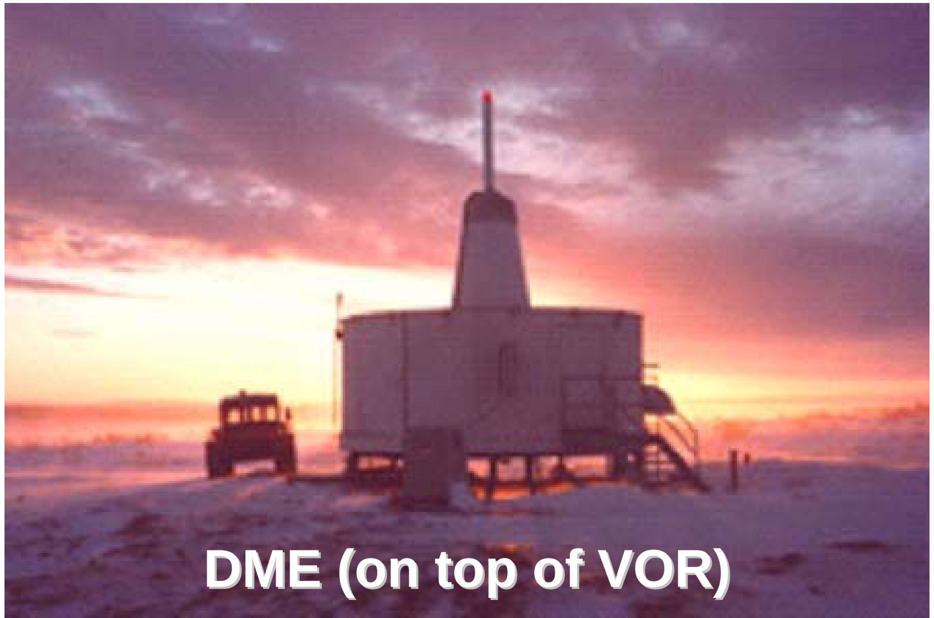
- 1929: First system tested
- 1946: (Provisional) ICAO selects ILS as primary landing air for international “trunk” airports
- Today ILS :
  - CAT I,
  - CAT II,
  - CAT III

ILS
Still Does a Great Job!

From 1950s

DME!

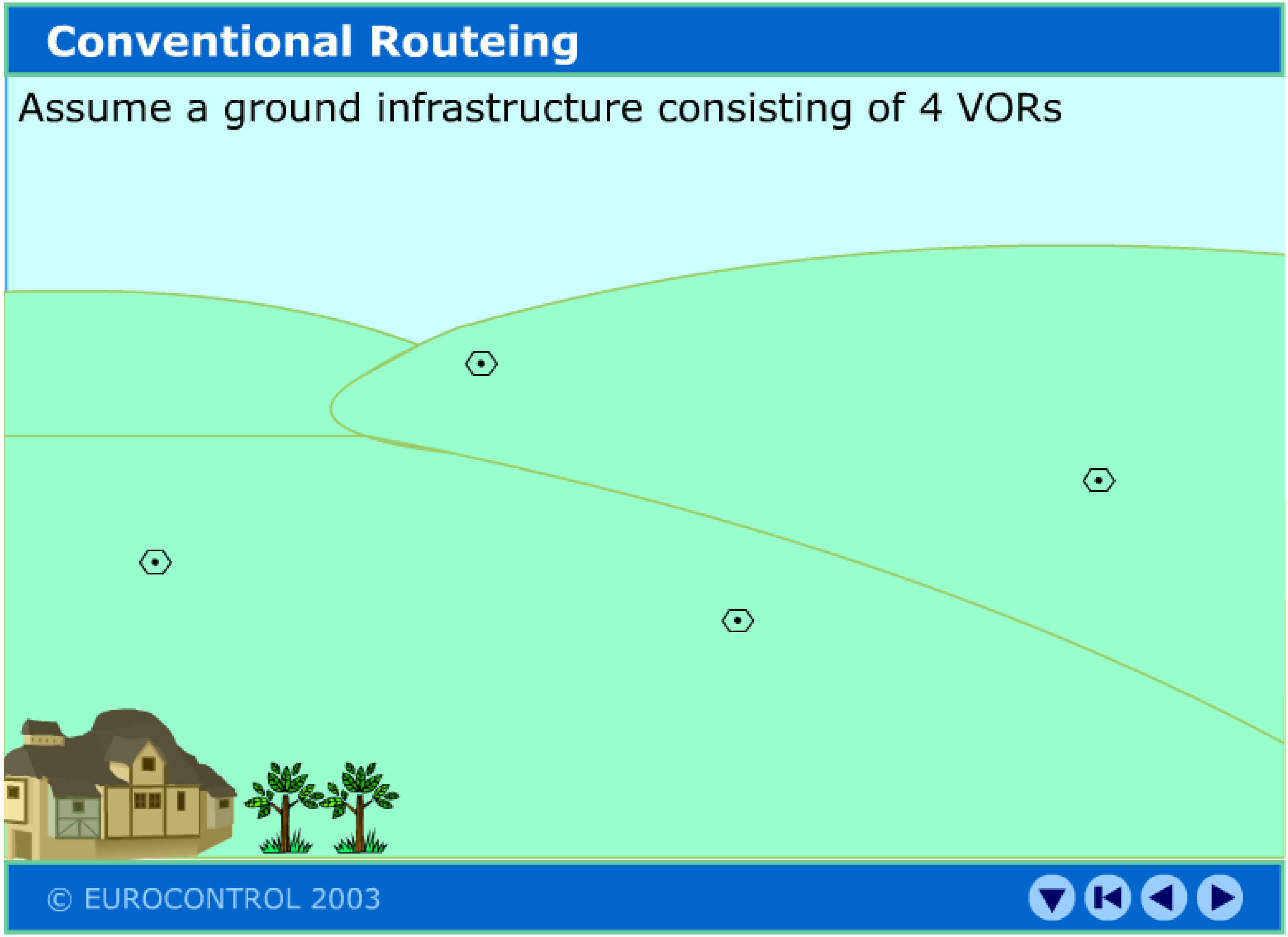
- 1961: first regular civil use (pilot tuned)
- In PBN, DME use is based on automatic tuning



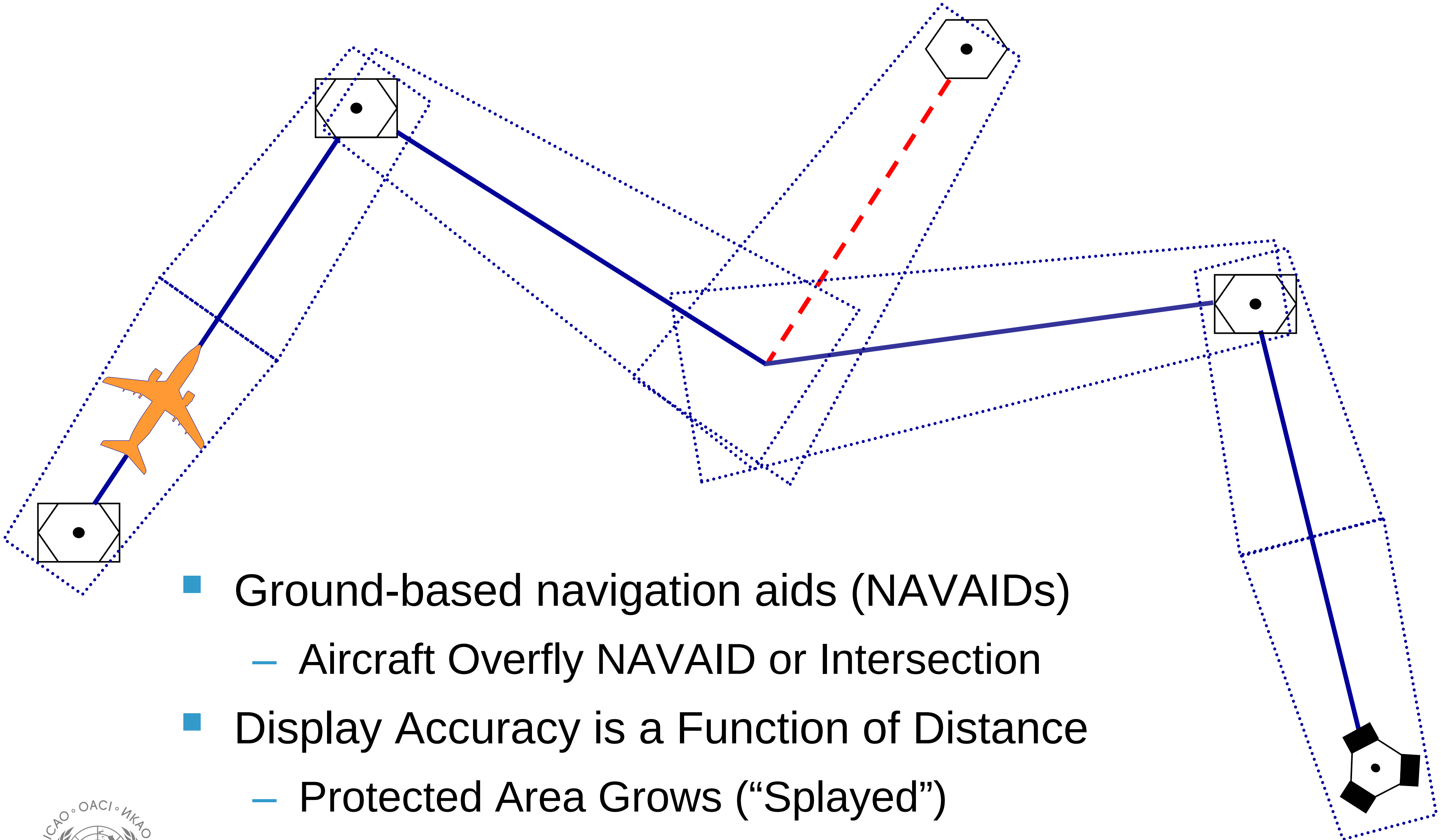
DME is incorporated into PBN

The 1970's Cockpit

Conventional Navigation



Conventional Navigation



- Ground-based navigation aids (NAVAIDs)
  - Aircraft Overfly NAVAID or Intersection
- Display Accuracy is a Function of Distance
  - Protected Area Grows (“Splayed”)

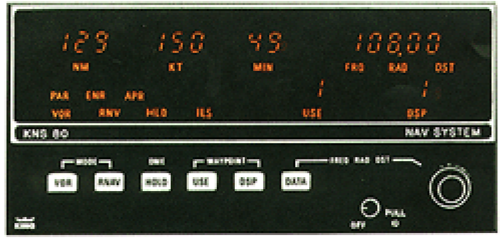
= Limited Design Flexibility

First Generation Digital Avionics

- Appeared in early 1970s
  - Basic ‘cruise control’
  - Capable of storing 4 manually inserted ‘waypoints’
  - Provided guidance on Course Deviation Indicator (CDI)
  - Flew to waypoint before switching to next leg
- Conventional ATS Routes:
  - Defined by NAVAIDs
  - NAVAID coordinates loaded into computer
  - Automatic route guidance provided from computer

Evolution to Area Navigation

- Long Range Navigation (LORAN)**
- Omega Radio Navigation System*
- Inertial Navigation
- VOR/VOR and VOR/DME
- Multi-sensor Flight Management System (FMS)
- GPS, GLONASS, and Augmentations



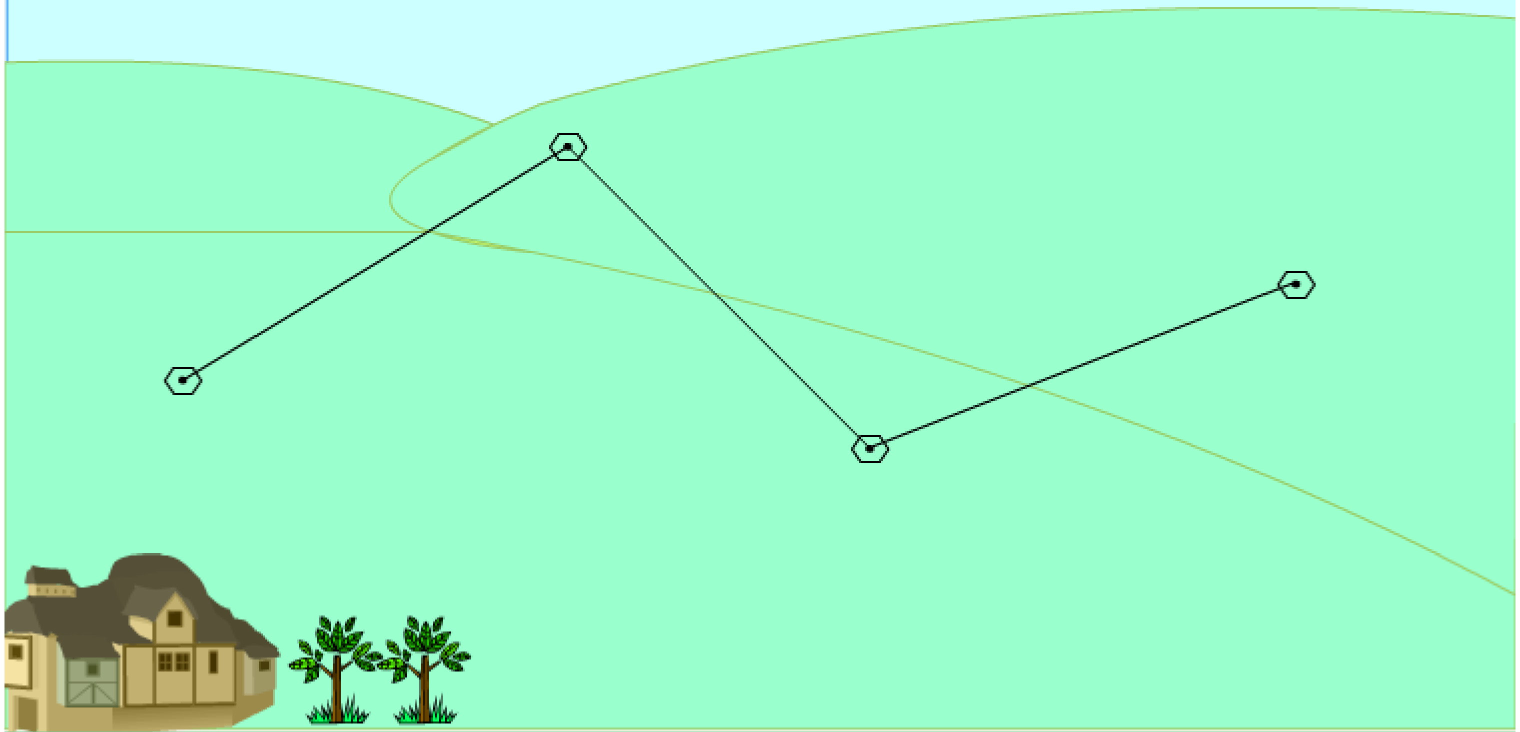
* Terminated in 1997

** US system terminated in 2010

What is Area Navigation?

RNAV Routeing

This section will describe how different navigation aids are used in a RNAV environment to provide a more flexible routing.



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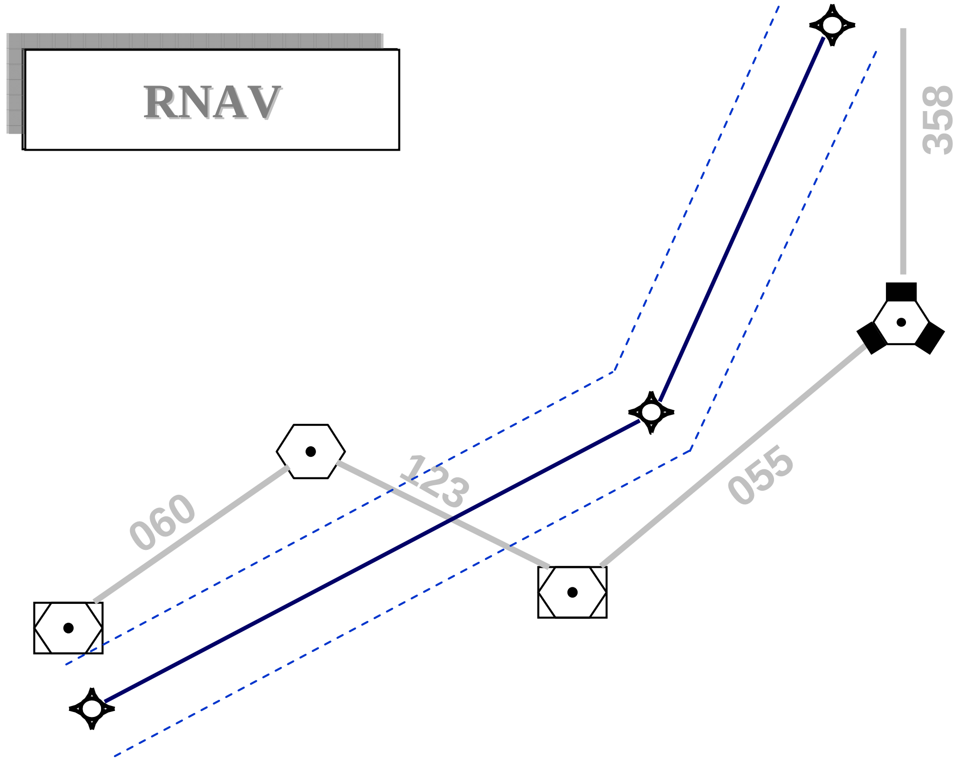
Definition of Area Navigation

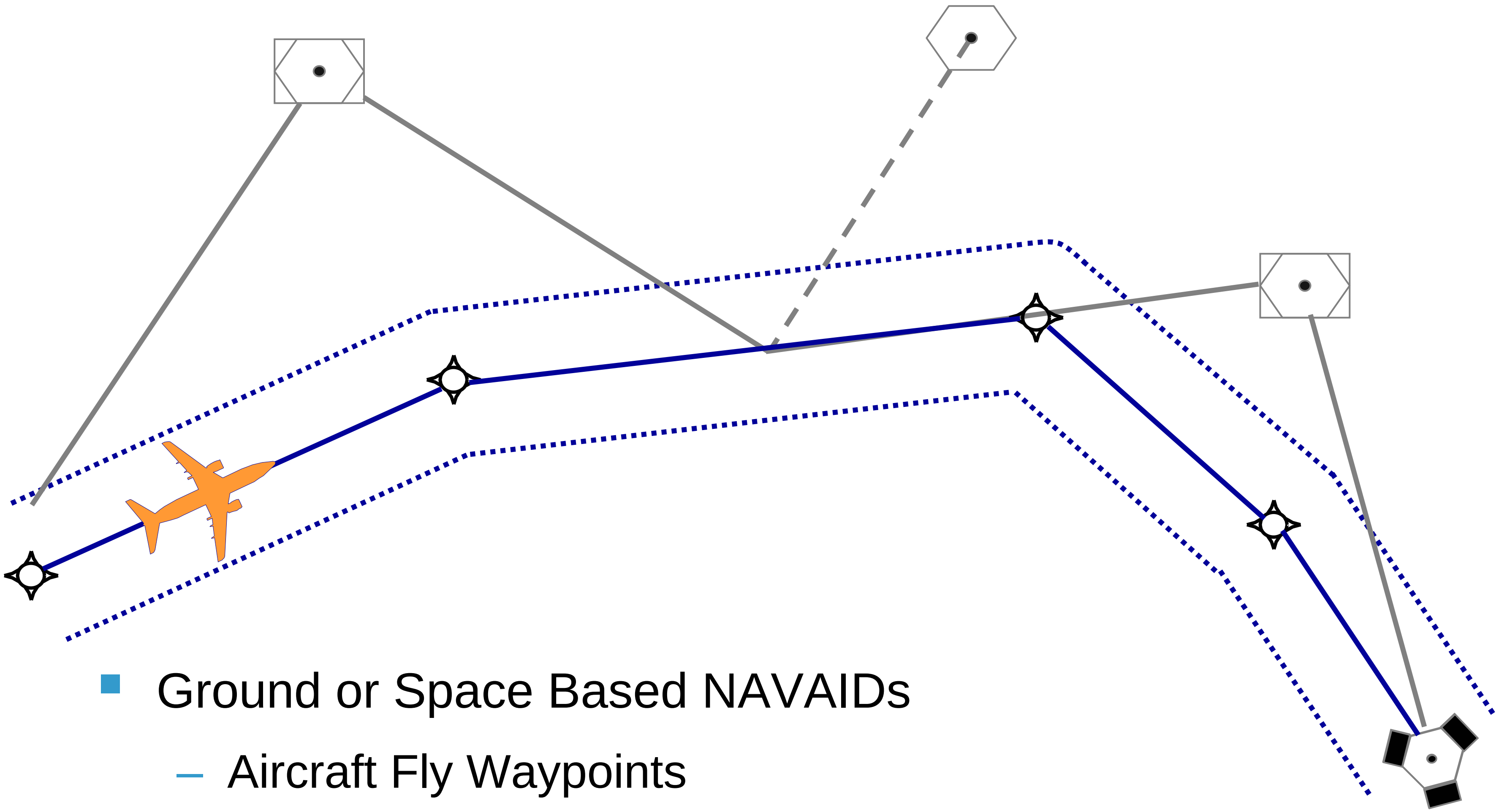
- **Area navigation** is a method of navigation which permits aircraft operation on any desired flight path:
  - within the coverage of station-referenced NAVAIDS, or
  - within the limits of the capability of self-contained systems, or
  - a combination of these capabilities



Blue line shows RNAV route without constraints of ground-based NAVAIDs

Area navigation is the key enabler for Performance Based Navigation

What Can Area Navigation Provide?

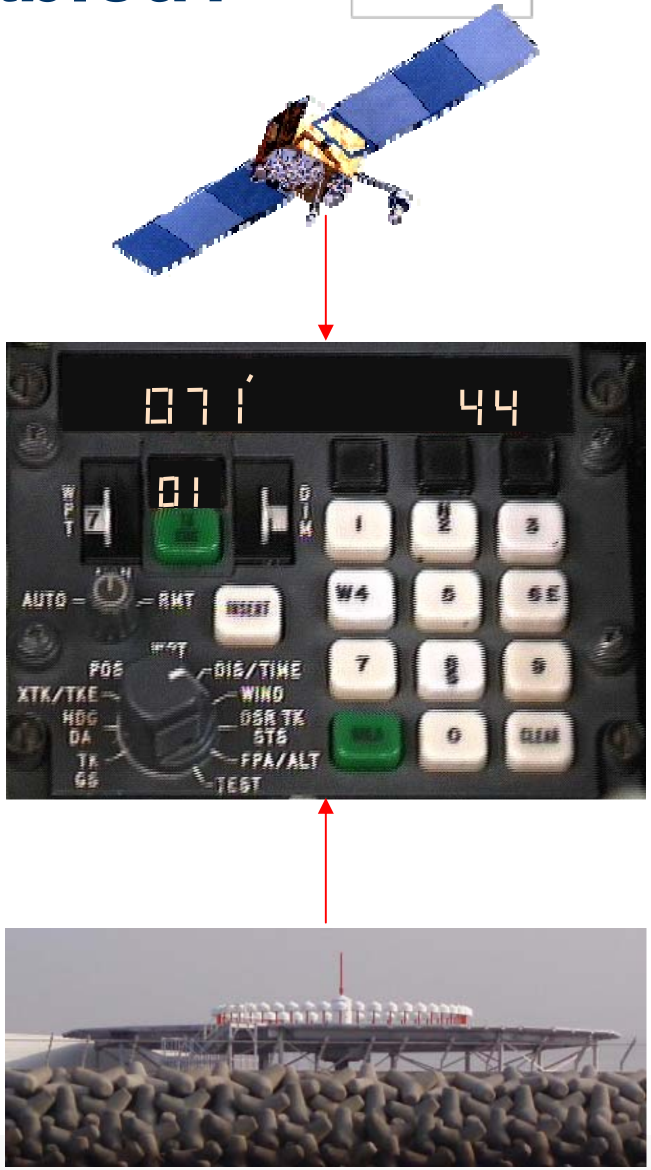


- Ground or Space Based NAVAIDs
  - Aircraft Fly Waypoints
- Protected Area Constant (“Linear’)

= Increased Design Flexibility

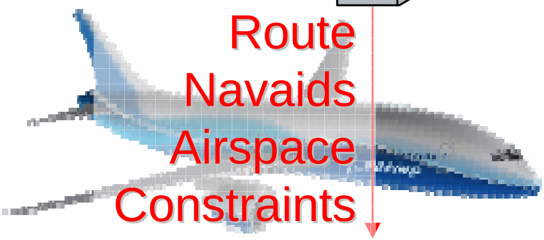
How is Area Navigation Enabled?

- Through the use of a navigation computer
- Waypoints (co-ordinates) are input into computer
  - Manual entry permitted but limits capabilities
  - Automatically with an integrated database
- Pilot creates route (series of waypoints) i.a.w. flight plan
- Computer estimates position using navigation sensors fitted and compares estimation to defined route
- Deviation between the position and defined path will create guidance information



Aircraft Functionality

Database



Route
Navaids
Airspace
Constraints

AC Management
Performance:
Climb & Descent
Turns

Position Estimation
Path Comparison
Path Corrections

Range and/or
Bearing Information

Navigation Databases

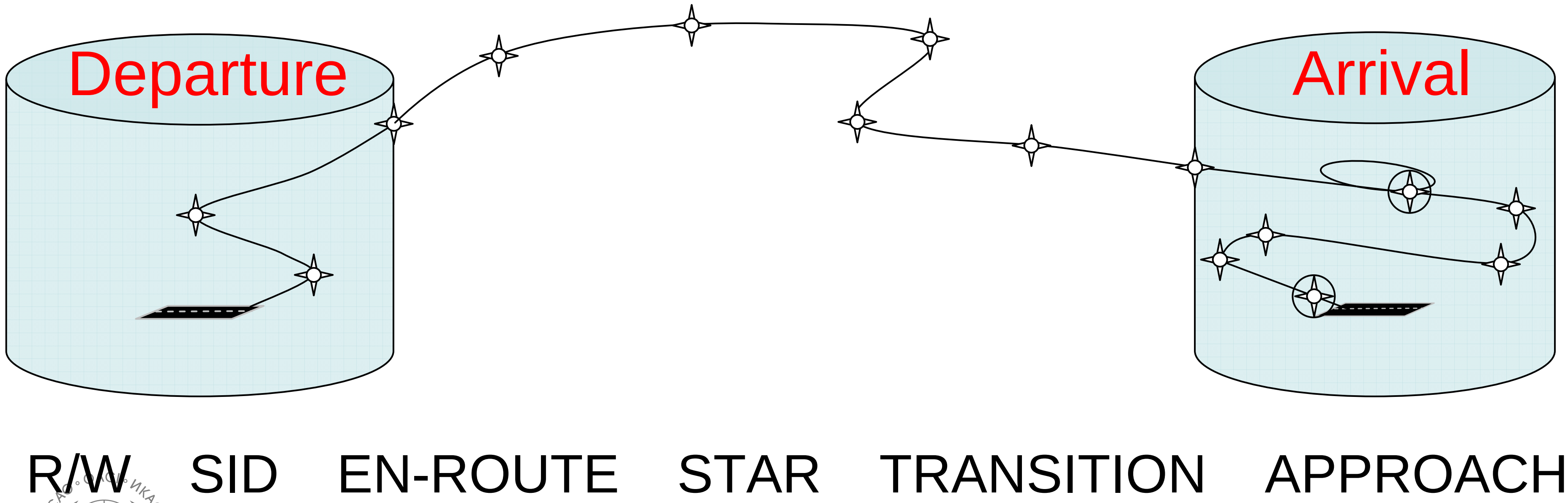
- Most navigation applications require a database
- Contains pre-stored information as requested by the AO such as:
  - NAVAIDs
  - Waypoints
  - ATS Routes
  - Terminal Procedures
  - Related information
- The navigation computer will use this information for flight planning and cross-checking of sensor information
- Databases are compiled by a specialist ‘datahouse’ and updated i.a.w. Annex 15 AIRAC cycle
- Today, the size of the database is cause for concern

Navigation Computer Functionality

- Computers built by different OEMs
  - Operating system differences - just like Microsoft, Apple, Linux
  - Industry standard ARINC 424
- Functionality defines what the computer is capable of:
  - Turn performance
  - Path terminators
  - Automatic leg sequencing
  - Offset
  - Database
  - Alerting
  - Outputs (Display)

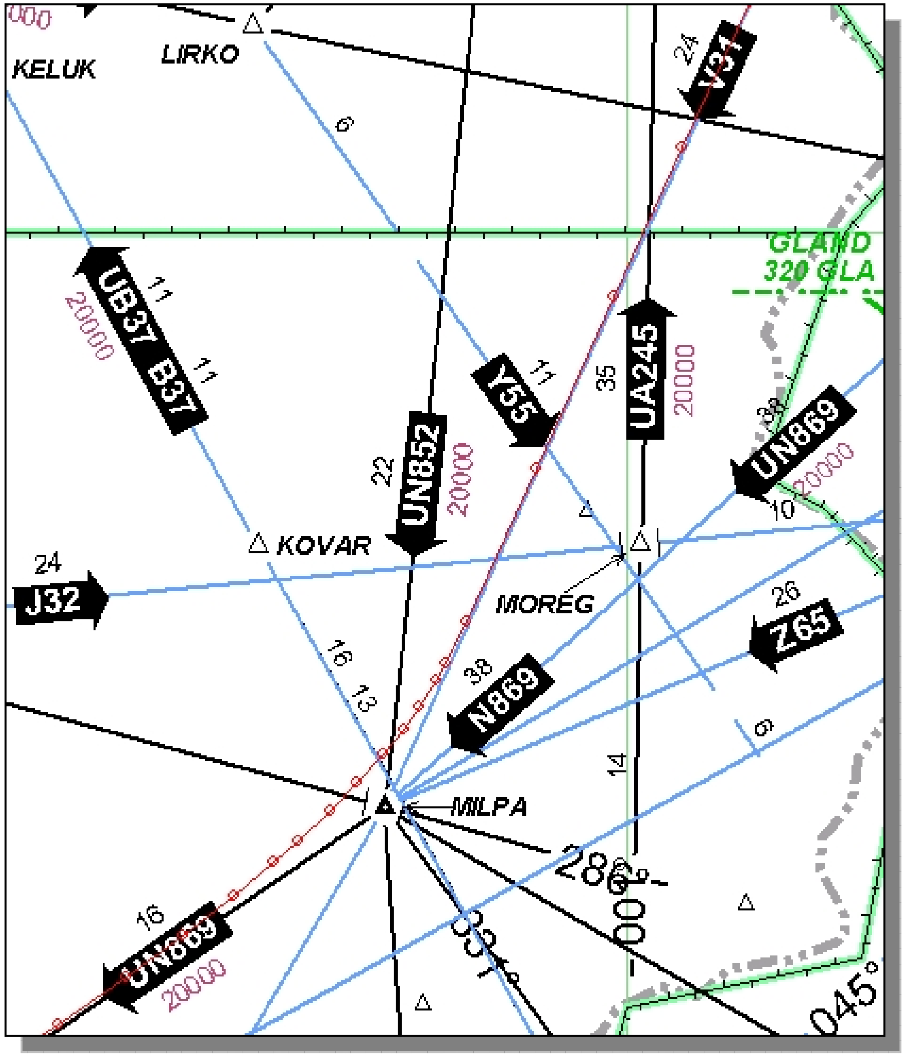
Flight Segments

- For the navigation computer, the flight consists of different elements known as ‘segments’
- Each segment is held in a different part of the database
- The segments must be connected together by the pilot
- ‘Route Discontinuity’ occurs when segments are not linked



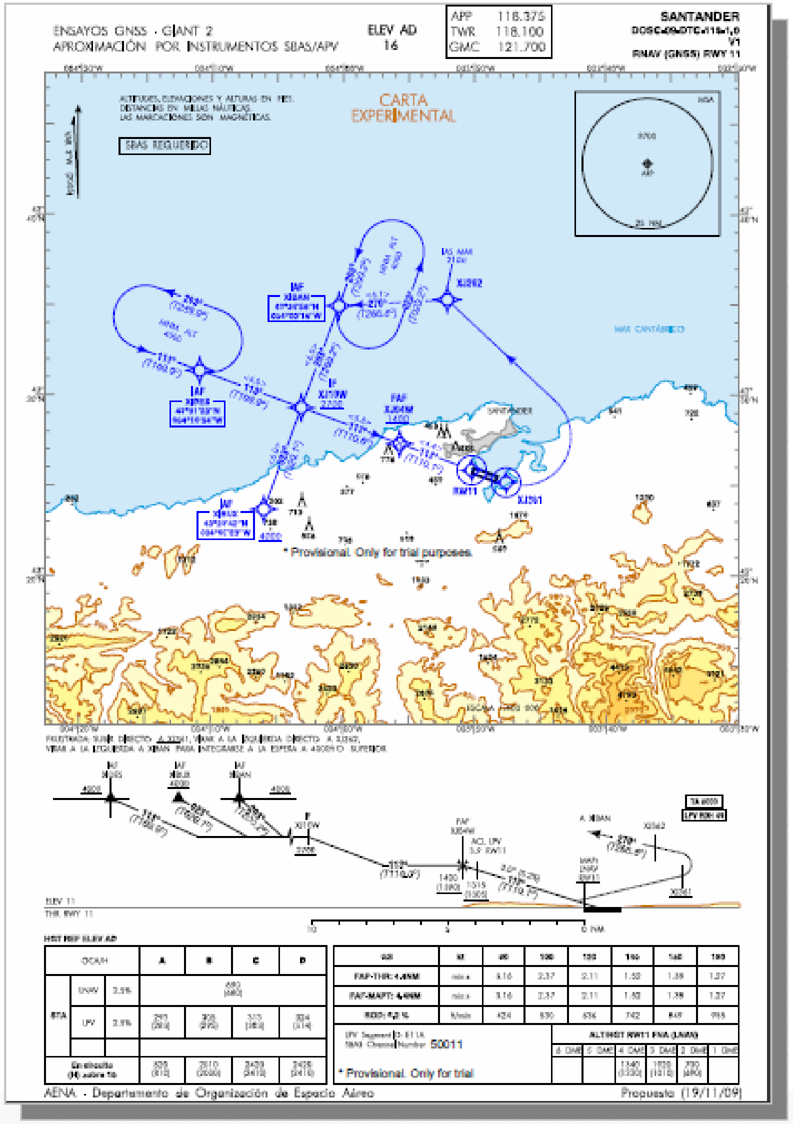
Turn Performance – En-Route

- Aircraft fly from waypoint to waypoint
- Track between waypoints known as ‘legs’
- Aircraft flies ‘legs’ as ‘To-To-To’
- At, or abeam, the waypoint the computer steps to the next one in the flight plan
- Computer will initiate turn approaching waypoint to be turn complete on next leg
- Turn anticipation is not always the same
  - Creates track dispersion



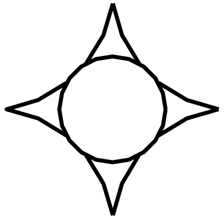
Instrument Flight Procedures

- IFPs define the departure and arrival paths of the aircraft
- Links terminal airspace to the ATS
  - Responsibility of Procedure Designers
- Computer limitation:
  - Only one STAR allowed per route
- So ‘Transition’ connects STAR to Approach segment
- Additional functionality enabled for IFPs, such as:
  - Waypoint Transitions
  - Path Terminators

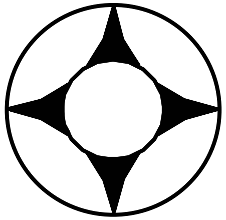


Waypoint Transition - IFP

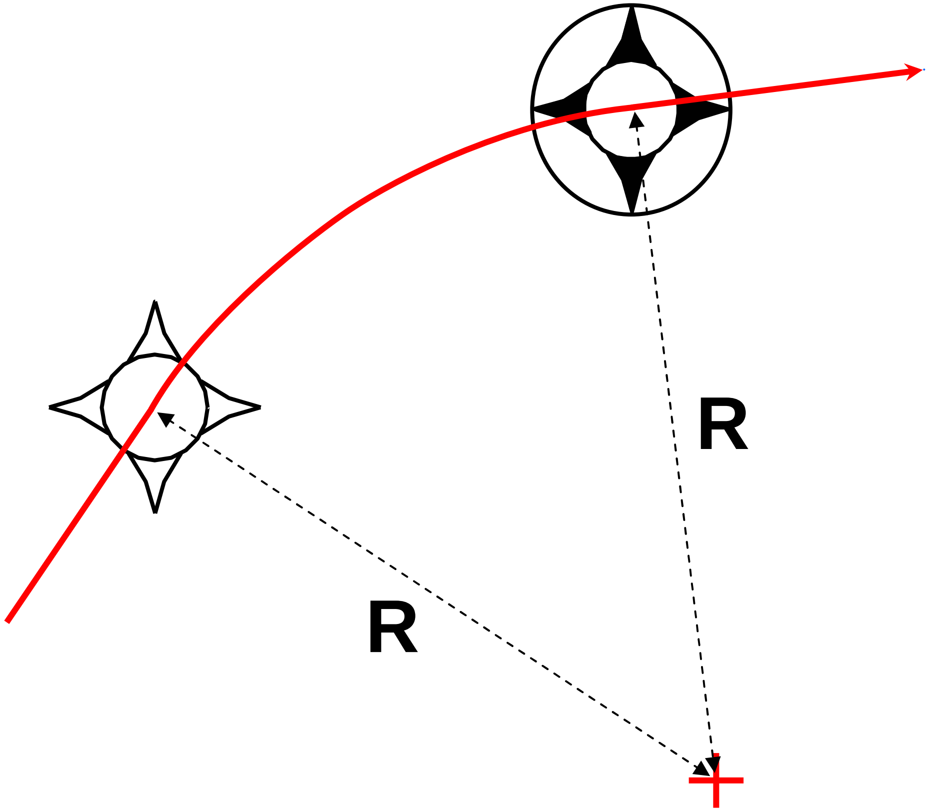
Fly-by



Fly-over

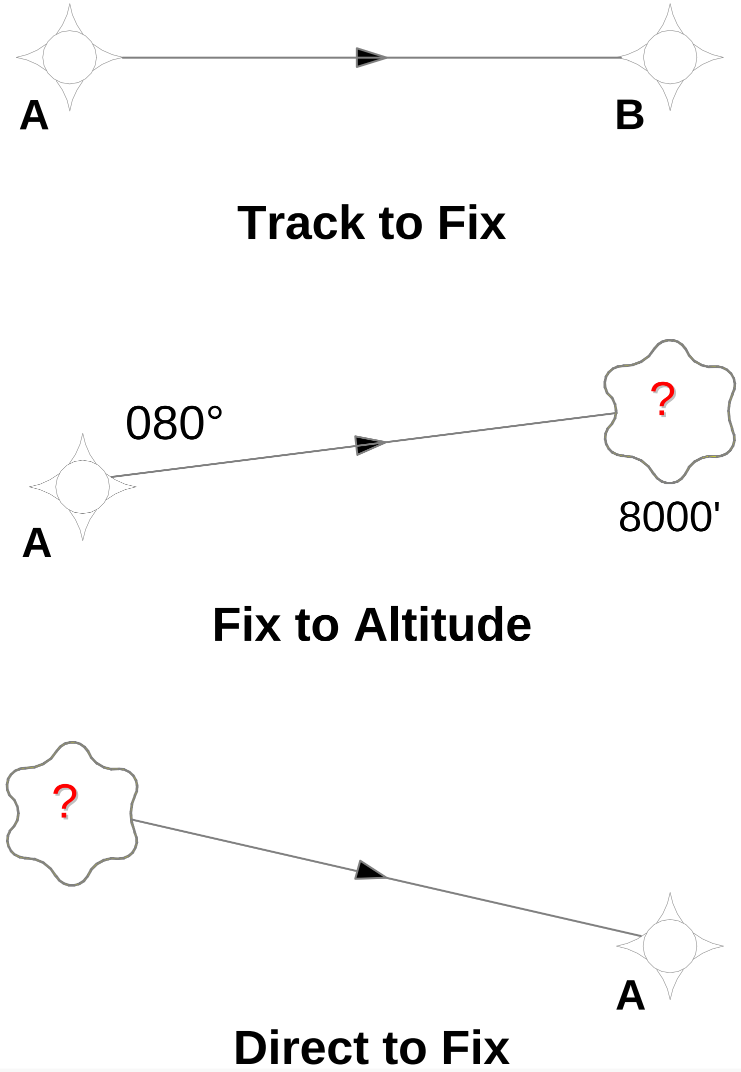


Radius to Fix



Path Termination - IFP

- How does the aircraft know what to do between waypoints?
- Industry has defined a set of actions which:
  - Tells the aircraft what to fly:
    - Track
    - Course
    - Heading
    - Direct
  - What success factor must be met to complete the action:
    - Altitude
    - Distance
    - Next fix
    - etc



Path Terminators - IFP

- ARINC 424 industry standards define Path Terminators
- Not all Path Terminators are used in PBN
- Path Terminators may be different or not enabled in some aircraft

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		

Today's Cockpit

FMS and Navigation

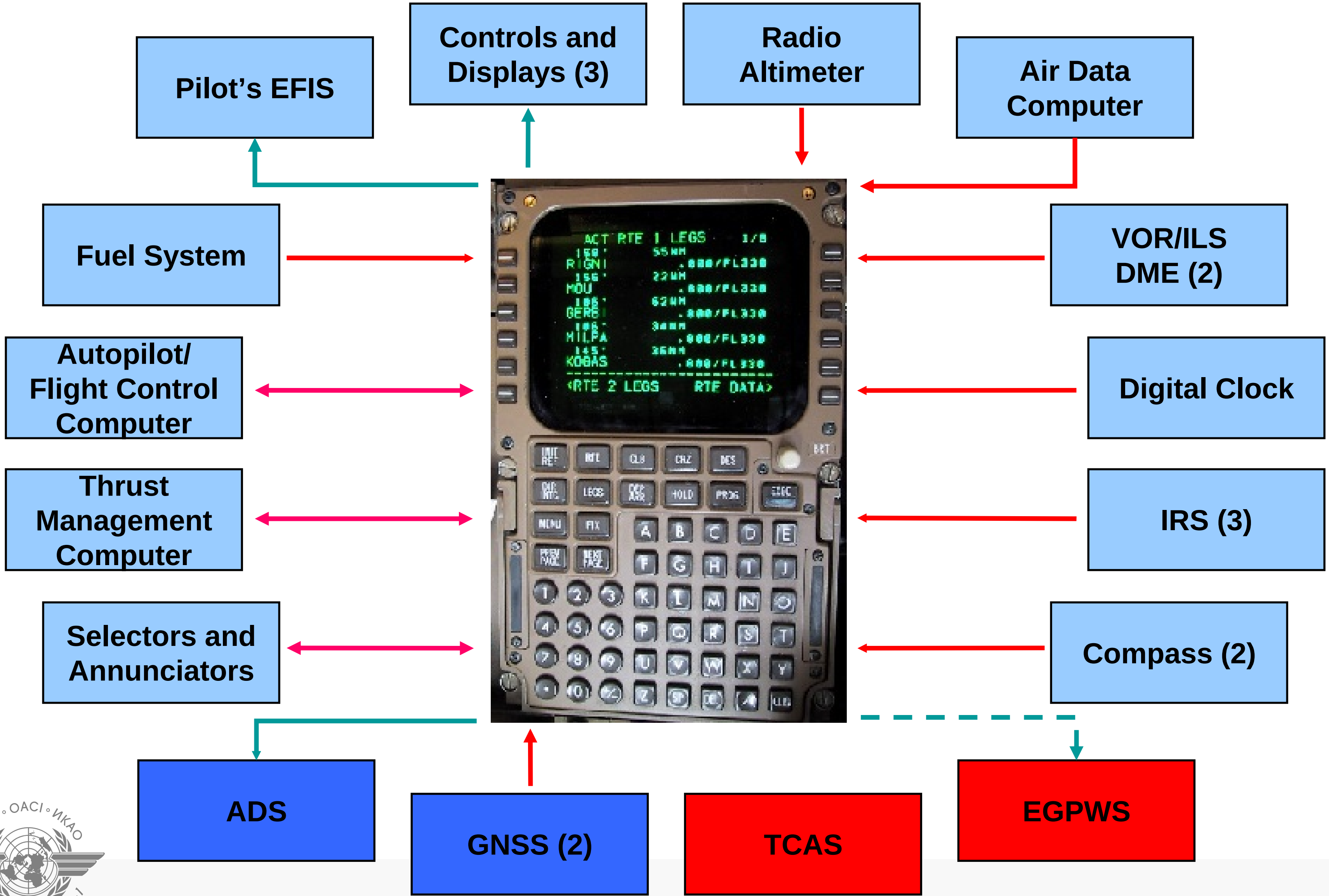
=

Navigation Computer (Positioning, Flight Planning, Trajectory Prediction)

AND

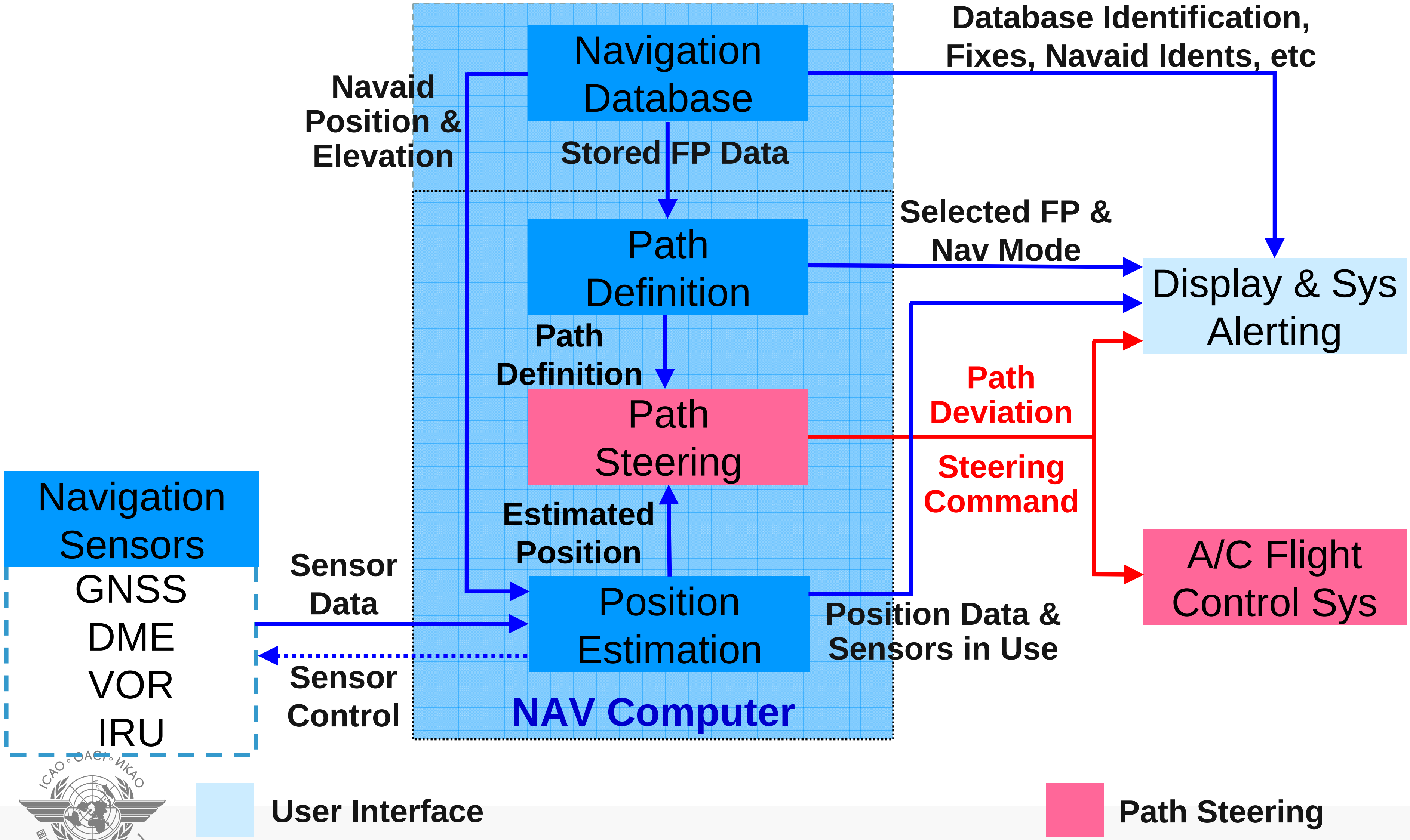
Aircraft Performance Management

Flight Management System



FMS Integrated Navigation Computer

Path Steering

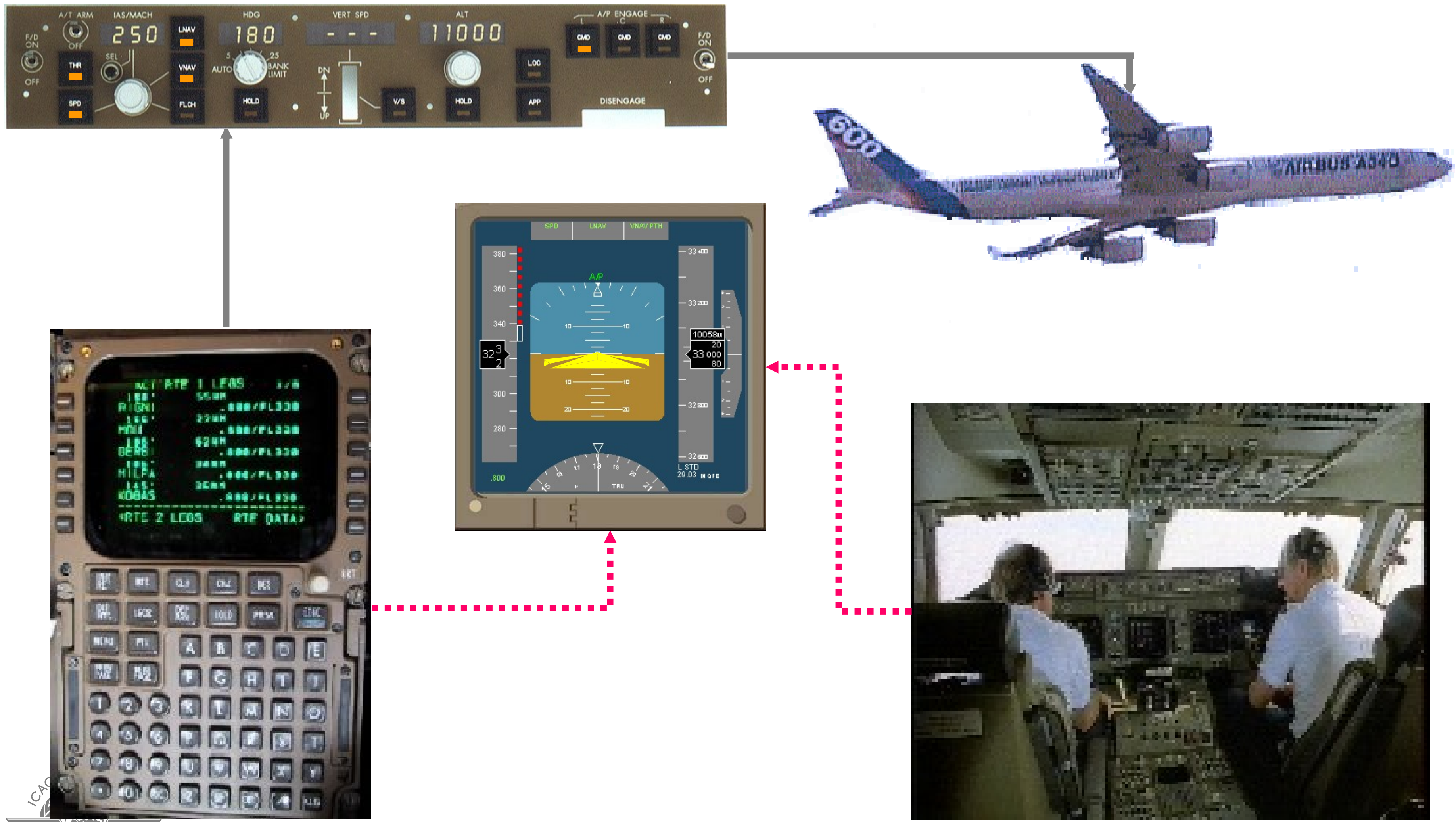


Navigational Accuracy

- In PBN the lateral track accuracy required for a navigation application is dependent on:
  - Navigation Sensors
  - Geometry of the NAVAIDs
  - Quality of navigation data
  - How the aircraft is flown
    - Automatic (AFCS)
    - Manually (following CDI)
  - Display of information
  - Human error (manual input to computer)

Uncoupled Steering

Coupled Steering

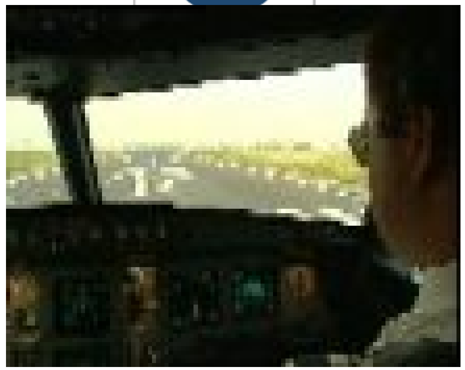


Flight Profile with FMS

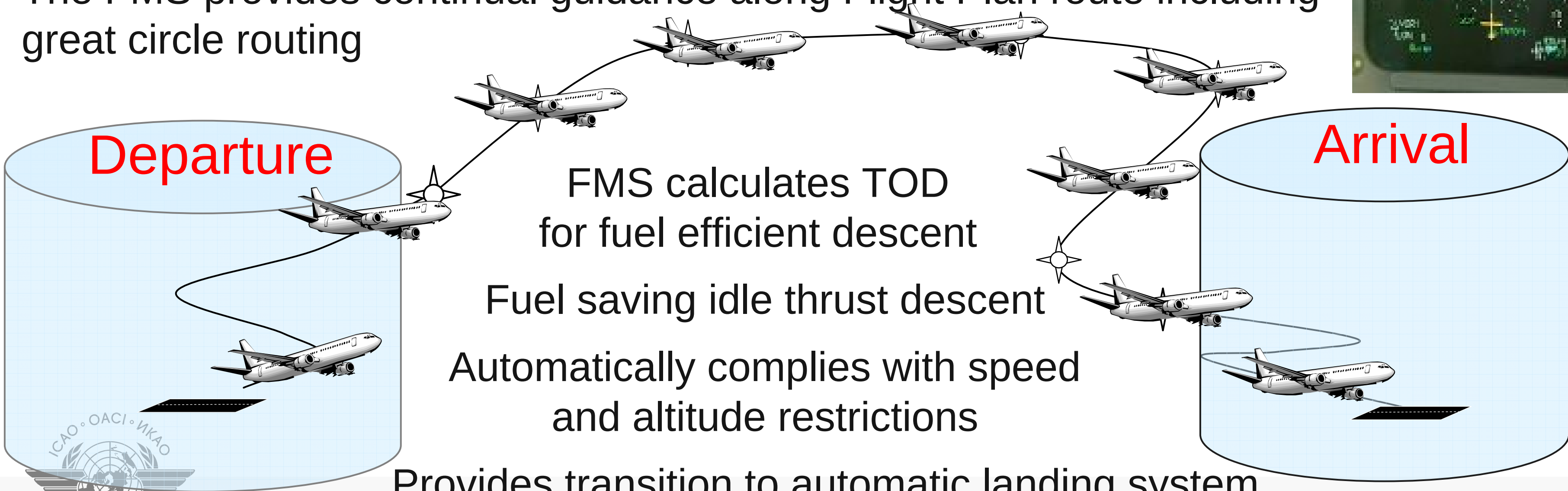
Before T/O, the Flight Plan Route is loaded into the FMS

After T/O, the FMS captures the assigned Flight Plan Route

The FMS commands speed and thrust for optimum economy calculating optimum altitude for the weight as the flight progresses



The FMS provides continual guidance along Flight Plan route including great circle routing



FMS calculates TOD for fuel efficient descent

Fuel saving idle thrust descent

Automatically complies with speed and altitude restrictions

Provides transition to automatic landing system

Advises pilot of correct landing speed

Summary

Conventional:
1950s+

Automatic:
Early 1970s

Area Navigation:
Europe 1998