Nav Specs and Procedure Design

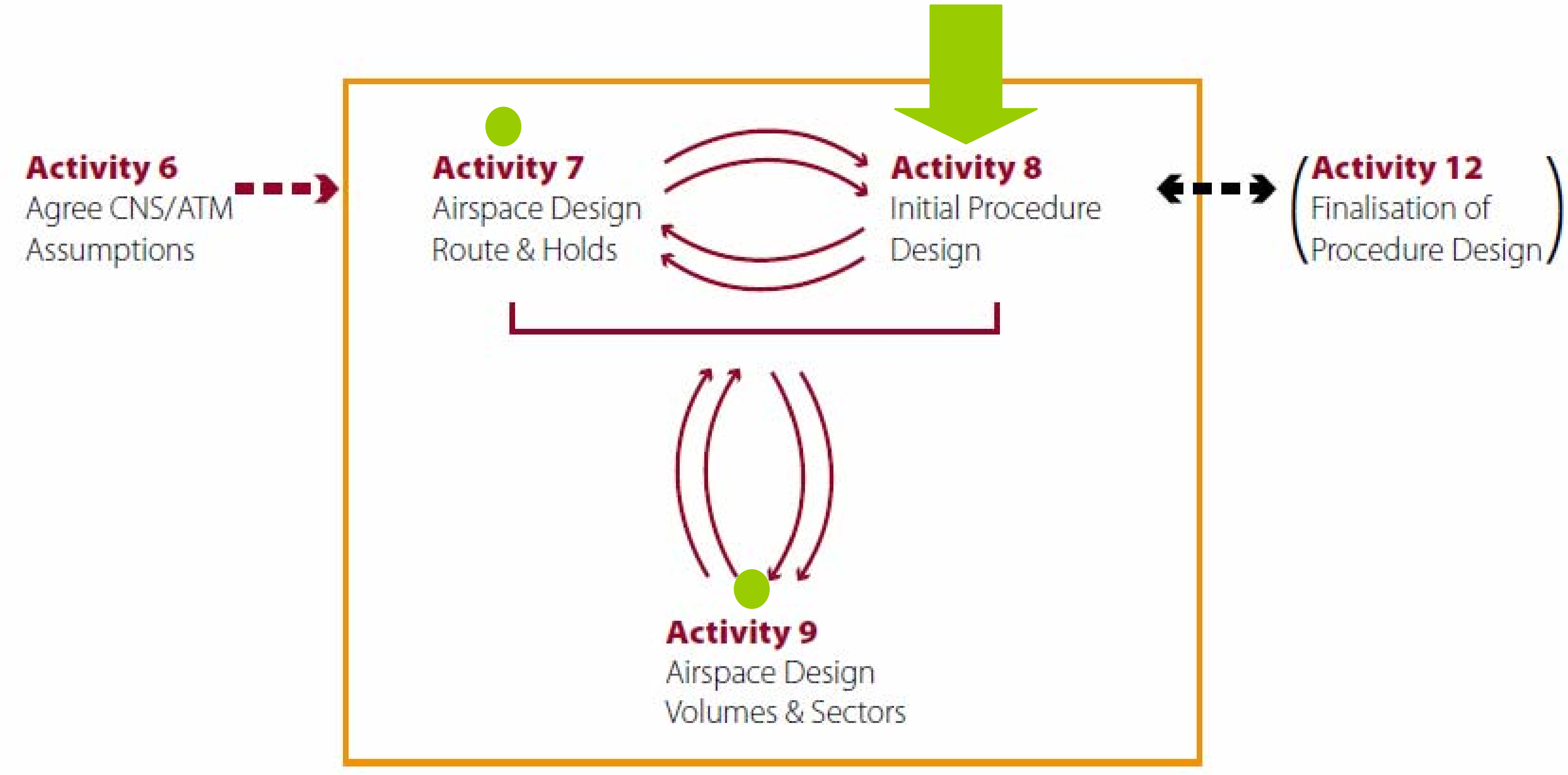
Module 12 – Activities 8 and 10

European Airspace Concept Workshops for PBN Implementation

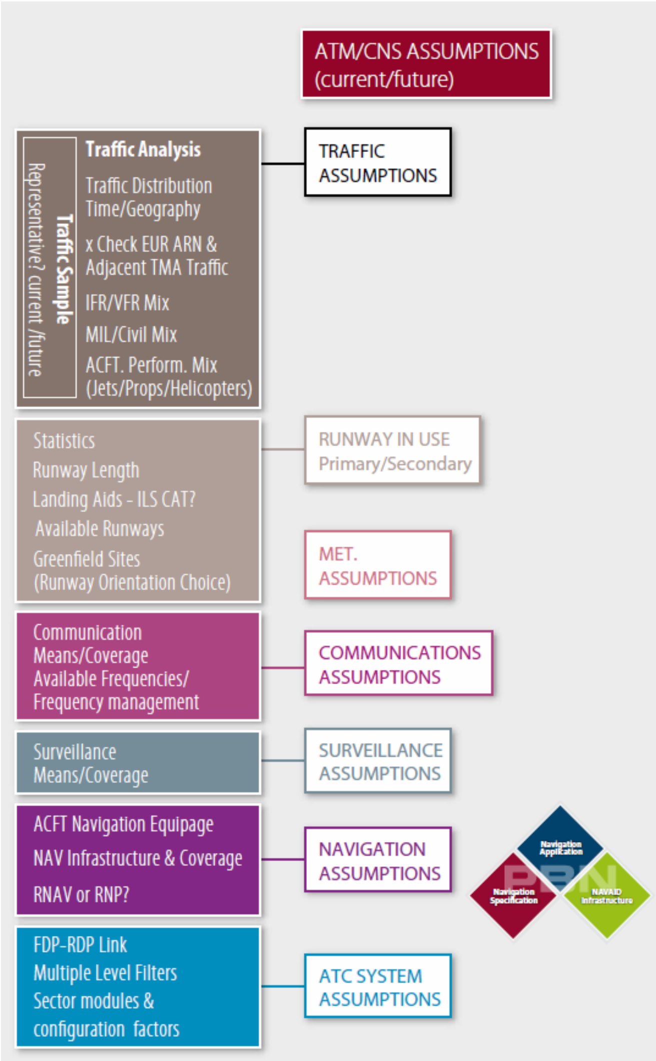
Learning Objectives

- By the end of this presentation you should understand:
  - The different nav specs and the phase of flight they relate to
  - The different functionalities and matching fleet capabilities to operational requirements
  - That an automatic solution may not be available and the importance of the iterative cycle
  - mixed mode environment issues and the use and limitations of mandates.

Overview

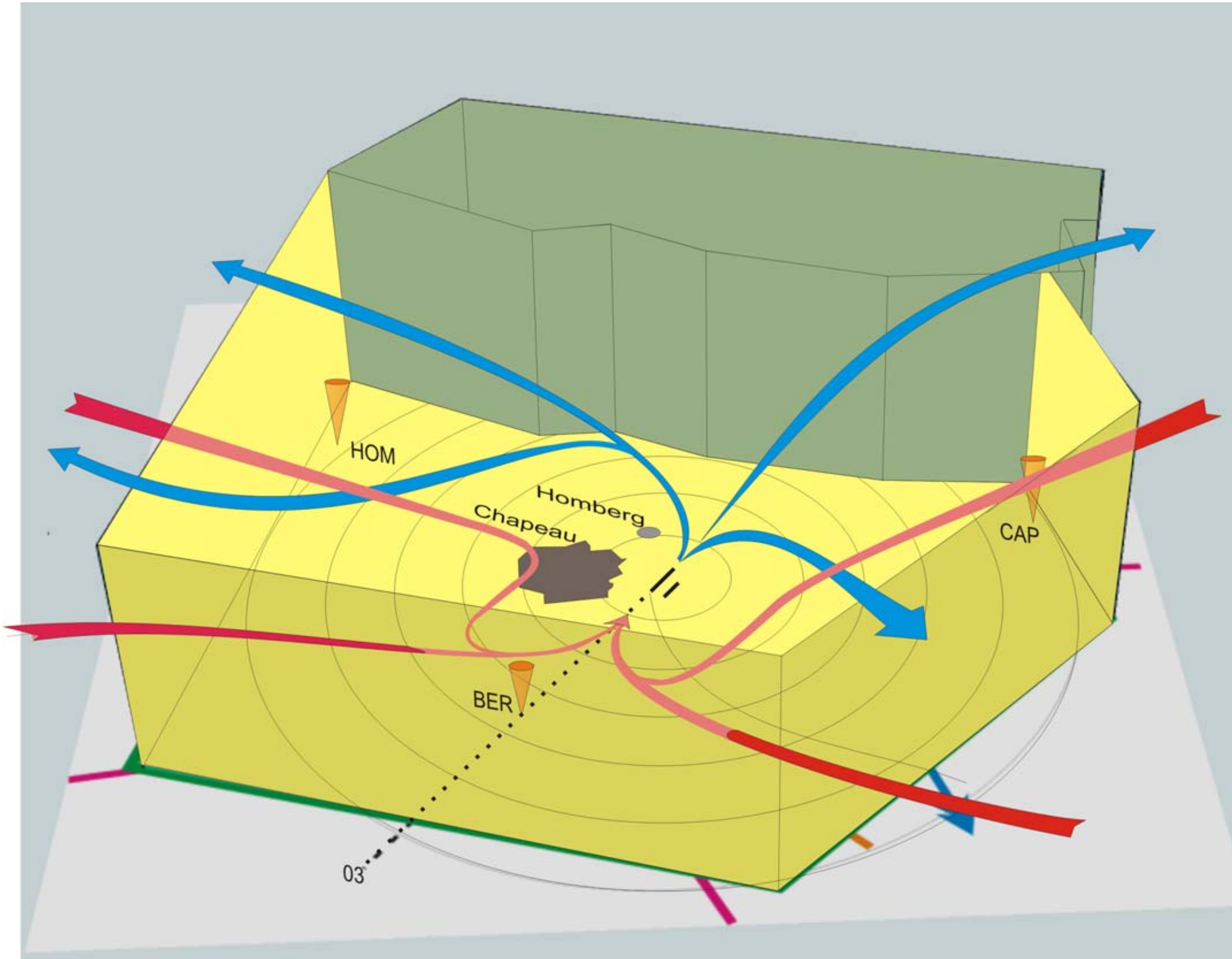

Activity 6
Agree CNS/ATM
Assumptions
Activity 7
Airspace Design
Route & Holds
Activity 8
Initial Procedure
Design
Activity 12
Finalisation of
Procedure Design
Activity 9
Airspace Design
Volumes & Sectors

Assumptions >> Design



- When agreeing assumptions, Airspace Design Team determines what's available in terms of :
  - Air Traffic
  - Runways
  - C
  - N
  - S
  - ATM System
- The Airspace Design Team should design its airspace based on realistic assumptions i.e. by relying on what does exist or what will exist at implementation date (*rather than on what one would wish to exist*).

Conceptual Design: What Next?



Confirming the Navigation Specification

What NAV SPEC is needed?

- Which phase of flight?
- How much confidence is needed in track keeping?
- Various requirements identified by Airspace Concept -
  - Vertical
  - Lateral
  - Longitudinal
- Is there a need for on-board performance monitoring and alerting?

What is ‘On-Board Performance Monitoring and Alerting’?

- The PBN concept uses “on-board performance monitoring and alerting” instead of “containment”
- The associated ICAO terms were previously *containment area, contained airspace, containment value, containment distance, obstacle clearance containment*
- Replaced by the *navigation accuracy* of TSE

Role of On-board Performance Monitoring and Alerting

- On-board performance monitoring & alerting:
  - Allows the flight crew to determine whether the RNP system satisfies the navigation performance required in the navigation specification
  - Relates to both lateral and longitudinal navigation performance
  - Gives ATC greater confidence regarding lateral track keeping.

Use and Scope of Navigation Specification by Flight Phase

PBN Manual includes airworthiness, operational and training guidance

NAVIGATION SPECIFICATION	FLIGHT PHASE							
				APPROACH				
	En Route Oceanic / Remote	En Route Continental	ARR	Initial	Intermed	Final	Missed*	DEP
RNAV 10 (RNP 10)	10							
RNAV 5		5	5*					
RNAV 2		2	2					2
RNAV 1		1	1	1	1		1	1
RNP 4	4							
RNP 2	2	2						
RNP 1*			1	1	1		1	1
A-RNP	2*	2 or 1	1	1	1	0.3	1	1
RNP APCH				1	1	0.3	1	
RNP AR APCH				1 - 0.1	1 - 0.1	0.3 - 0.1	1 - 0.1	
RNP 0.3		0.3	0.3	0.3	0.3		0.3	0.3

* Limitation on use – check against PBN Manual Volume II. Part A Table II-A-1-1

Use and Scope of Navigation Specifications

- **ICAO navigation specifications do not address all airspace requirements (e.g., comm, surv) necessary for operation in a particular airspace, route or area**
  - These will be listed in the AIP and ICAO Regional Supplementary Procedures
  - Incumbent upon States to undertake a safety assessment in accordance with provisions outlined in Annex 11 and PANS-ATM, Chapter 2
- **ICAO PBN Manual provides a standardized set of criteria, but is not a stand-alone certification document**
  - Examples: RNP 4, RNAV 1, RNP AR APCH

What kind of Nav Spec?

- For Terminal?
- RNAV or RNP
- Influencing factors:
  - Airspace designed
  - Complexity of the design?
  - Which aircraft are to be catered for?

Procedure Design Considerations

Aircraft Types you cater for

- Local fast regionals

- Occasional older visitors
  - lack of functionality

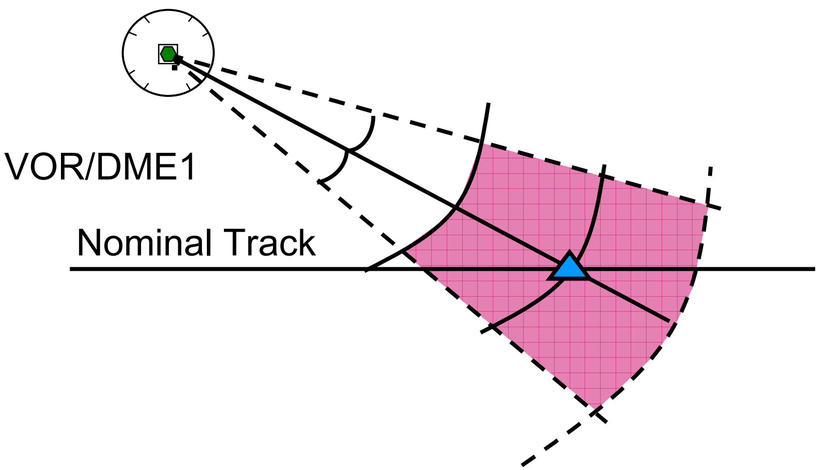
- Heavy slow long-hauls

NAVAID Coverage

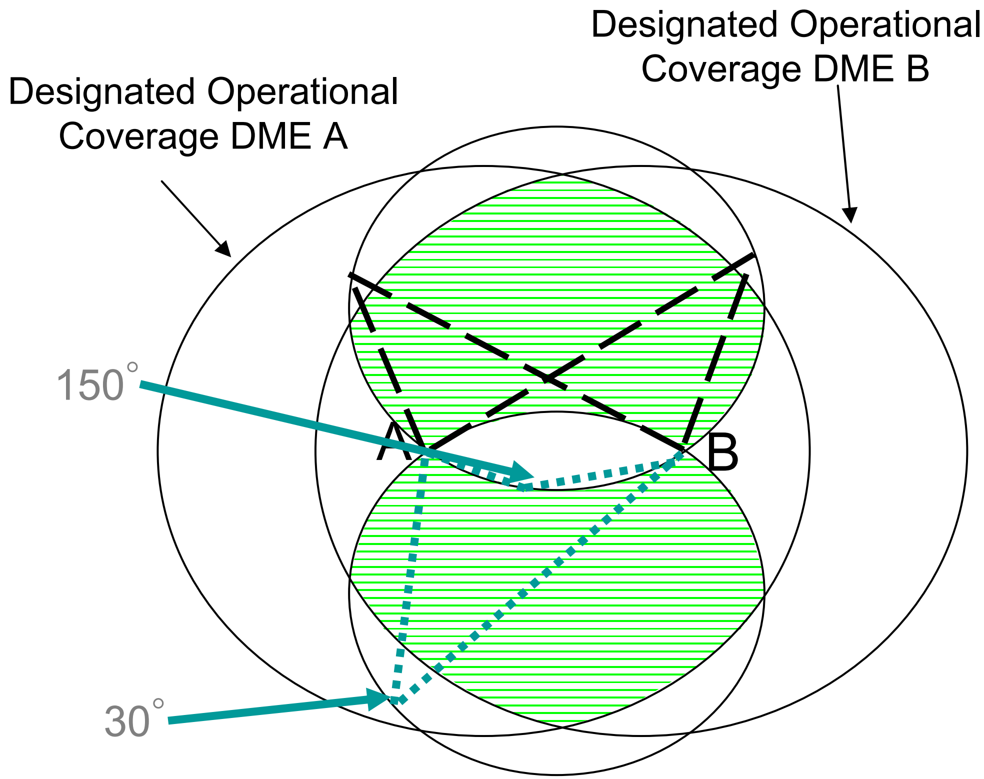
- Geographical Distribution of Navaids
- Accuracy
- Continuity of Service
- Availability
- Redundancy

Geographical Distribution of Navaids

VOR/DME

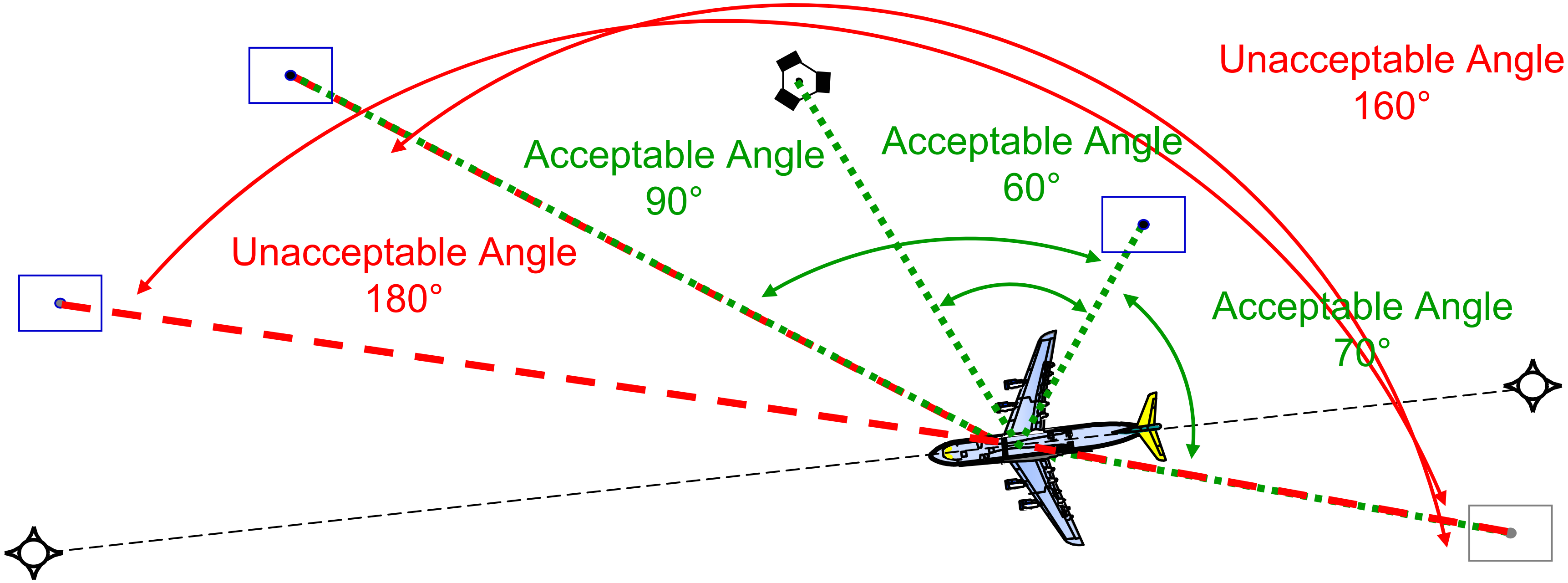


DME/DME



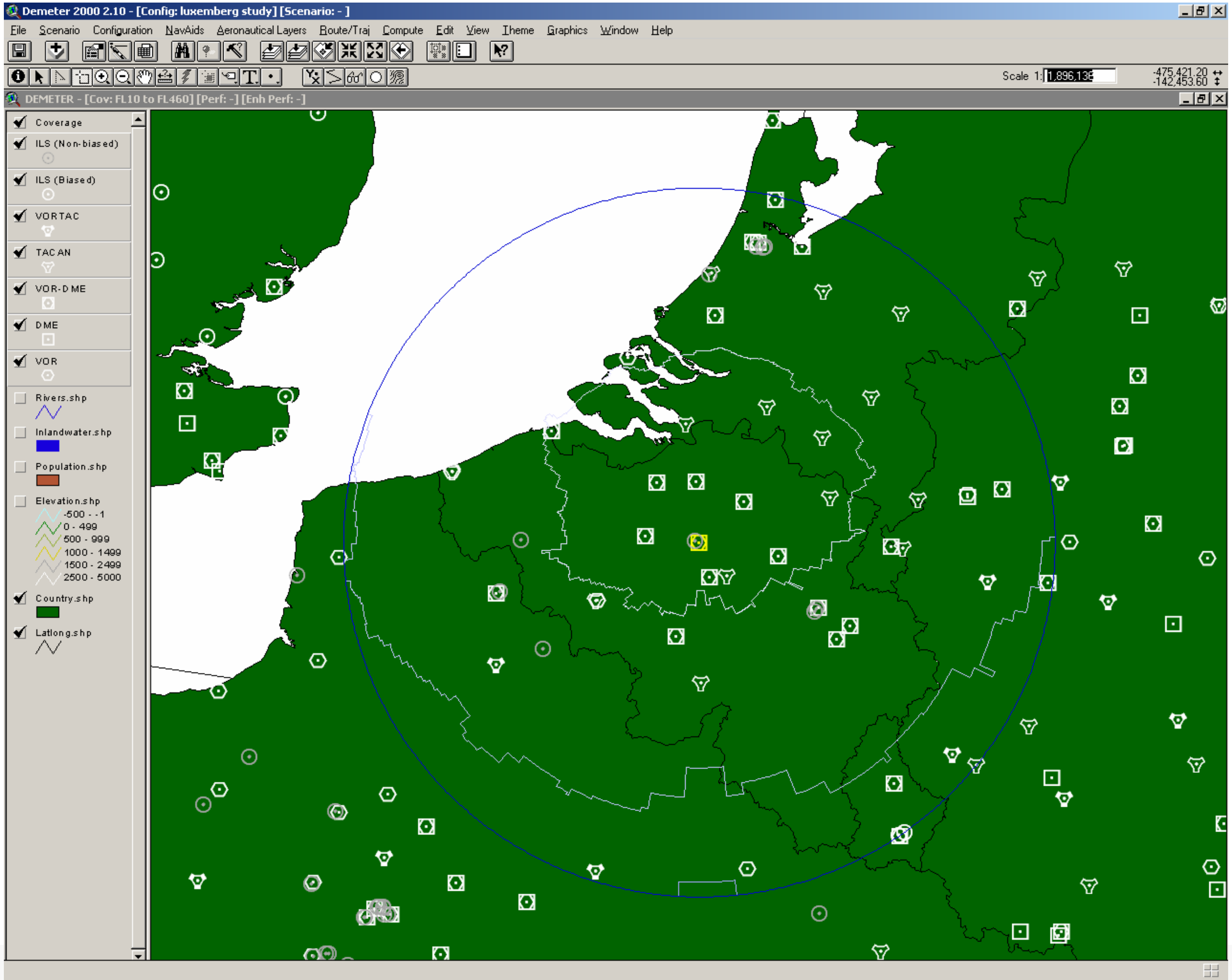
DME/DME Geometry

- For DME/DME systems using DME facility pairs, geometry solutions require two DMEs to be ≥ 30°and ≤ 150°



Coverage - Demeter

- Effect of topography on a single DME station
- Coverage from 1000’ to FL460
- Predicted reception range from 2000’ to 5000’ AGL



Performance - Demeter

EUROCONTROL

- Using all Belgium DMEs
- Angles subtended colour coded at FL95:

80°-90°

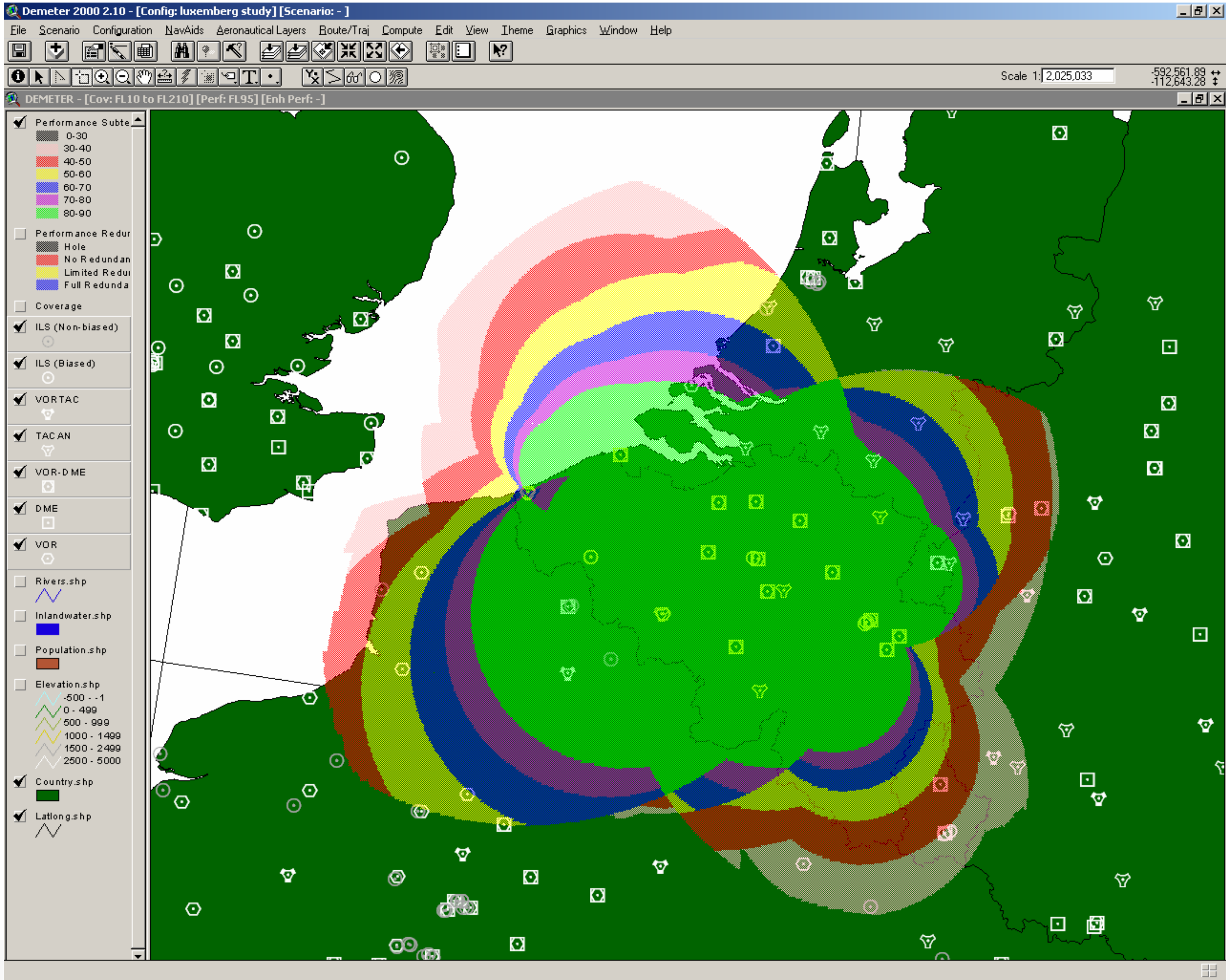
70°-80°

60°-70°

50°-60°

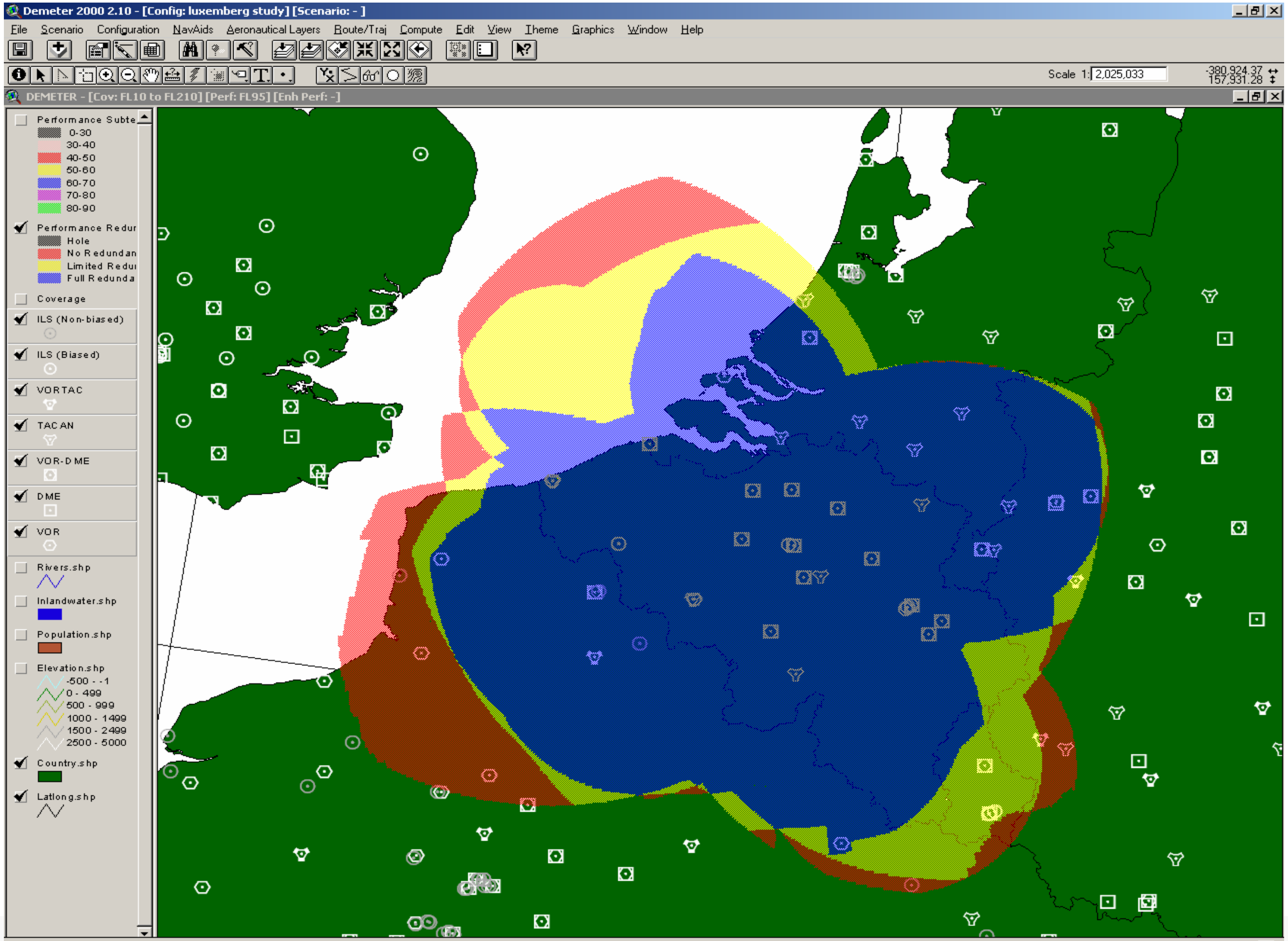
40°-50°

30°-40°



Redundancy - Demeter

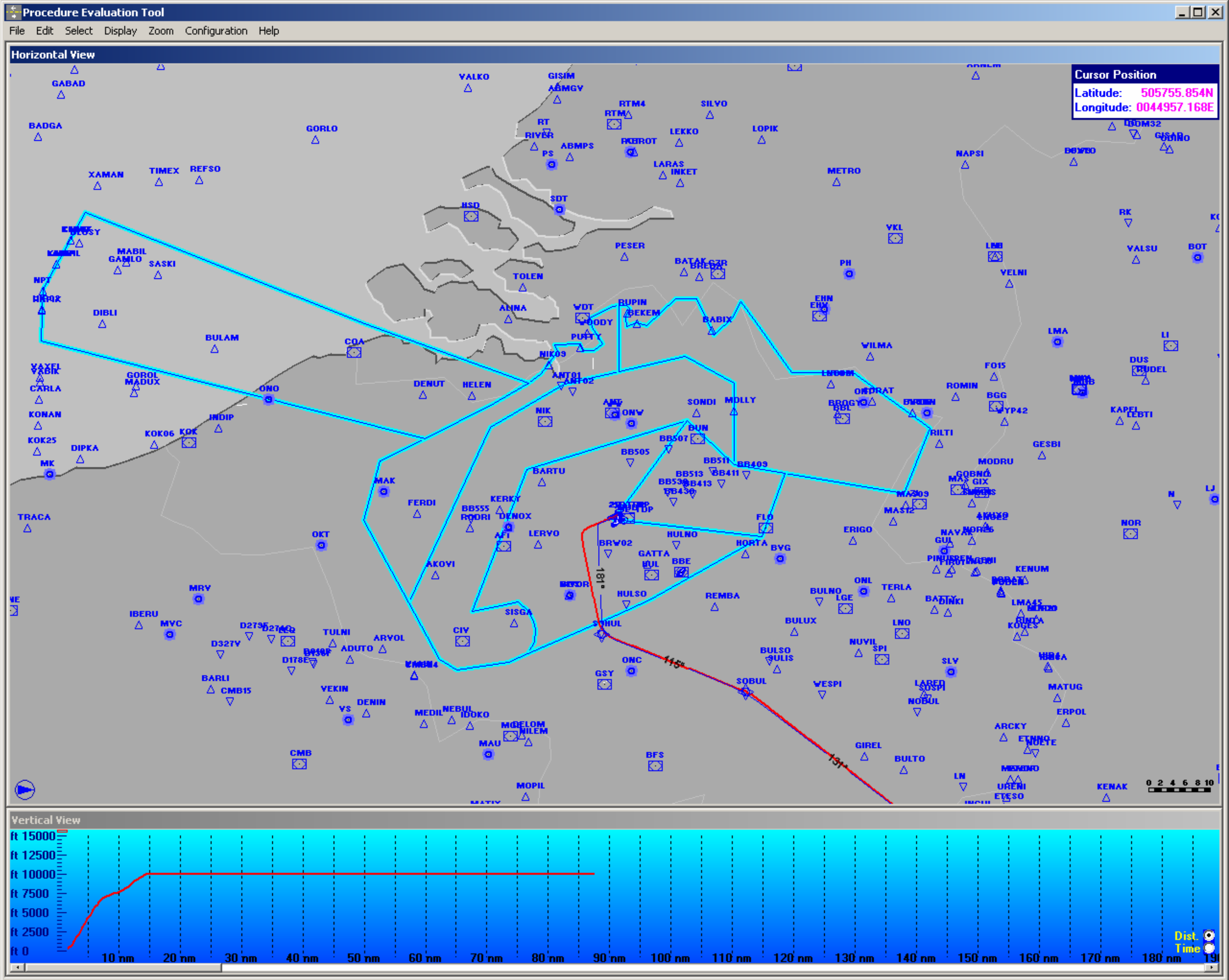
- Using all Belgium DMEs
- At FL95
- Colour coded number of DMEs visible:



Redundancy

(blue)	Full
(yellow)	Limited
(red)	None

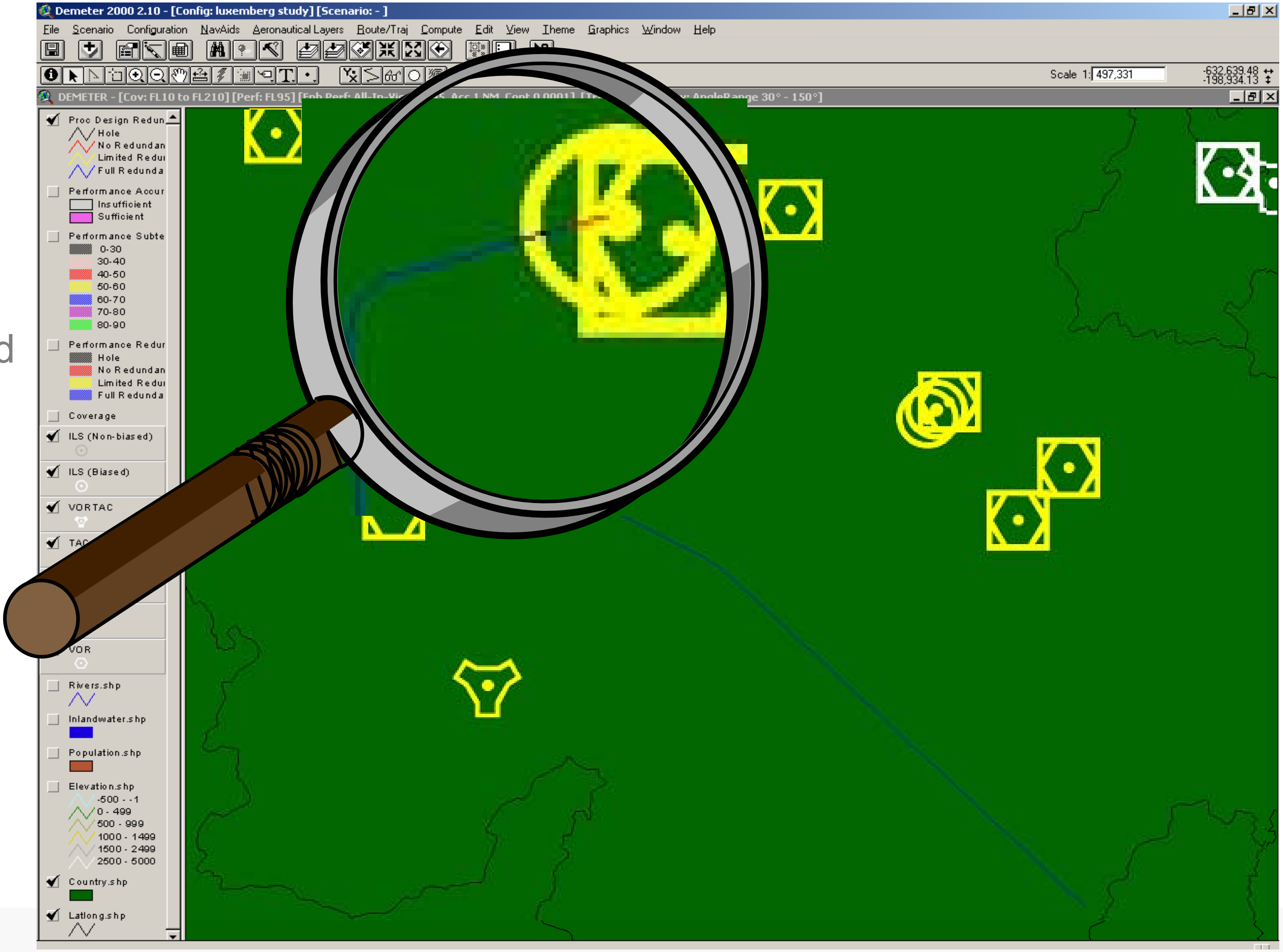
Procedure Assessment - Brussels



Redundancy Assessment - Brussels

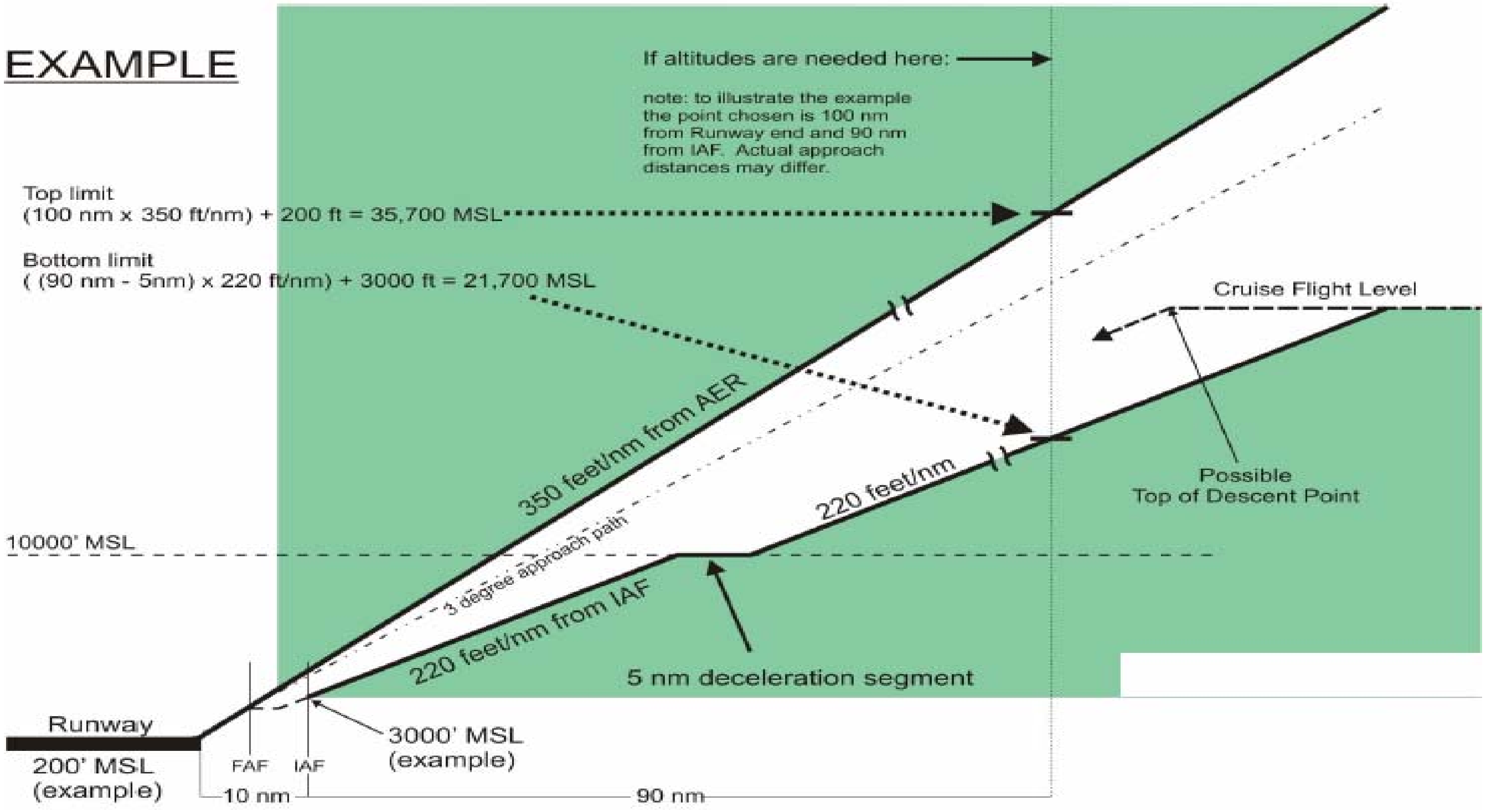
Redundancy

- Full
- Limited
- None

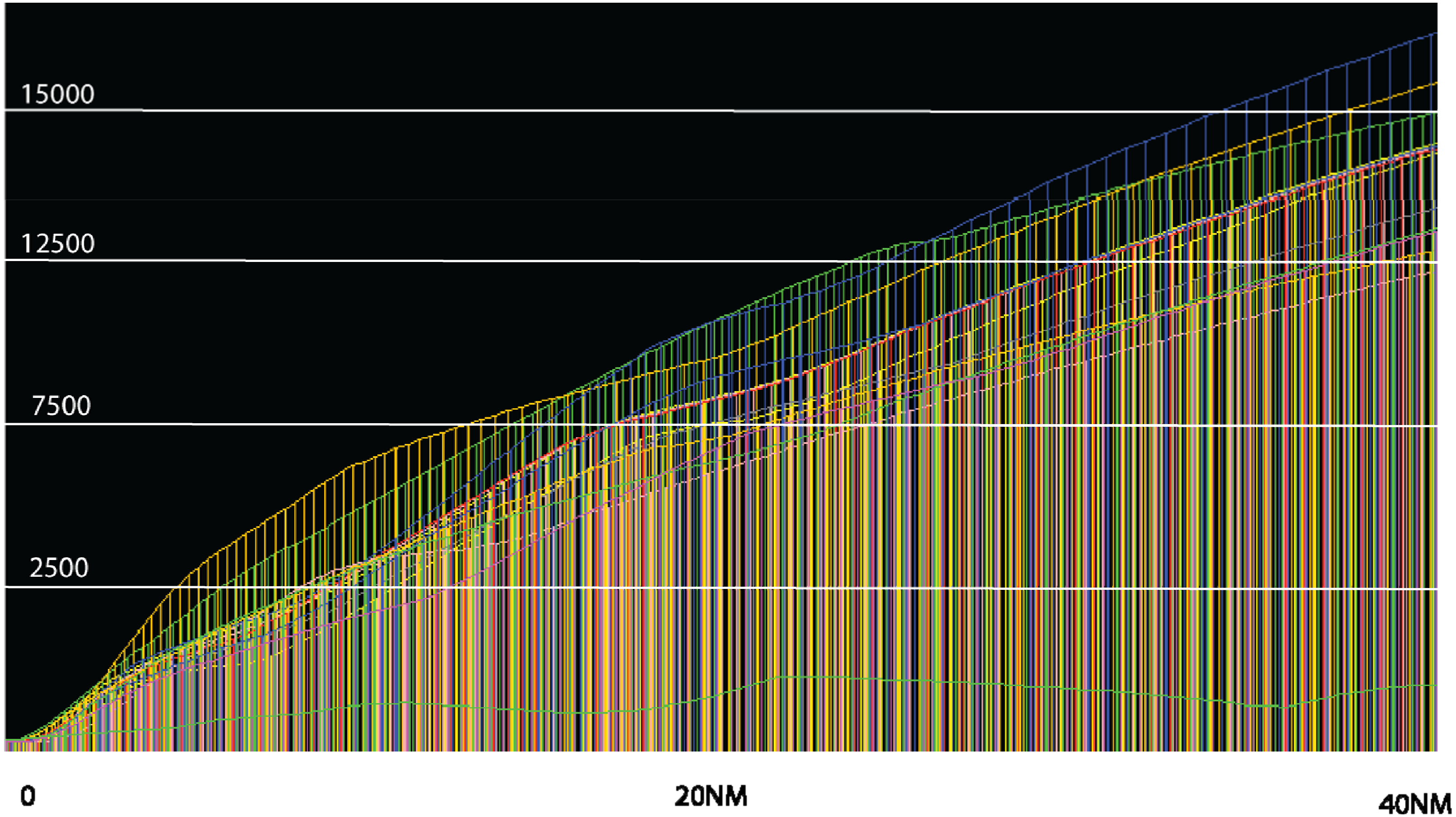


Obstacle Constraints

Descent Gradient Constraints



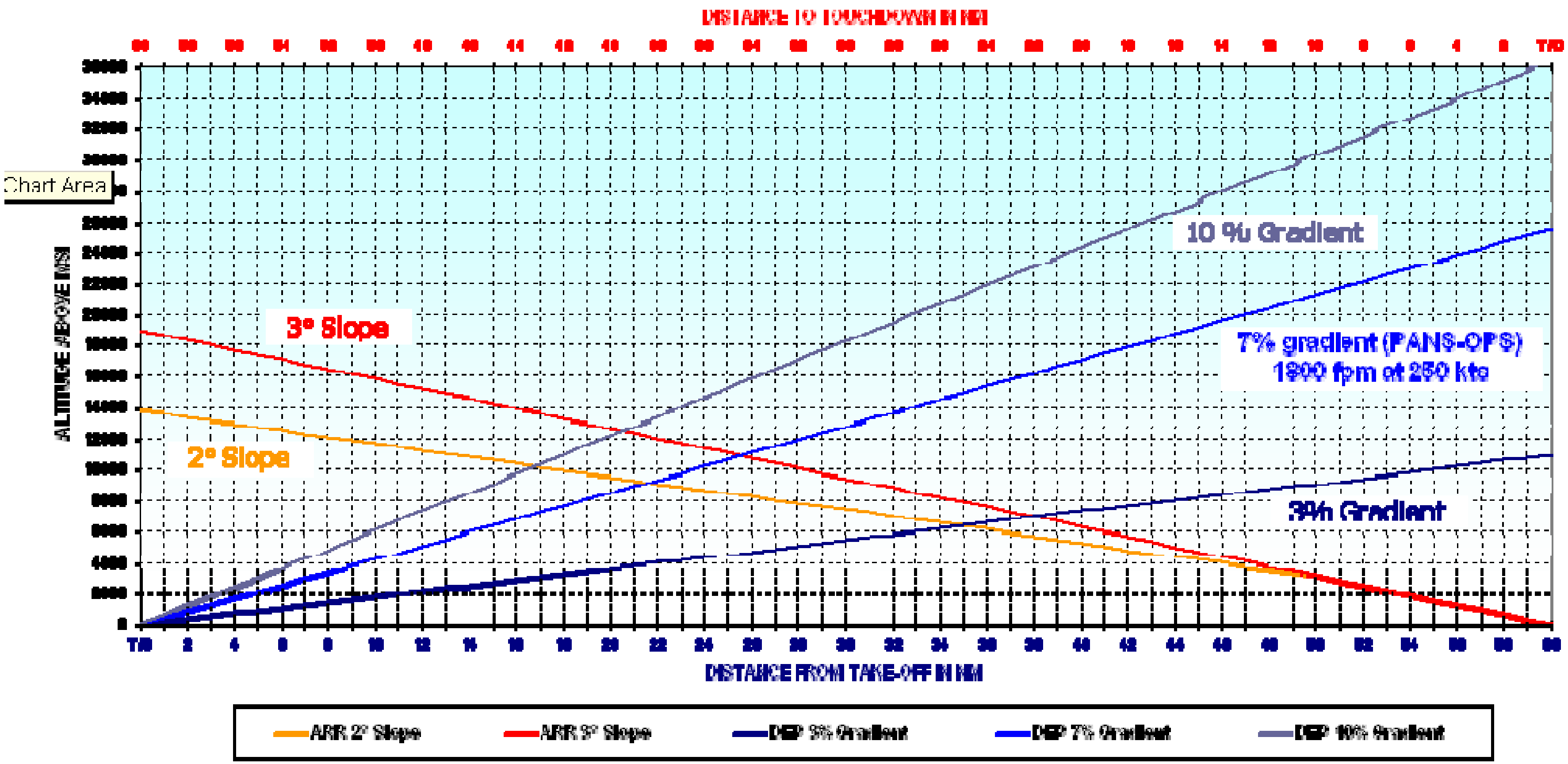
Actual Climb profile Constraints



Theoretical Climb/Descent Profiles

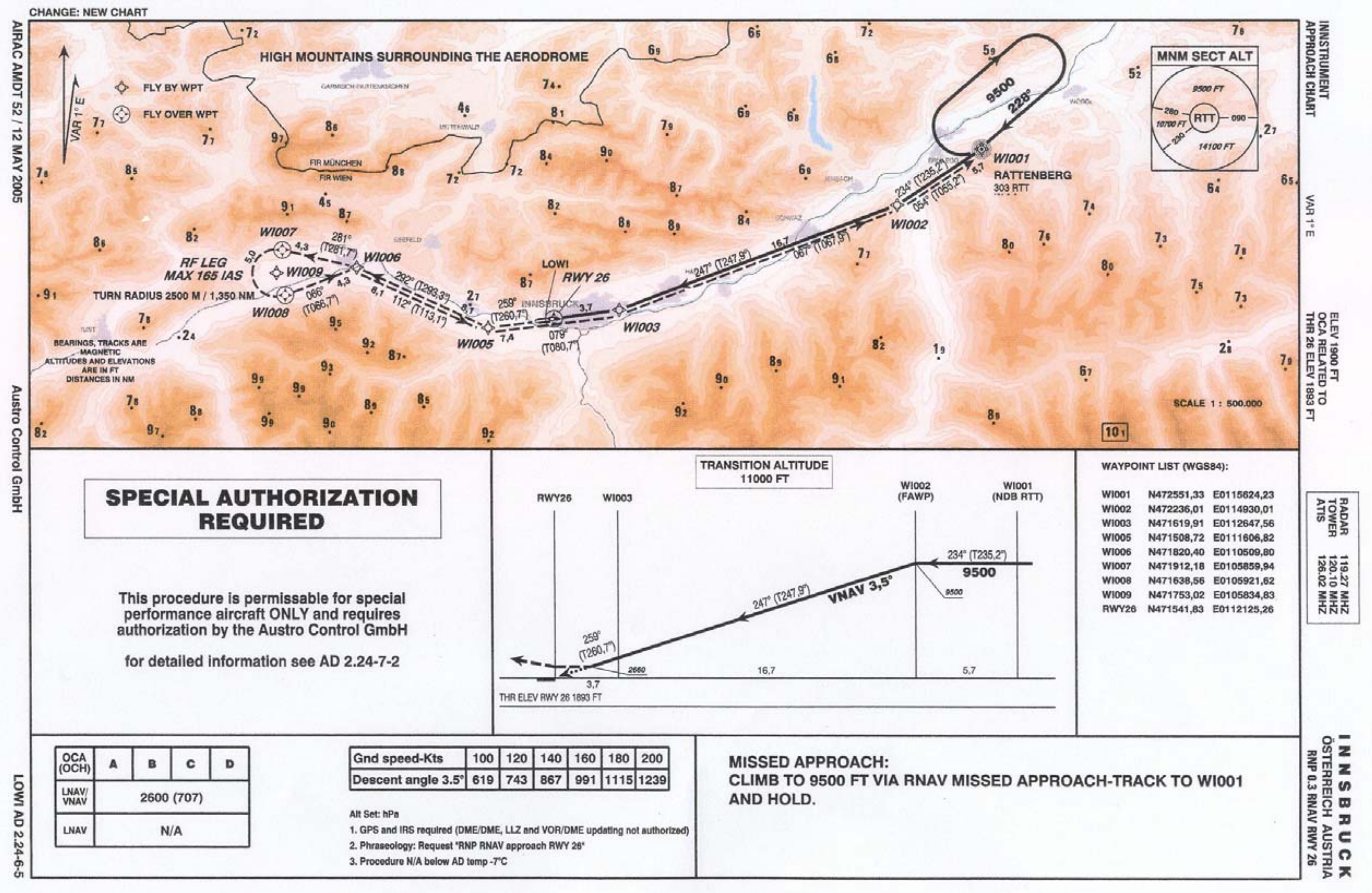
EUROCONTROL

VERTICAL INTERACTION BETWEEN UNCONSTRAINED DEP & ARRIVAL [ELEV. @ MSL]



SAMPLE CHART ONLY: SIMILAR GRAPHS SHOULD BE DEVELOPED FOR EACH IMPLEMENTATION DEPENDING ON FLEET

The Procedure



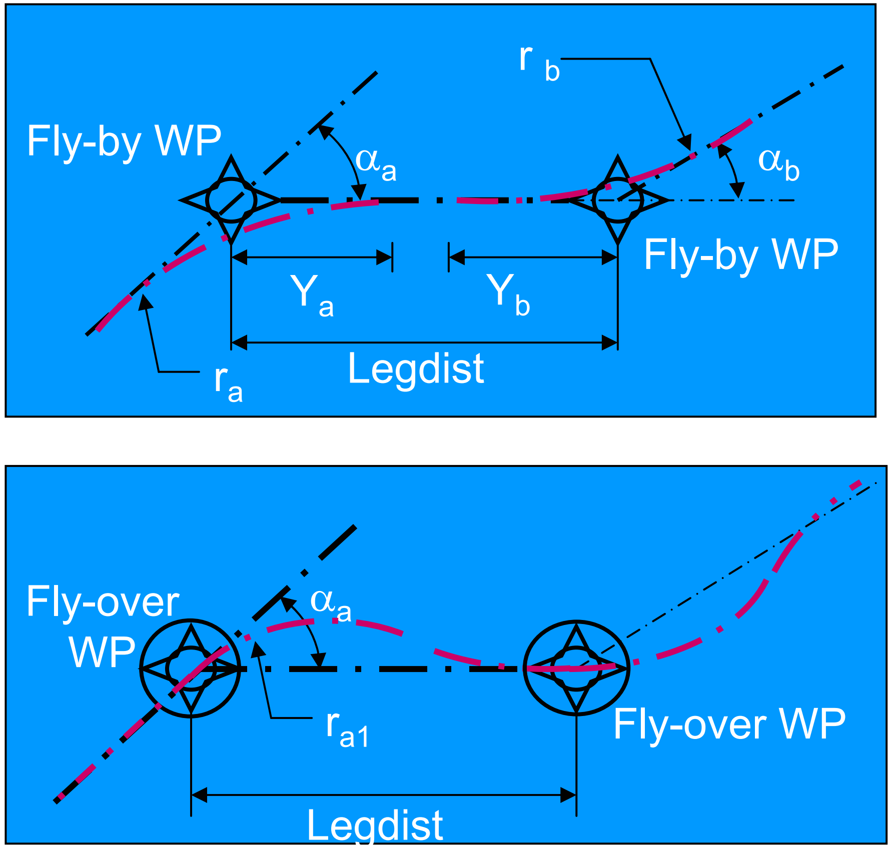
RNAV Performance

- RNAV System
  - RNAV 5
  - RNAV 1
  - RNP
- RNAV Sensor
  - VOR/DME
  - DME/DME/IRU
  - GPS
  - SBAS

RNAV Waypoint: GNSS

- Navigation accuracy depends upon:
  - Satellites in View
  - Geometry
  - Satellite serviceability
- Accuracy (Selective Availability off): ± 20m

Track Distances Between Turns



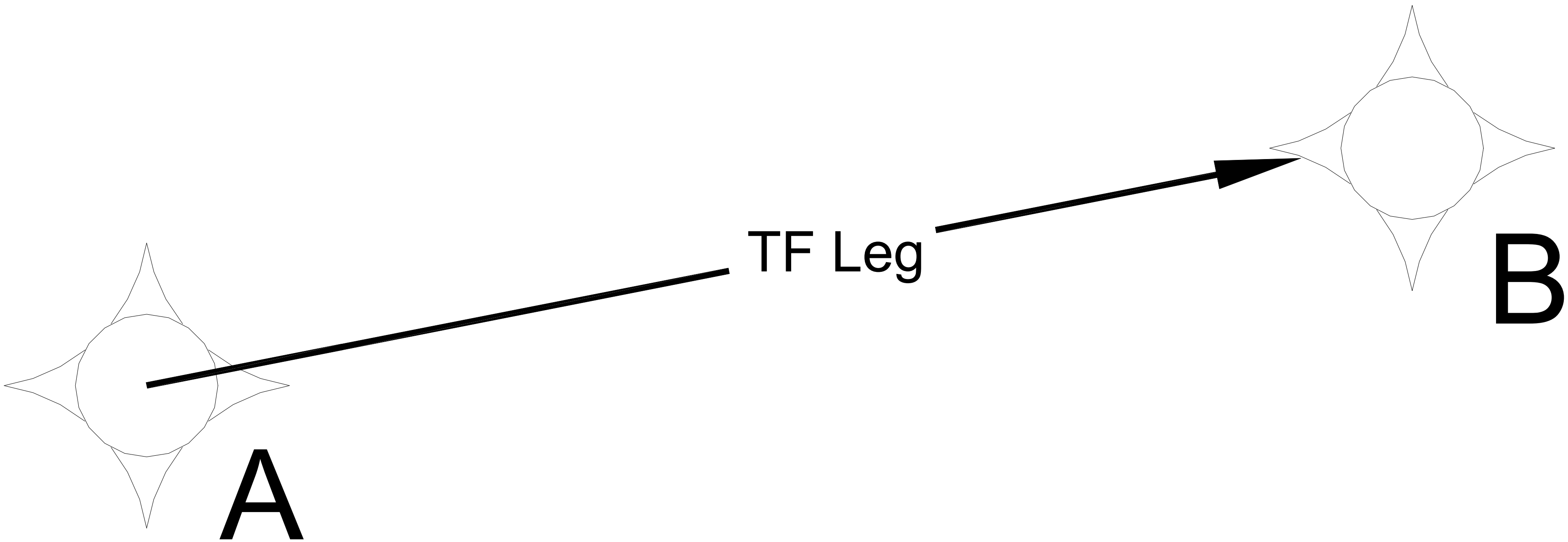
Path Terminators

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		

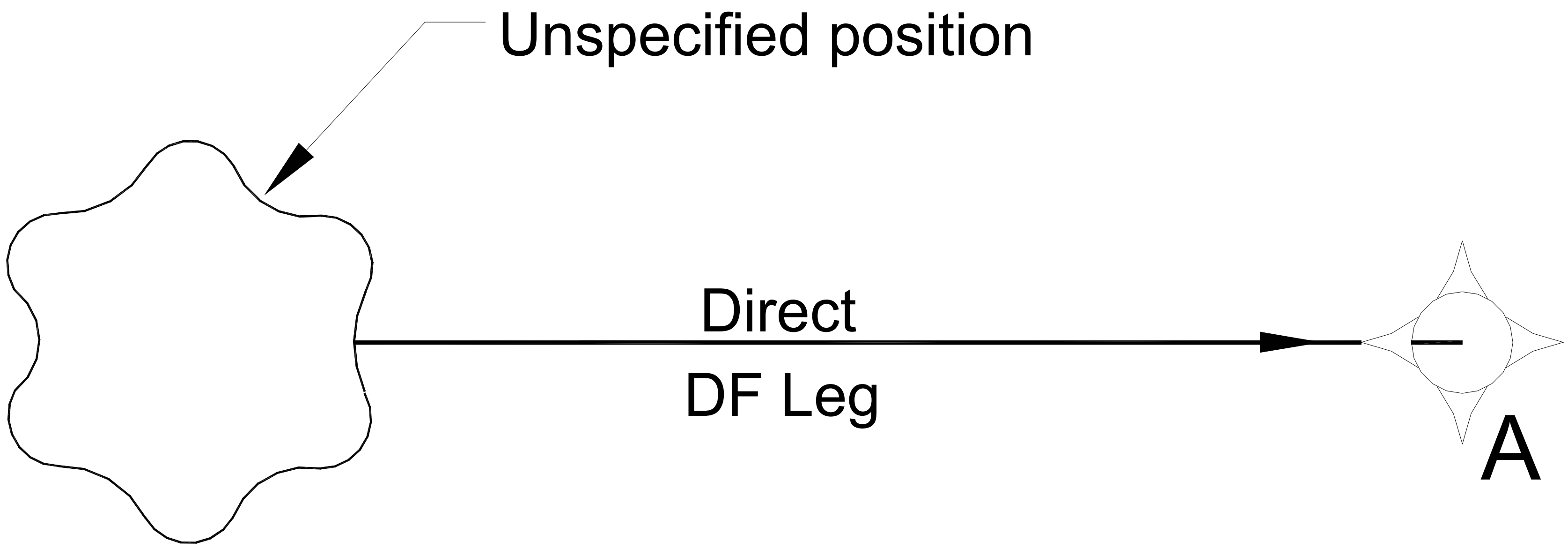
Common Path Terminators

- Track to Fix - TF
- Direct to Fix - DF
- Course to Fix - CF
- Fix to Altitude - FA
- Course to Altitude - CA
- Heading to Altitude - VA
- Radius to Fix - RF
- Fix to Manual Termination - VM

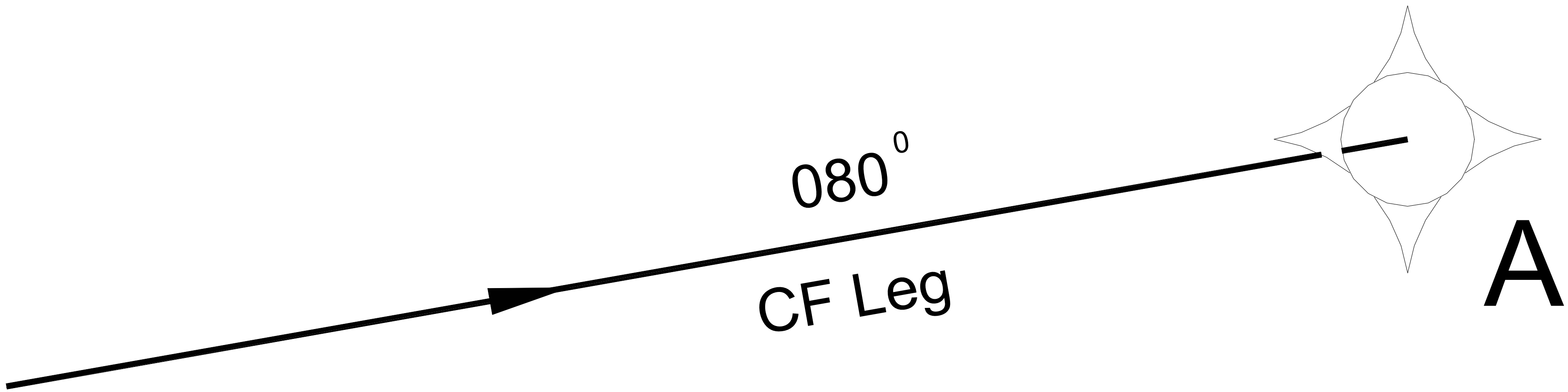
Track to Fix



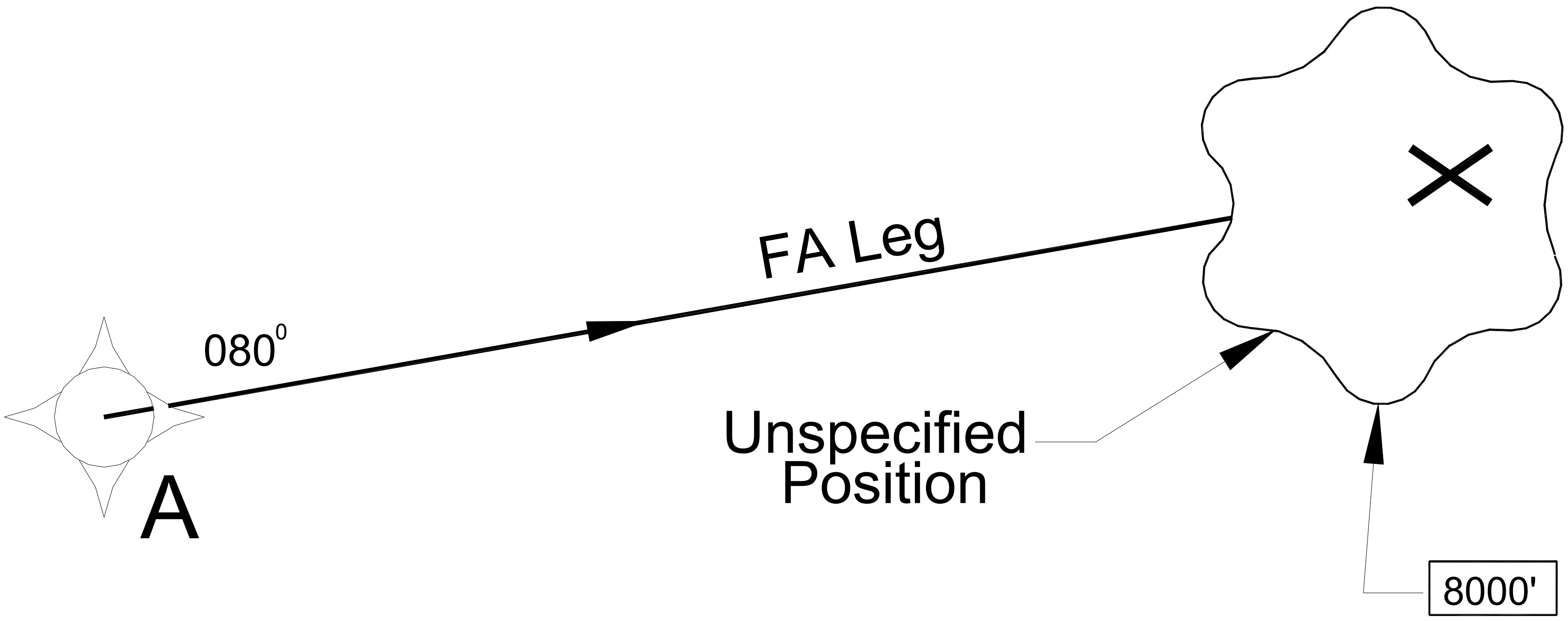
Direct to Fix



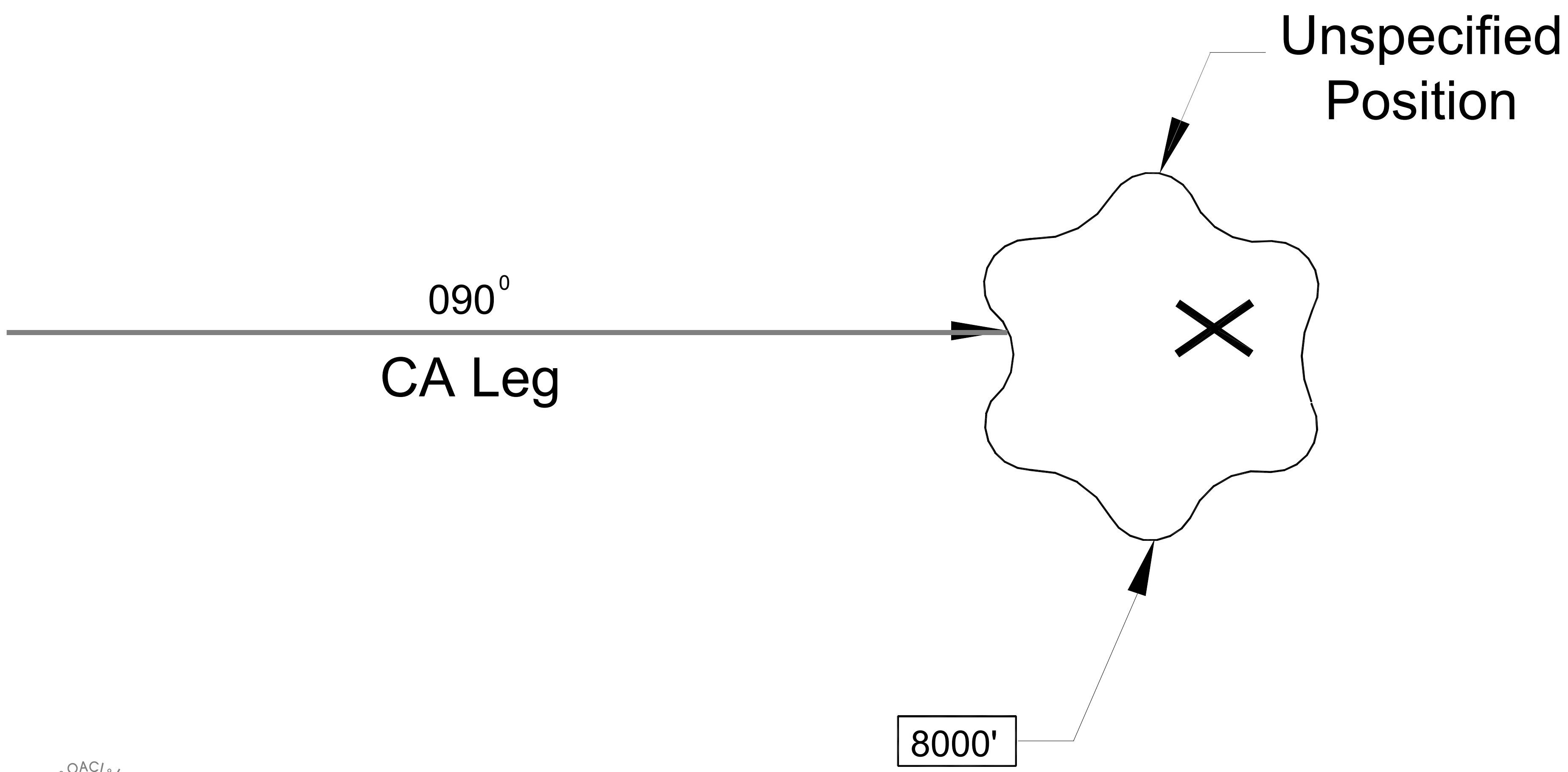
Course to Fix



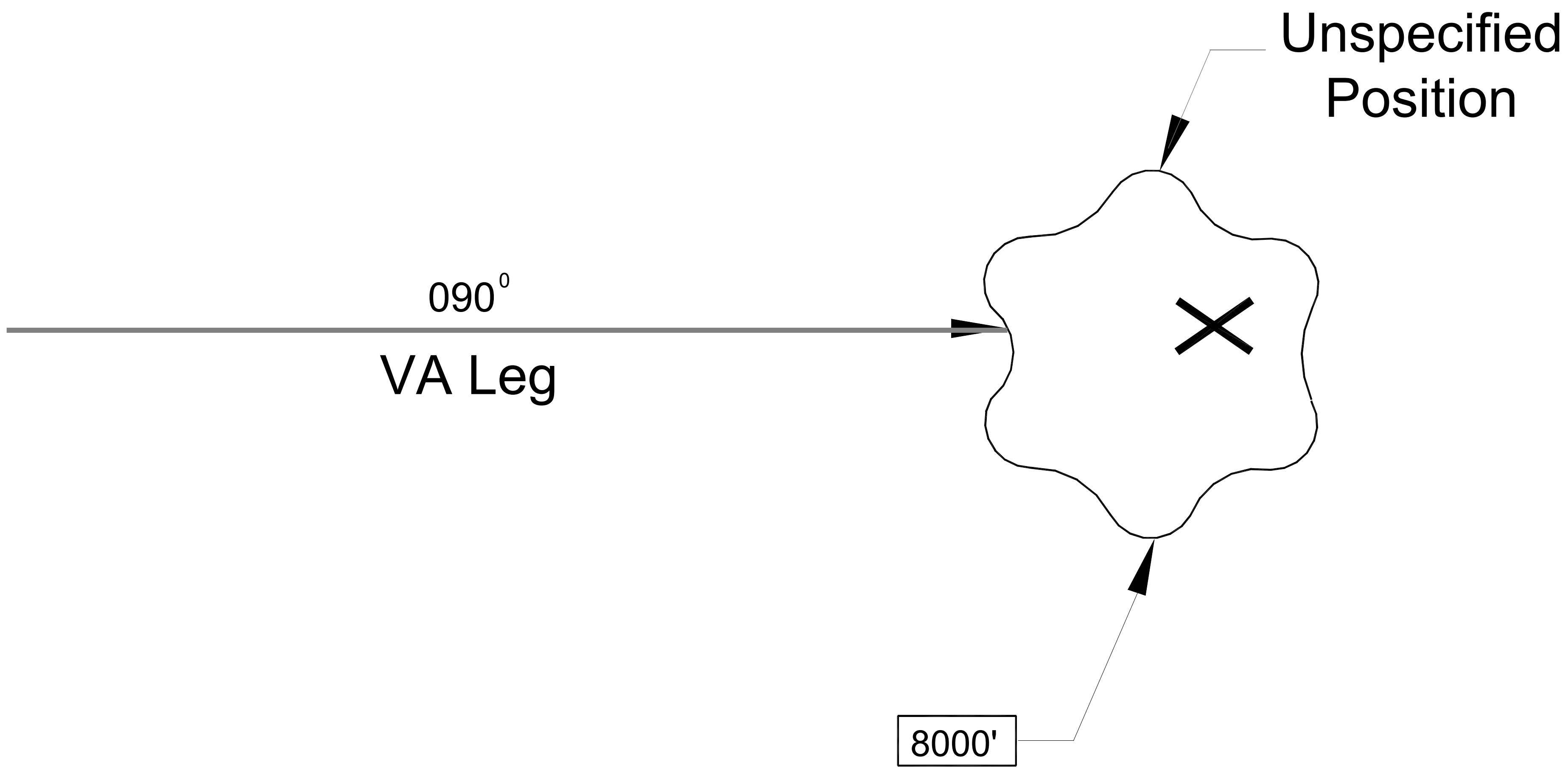
Fix to Altitude



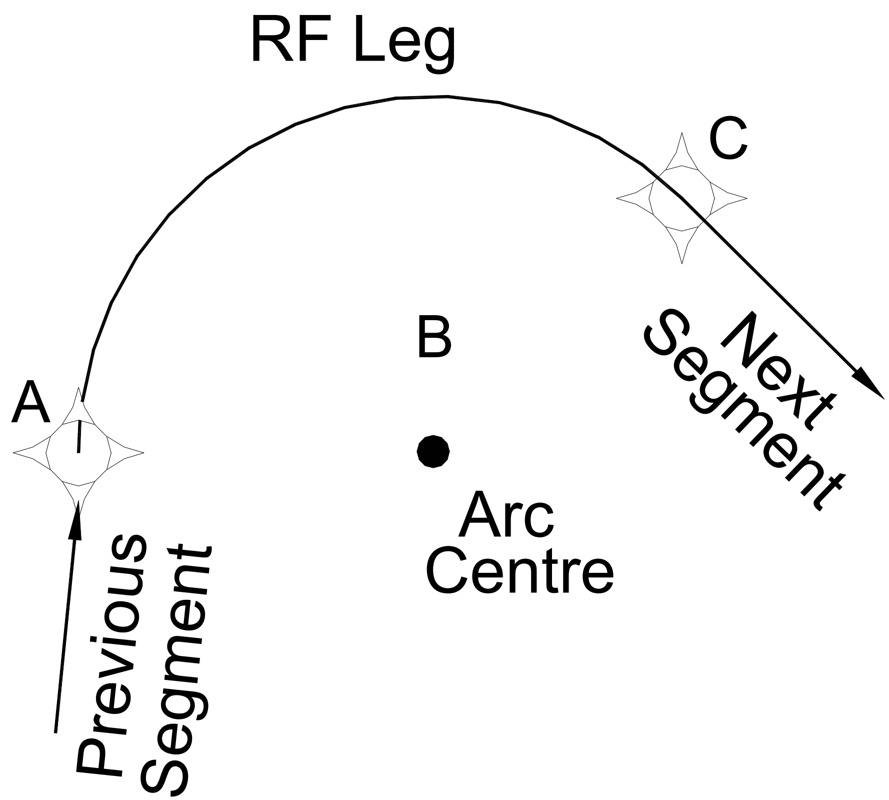
Course to Altitude



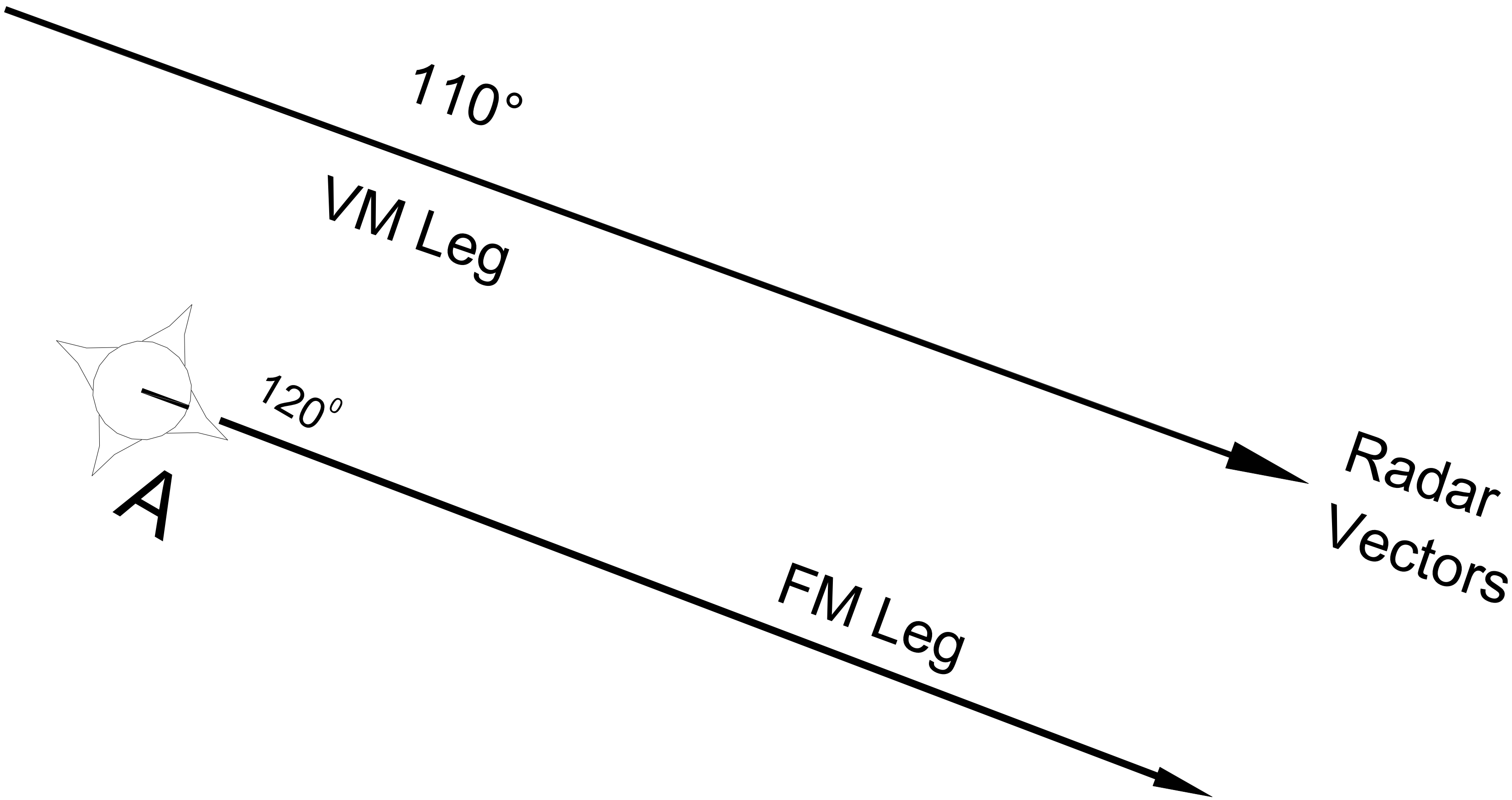
Heading to Altitude



Radius to Fix



Heading or Fix to Manual Termination



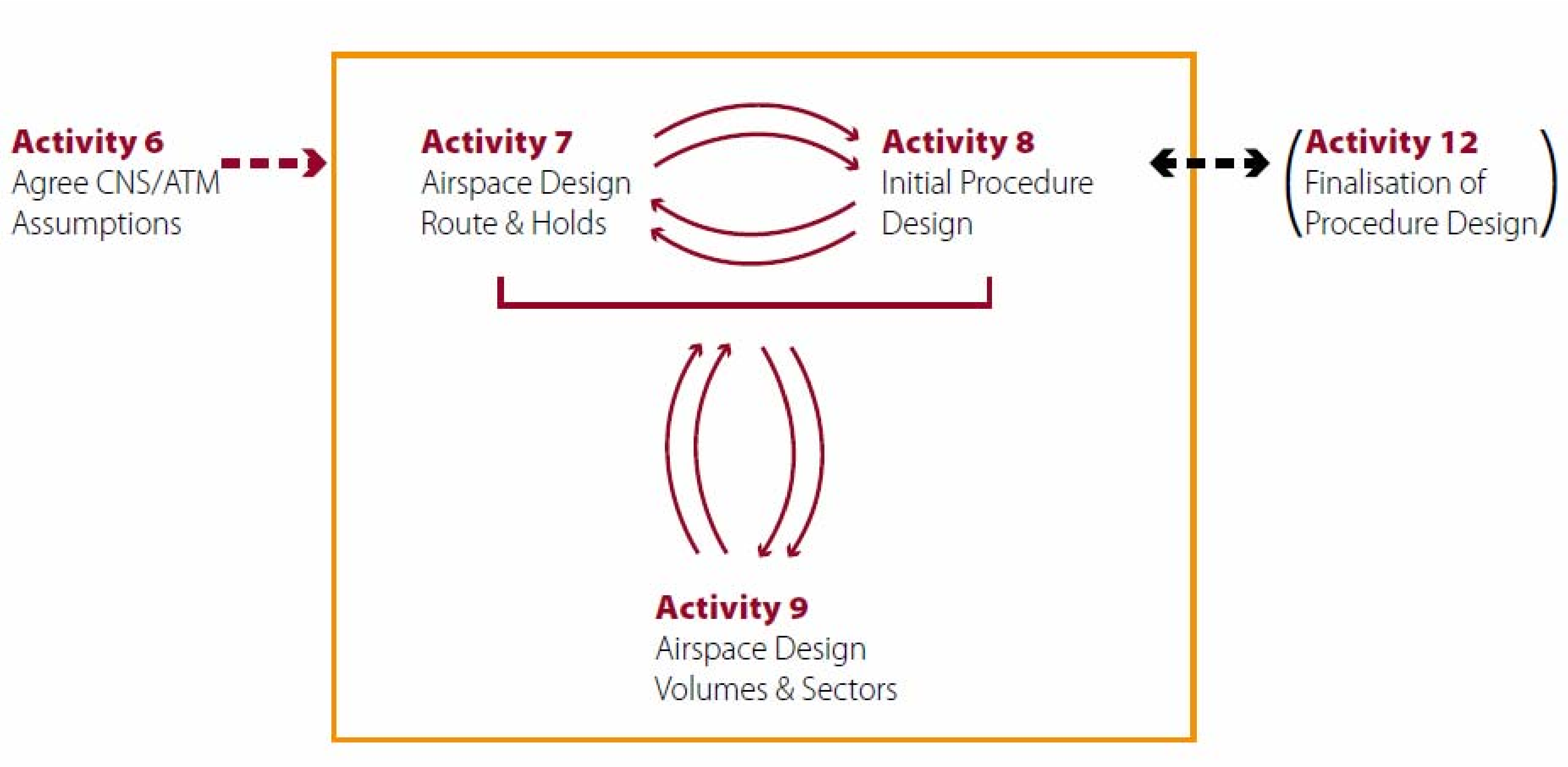
Speed and Altitude Constraints

- Speed constraints allow tighter turns and can assist ATC function
- Altitude constraints can provide separation from obstacles and other traffic - minimum climb gradients must still be published.

Reminder - Steps so far!

- What is the Intended Purpose – as per Airspace Concept
- Which Operators and Aircraft Types – as per traffic sample (assumptions)
- What is the Navaid Coverage – as per infrastructure assumptions
- What are the Environment Constraints – determined by Airspace Design Team
- What other Constraints, incl. obstacles?
- Design the Procedure

Overview



Activity 6
Agree CNS/ATM Assumptions
Activity 7
Airspace Design Route & Holds
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Finalisation of Procedure Design
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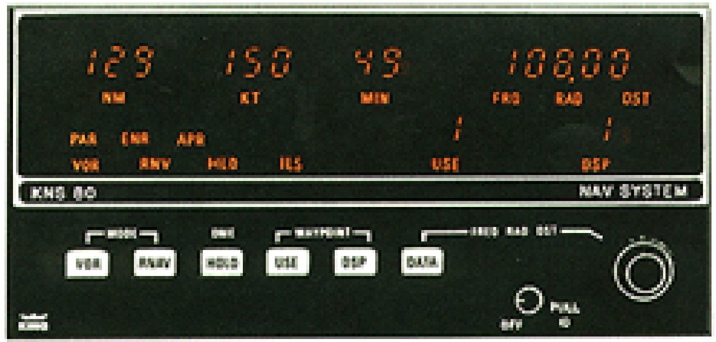
Airspace Design Volumes & Sectors

Thank You

Possible implementation of On-Board Monitoring and Alerting

NSE	FTE	PDE
		

NSE

- Alerting Threshold:
  1 x accuracy level (Nm)
- Probability missed alerting:
  10^{-7}/Flight Hour

FTE

- Crew procedure based on display scaling.
- Effective threshold:
  ½ full scale deflection
- Probability missed alerting:
  Not quantified. Crew procs.

PDE

- Based on data quality process
- LOA or equivalent
- Gross error check:
  Crew procedure

TSE Monitoring and Alerting

All Components monitored or controlled

Role of On-board Performance Monitoring and Alerting (3)

- **"On-board" means the performance monitoring and alerting is on-board the aircraft**
- **"Monitoring" relates to NSE and FTE**
  - PDE is constrained through database integrity and functional requirements on the defined path
  - "Monitoring" refers to the monitoring of the aircraft's performance; ability to determine positioning error and/or to follow the desired path
- **"Alerting" is related to monitoring**
  - Flight crew alerted if navigation system not performing to requirement

Application of On-board Performance Monitoring and Alerting (1)

- **Performance monitoring**
  - Aircraft (or aircraft and pilot in combination)
  - Required to monitor TSE
  - Provides an alert if accuracy requirement is not met, or if probability is larger than 10^{-5} that TSE exceeds 2 x accuracy value
- **Net effect of RNP navigation specifications is to bound TSE distribution**
  - PDE negligible; FTE known; NSE varies

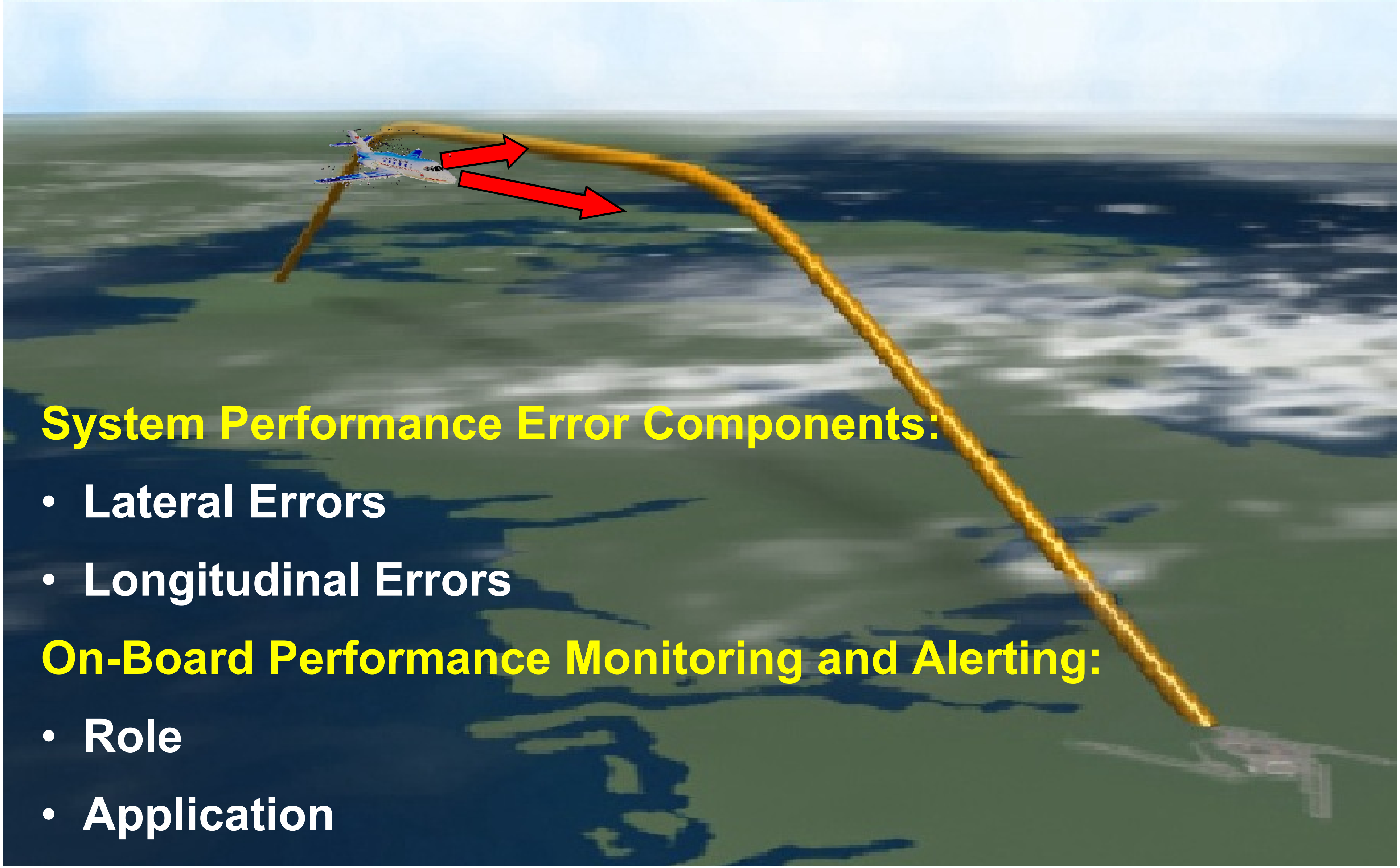
Application of On-board Performance Monitoring and Alerting (2)

- RNP specifications provide assurance that TSE is suitable for the operation
- Aircraft
  - TSE remains ≤ required accuracy for 95% of flight time; and
  - Probability TSE for each aircraft exceeds specified TSE (2 x RNP) without annunciation is $< 10^{-5}$
- **Performance monitoring is not error monitoring**

Application of On-board Performance Monitoring and Alerting (3)

- Safety assessment
  - Performance monitoring and alerting for RNP 4, RNP 1 and RNP APCH does not obviate need for safety assessments
  - Cannot assume appropriate route spacing is 4 x RNP
  - Navigation database errors not covered by nav specs
- RNP AR APCH
  - Additional requirements to more tightly control each error source

Navigation Performance



System Performance Error Components:

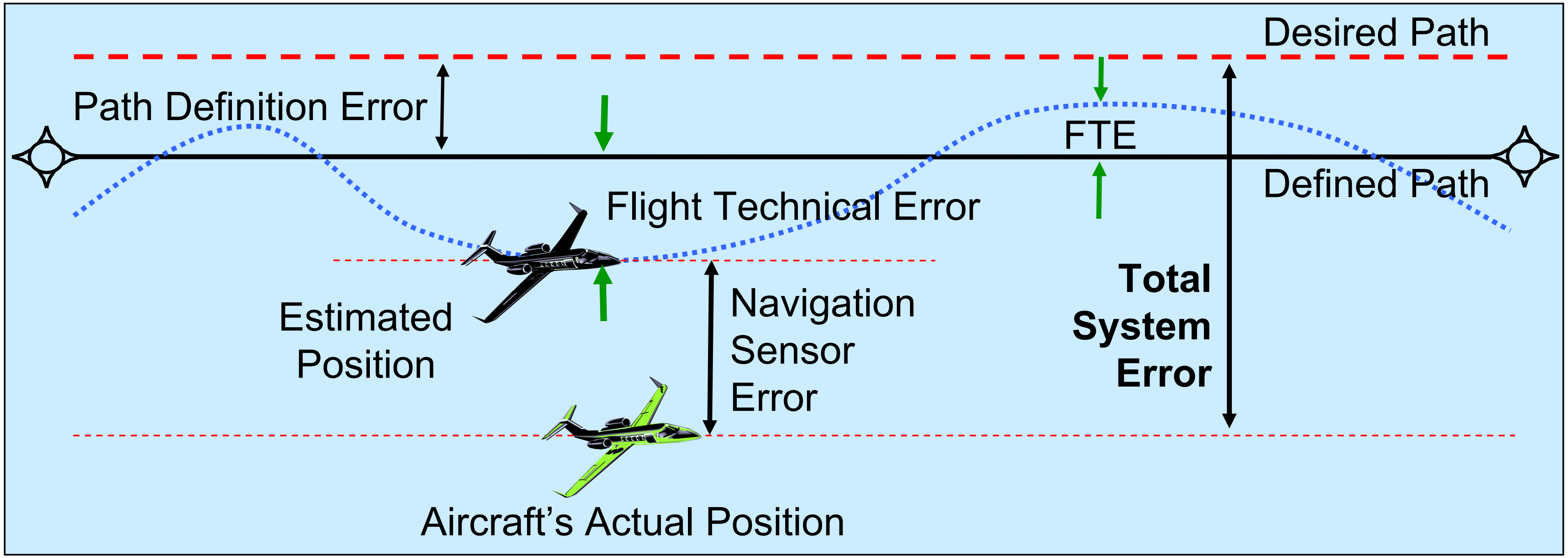
- Lateral Errors
- Longitudinal Errors

On-Board Performance Monitoring and Alerting:

- Role
- Application

System Performance Error Components

- Lateral navigation errors (95% of flight time)
  - Characterized by the Total System Error (**TSE**):



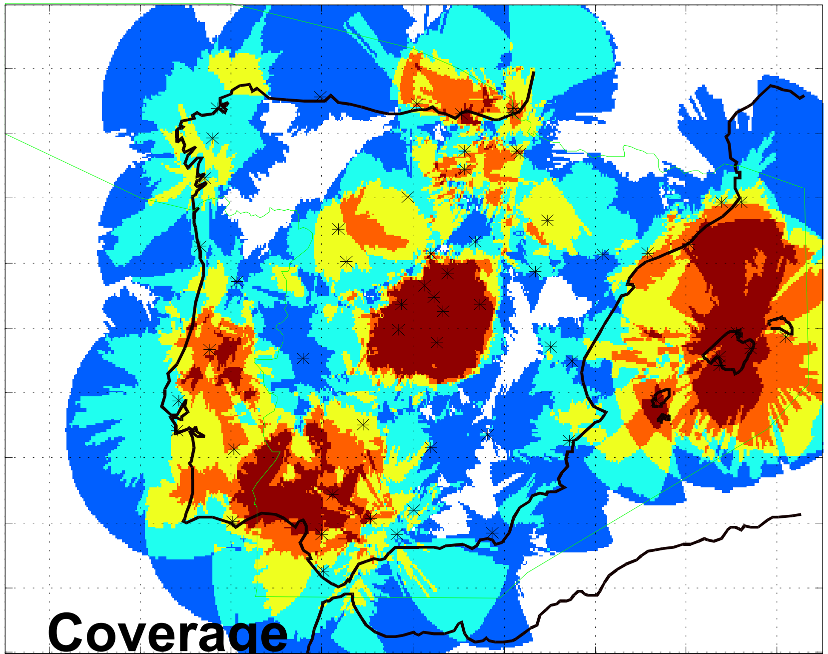
  - TSE is the Root Sum Square (RSS) of 3 errors:
    PDE, **NSE** and **FTE**

Navigation Sensor Error

SENSOR	2σ (95%)
C-VOR D-VOR	+/- 4½º +/- 2½º
DME	+/- 0.2 NM
GNSS (GPS L1 C/A)	+/- 20 m (SIS: +/- 17 m)

INS	1-2 NM/h

Other Tools



- DEMETER is not the only tool
- Example of Spanish tool
- DME assessment FL 50