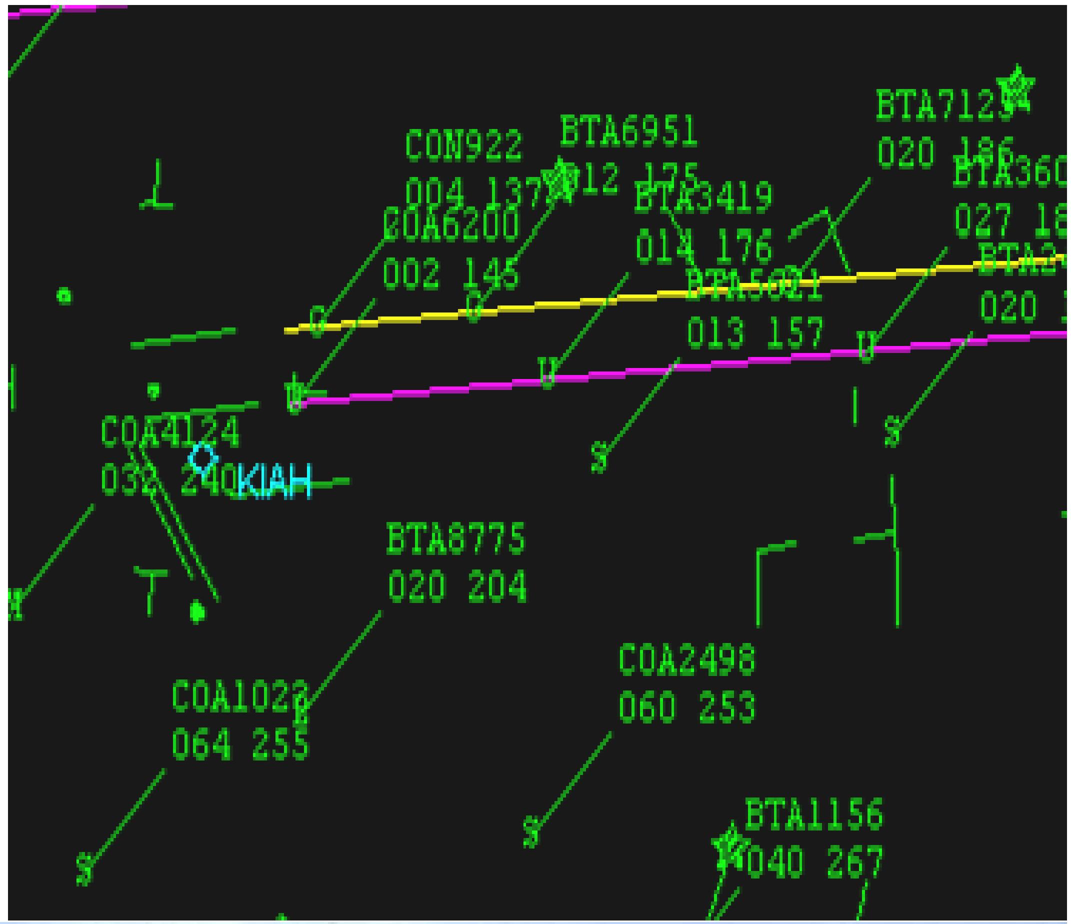
Performance Based Navigation
Introduction to PBN

Air Navigation Bureau
ICAO Headquarters, Montreal

Presentation Overview

Performance Based Navigation

- Aviation Challenges
- Navigation in Context
- Transition to PBN
- Implementation
  - Global Task Force
- Continuous Descent Operations(CDO)
  - Understanding
  - Types
  - ATC involvement

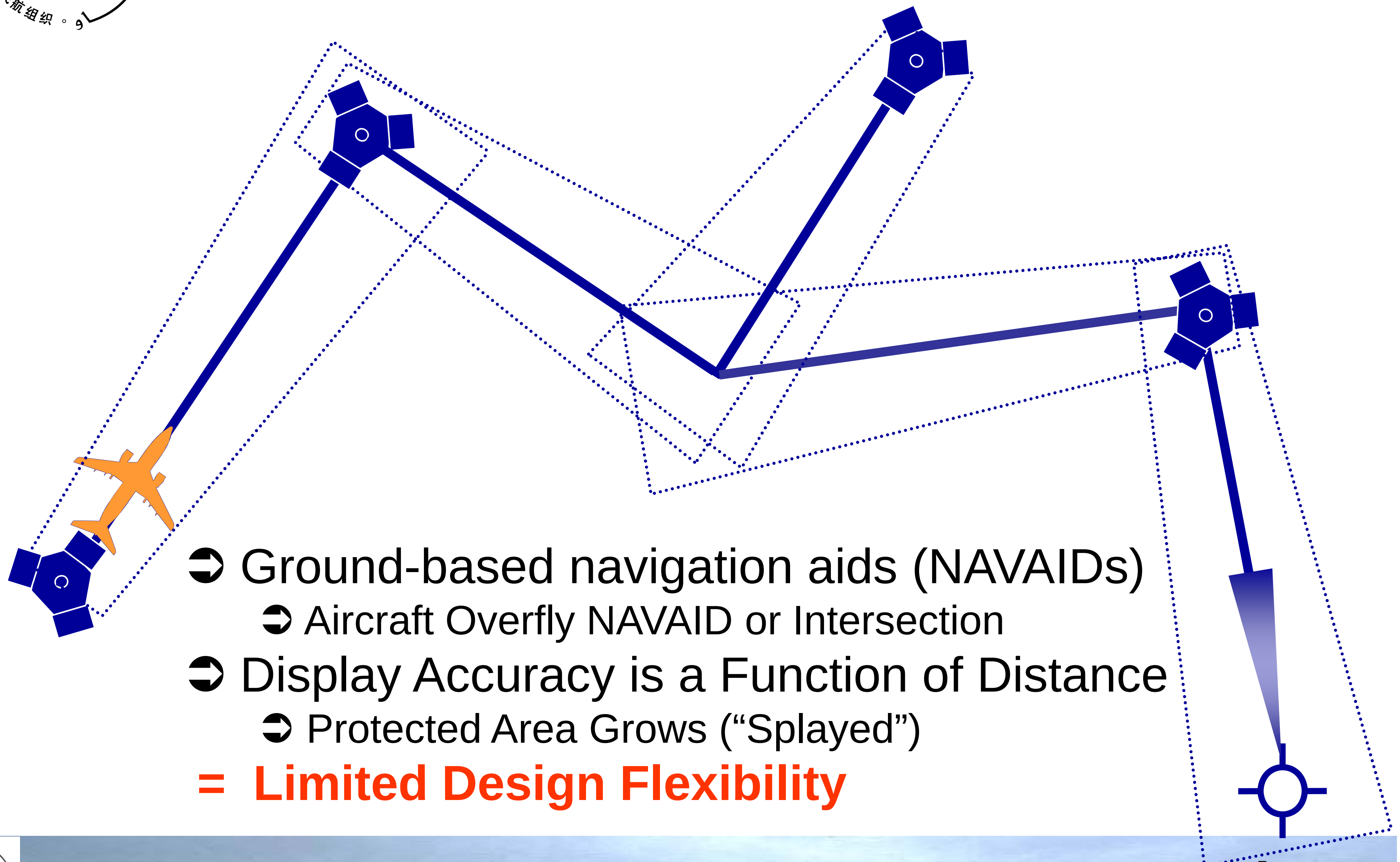


Aviation challenges

:

- Growing demand for solutions to airspace congestion
- Growing fuel efficiency requirements
- Growing Environmental requirements
- Growing demand for RNAV approaches (safety, accessibility)
- **Most can be met with current technology, but standardization and operational requirements have to be put into place**

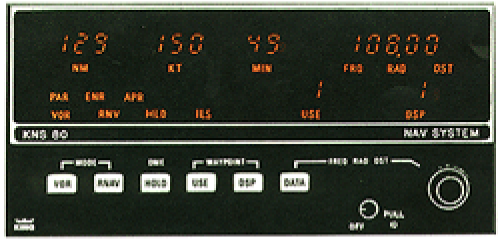
Conventional Navigation



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

= Limited Design Flexibility

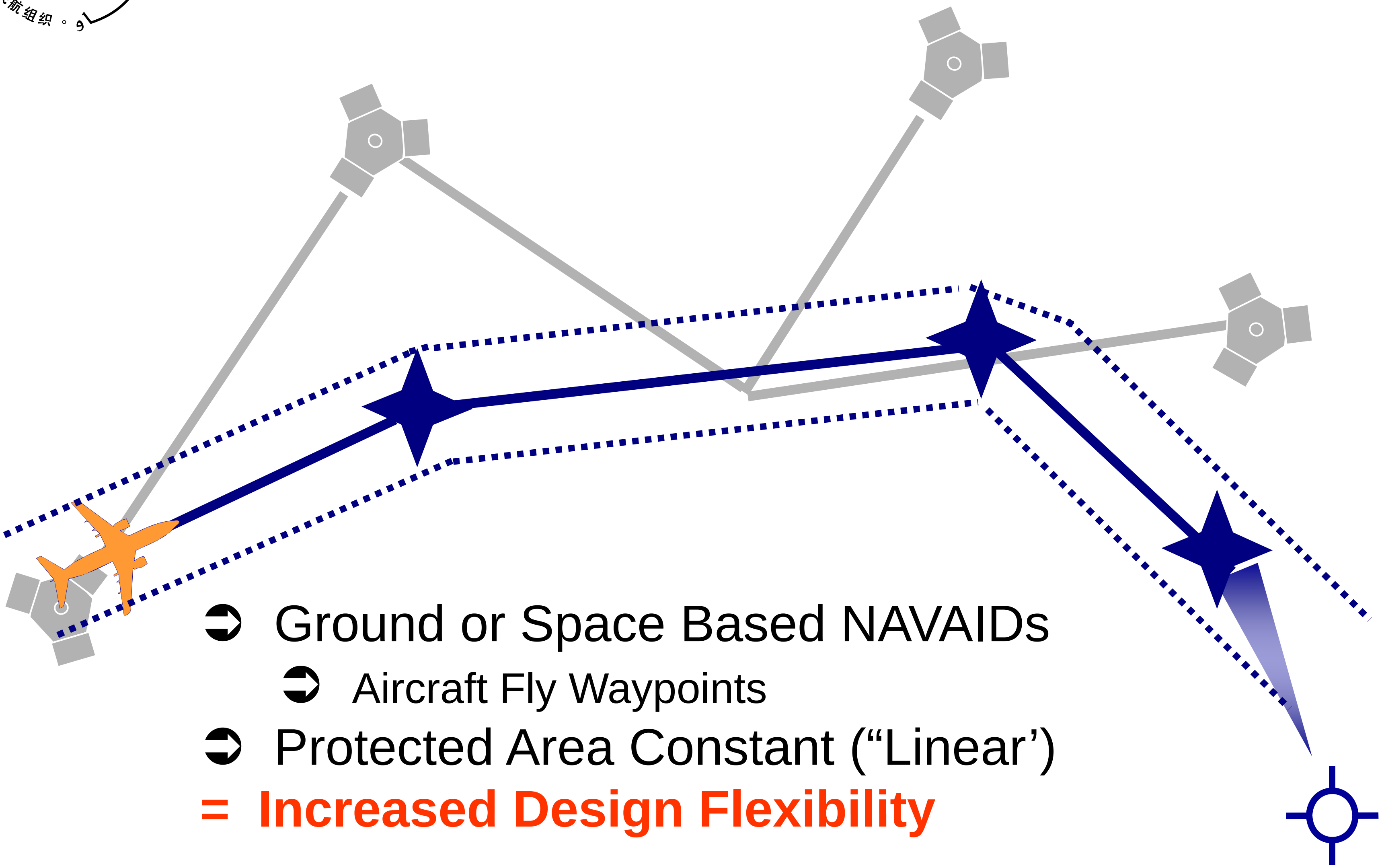
Evolution of RNAV



- – 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

Area Navigation (RNAV)



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

= Increased Design Flexibility

RNAV shortfalls

RNAV:

- Only technology based
- No clear specification among States
- Problems with inoperability
- FANS identified need for performance based navigation and developed *Required Navigation Performance* capability concept :
  - To avoid need for ICAO selection between competing systems
- Addressed only the en-route phase of flight (RNP-10 and RNP-4) for oceanic and remote applications
- No ICAO RNP requirements for continental enroute and terminal applications. This led to:

Proliferation of national standards

Wide variety of functional requirements

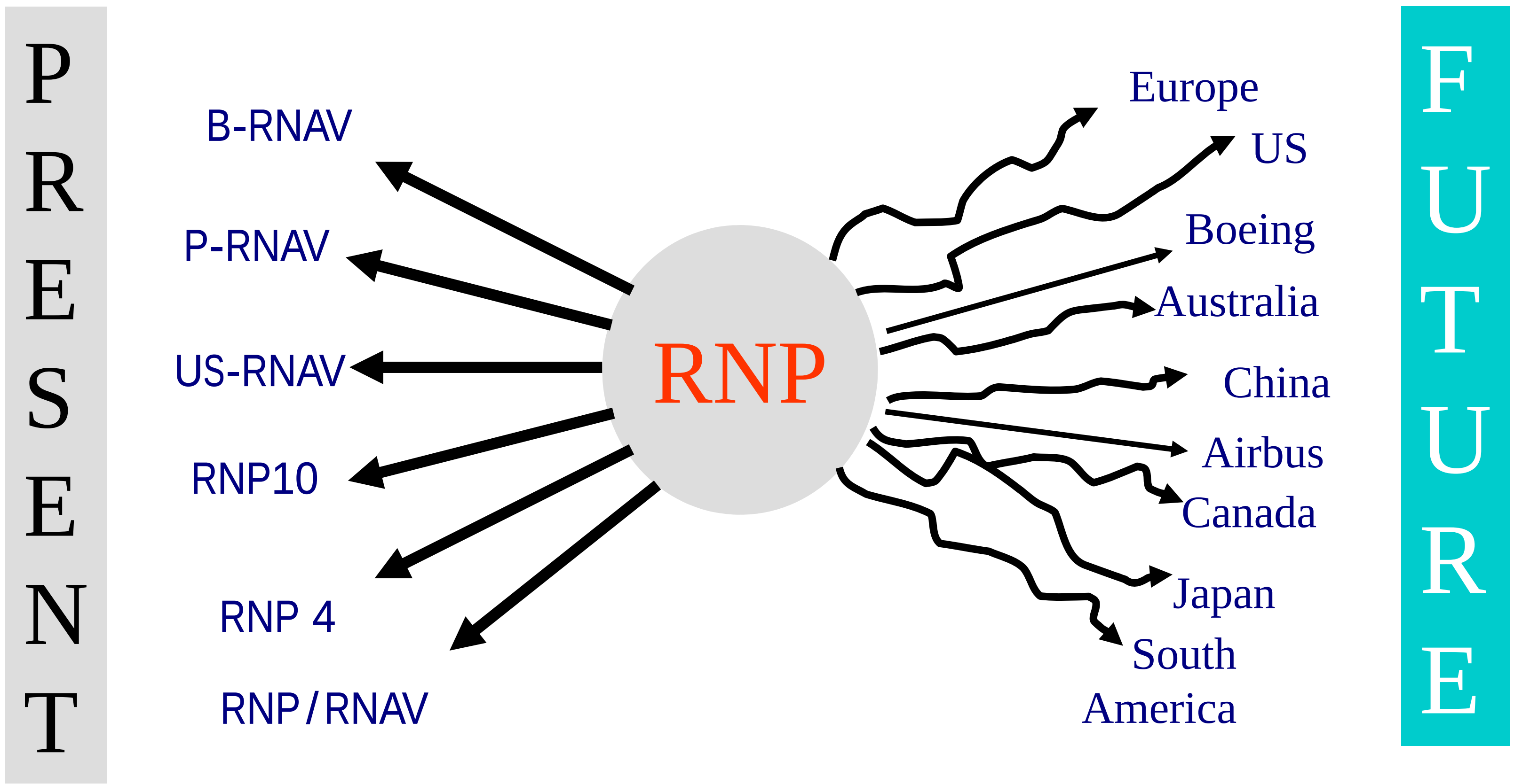
Variety of required navigation sensors

Differing air crew requirements

Differing industry concept of RNP (on-board performance monitoring and alerting)

Lack of global harmonization

Are we now going the right way?



Not safe, not efficient, costly, confusing

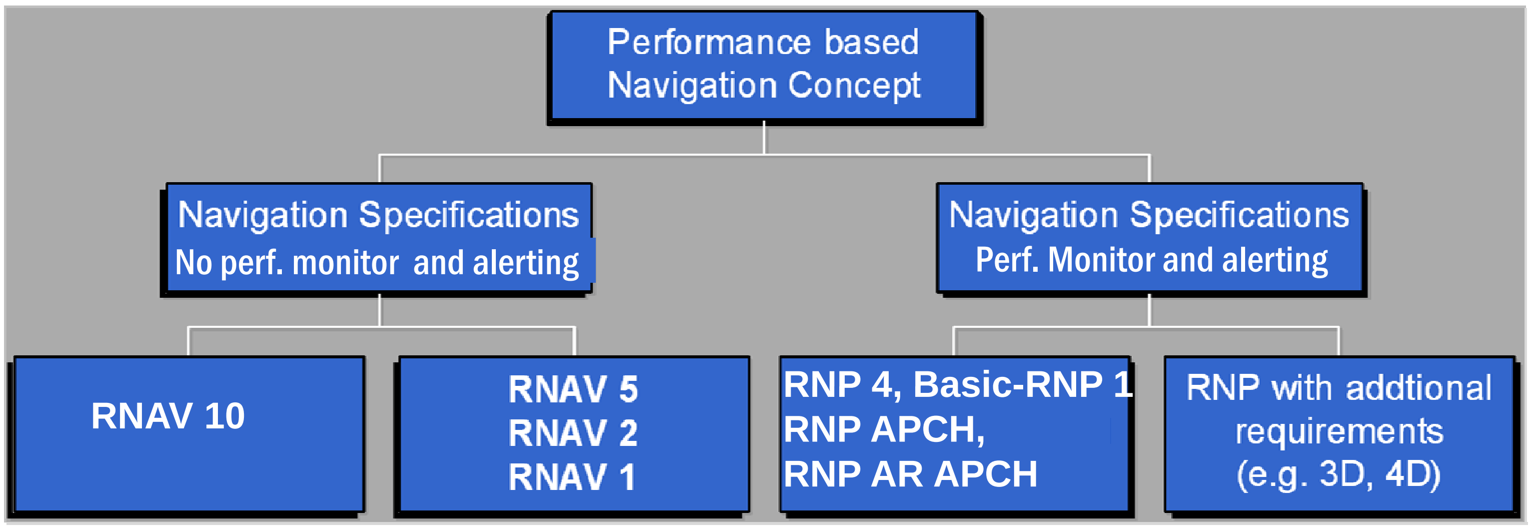
Transition to Performance Based Navigation

- Navigation based on specified system performance requirements for aircraft operating on a air traffic route, instrument approach procedure, or in a designated airspace
  - Potential for aircraft to demonstrate requirements compliance through a mix of capabilities, rather than only specific equipment
  - Regulators will not always need to write new compliance documents for new capabilities

PBN makes a clear distinction between *RNAV Applications* and *RNP Applications*

PBN Study Group (PBNSG)

Performance Based Navigation Concept

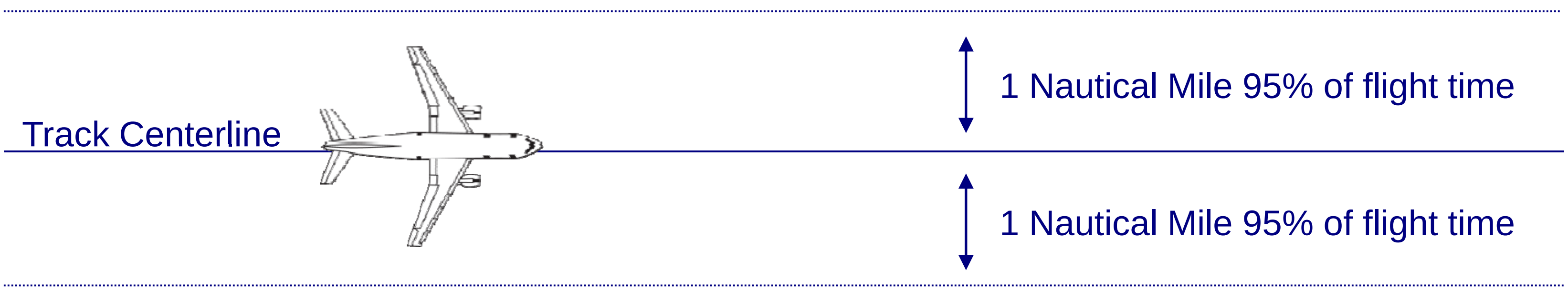


Performance Based Navigation (PBN)

Area navigation based on performance requirements for aircraft that are described in navigation specifications

RNAV Application (notional)

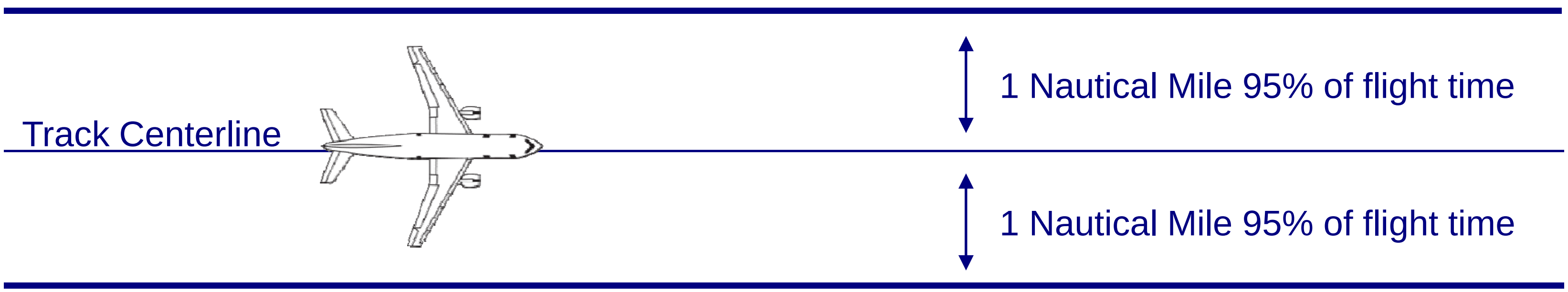
RNAV 1



RNP Application (notional)

RNP 1

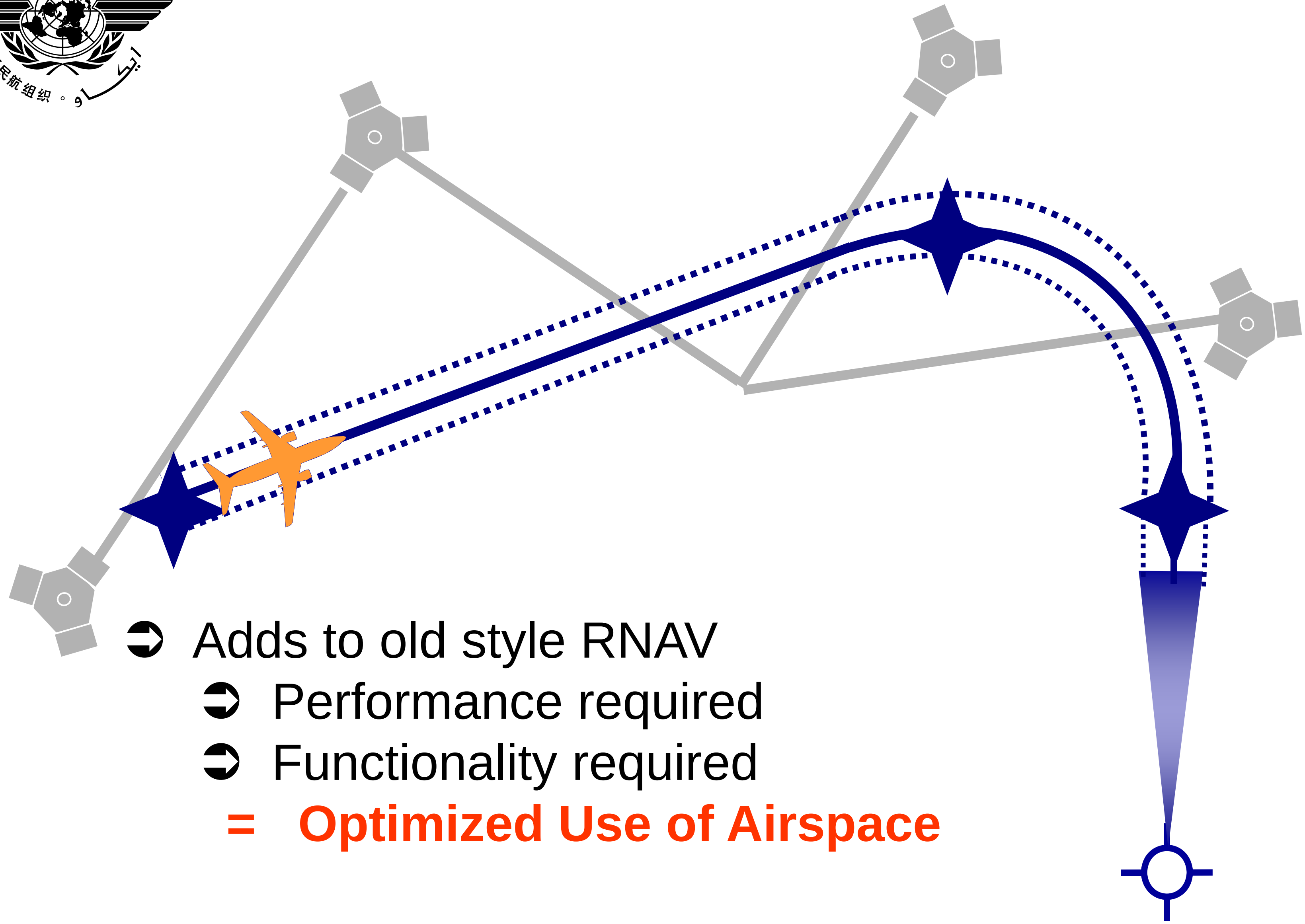
Alert to Pilot



The Key Difference:

On-Board Performance Monitoring and Alerting

PBN

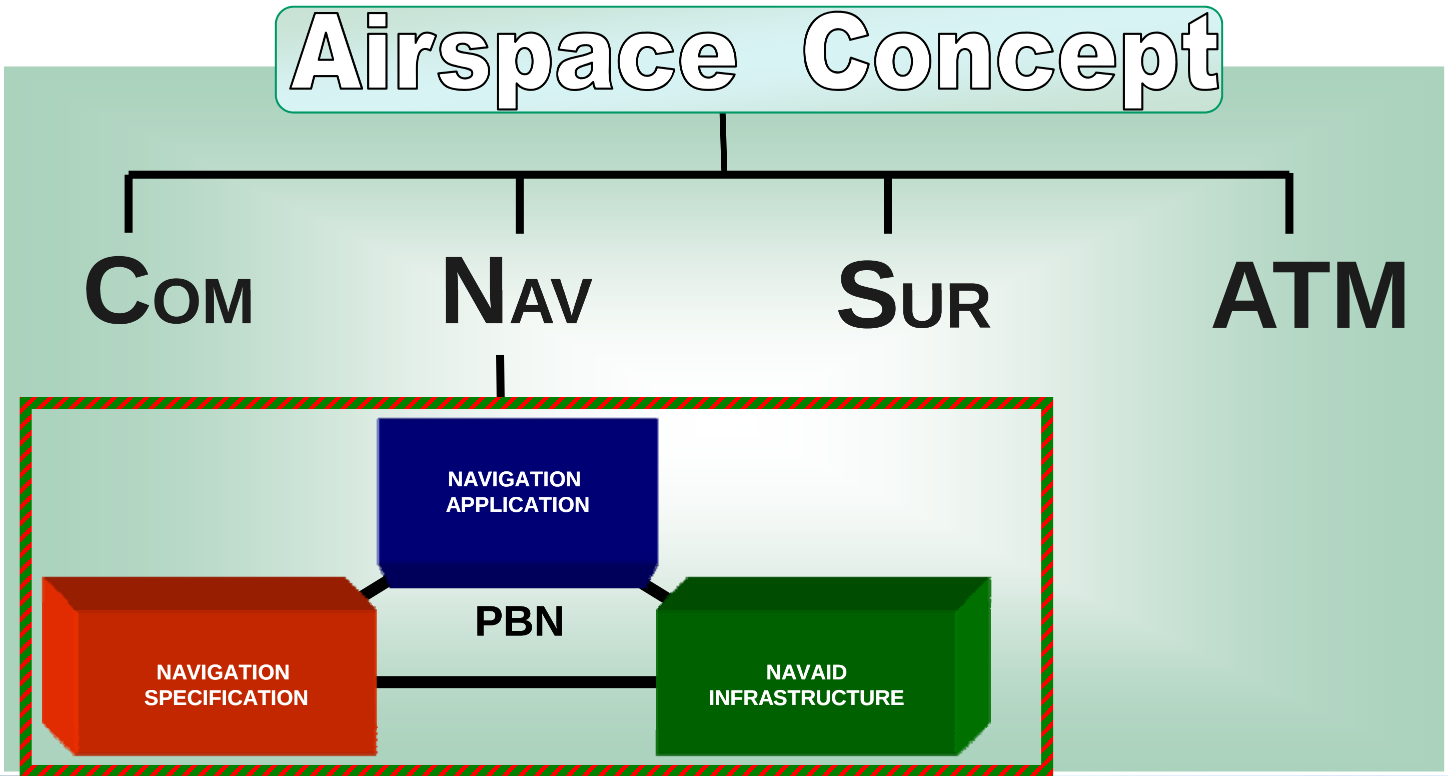


- Adds to old style RNAV
  - Performance required
  - Functionality required

= Optimized Use of Airspace

Context of PBN

ICAO GLOBAL ATM CONCEPT



Global PBN

Standards and Guidance

- 2007: Assembly resolution 36-23 is adopted
- 2008*:* ICAO established a PBN study group
- 2008: ICAO Doc 9613, *Performance Based Navigation* (PBN) Manual
- 2010: ICAO Doc 9931, *Continuous Descent Operations* (CDO) Manual
- 2010: ICAO PBN *Operational Approval Manual*
- 2010: Develop a *Continuous Climb Operations* (CCO) Manual
- 2010: Update *Global Navigation Satellite System* (GNSS) manual

Global PBN

Training, Education, and Familiarization

- 2007-09: PBN Seminars conducted in every ICAO region.

  (in coordination with Eurocontrol and FAA)

- 2010-11: ICAO Continuous Descent Operations (CDO) seminar conducted in every ICAO region.
- 2010-11: ICAO PBN Airspace Workshop conducted in every ICAO region. (in coordination with Eurocontrol and FAA)
- 2010-11: ICAO PBN Operational Approvals Workshop conducted in every ICAO region.

Global PBN

Actual Implementation

Global PBN Task Force:

- – Promotion Team.
- – Implementation Support Team (IST).
- – Implementation Management (GO) Team.

- 2010-11: ICAO PBN Go-Team visits to every ICAO region, which will do gap-analysis and practical application of PBN and CDO to States. (in coordination with IATA and industry partners)

Continuous Descent Operation (CDO) ICAO Doc 9931

“Done in collaboration with States around the world, through ICAO’s Instrument Flight Procedures Panel”

PBN Programme Office

ICAO

Understanding Continuous Descent Operations (CDO)

Continuous Descent Operations :

- Are enabled by airspace design, procedure design and ATC facilitation
- Where the aircraft descends continuously
- Employing minimum engine thrust, in a low drag configuration

Optimum CDO

An optimum CDO starts from the Top of Descent

Reducing:

- ATC/Pilot communication
- segments of level flight
- noise
- fuel burn
- emissions,

While Increasing:

- predictability to ATC/Pilots
- flight stability.

Optimum Vertical Path

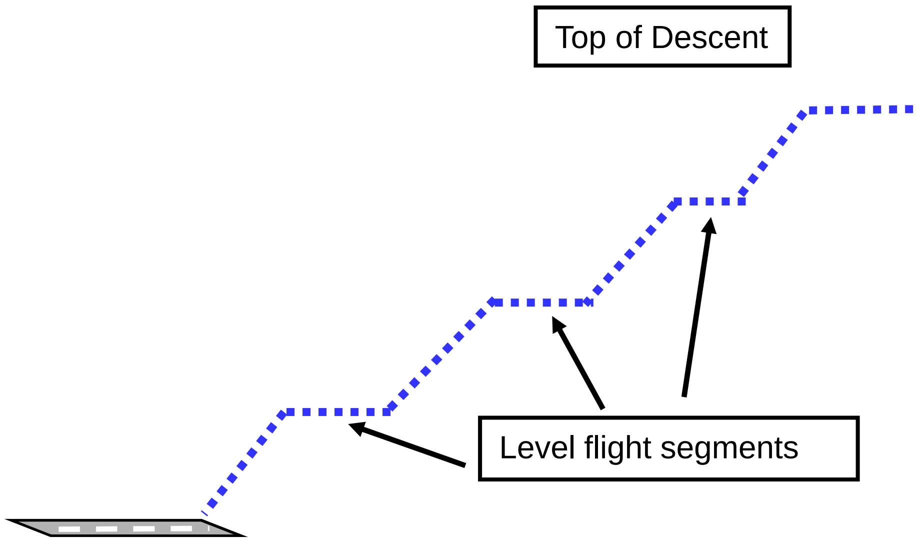
The optimum vertical path angle will vary depending on:

- type of aircraft
- its actual weight
- the wind
- air temperature
- atmospheric pressure
- icing conditions
- and other dynamic considerations

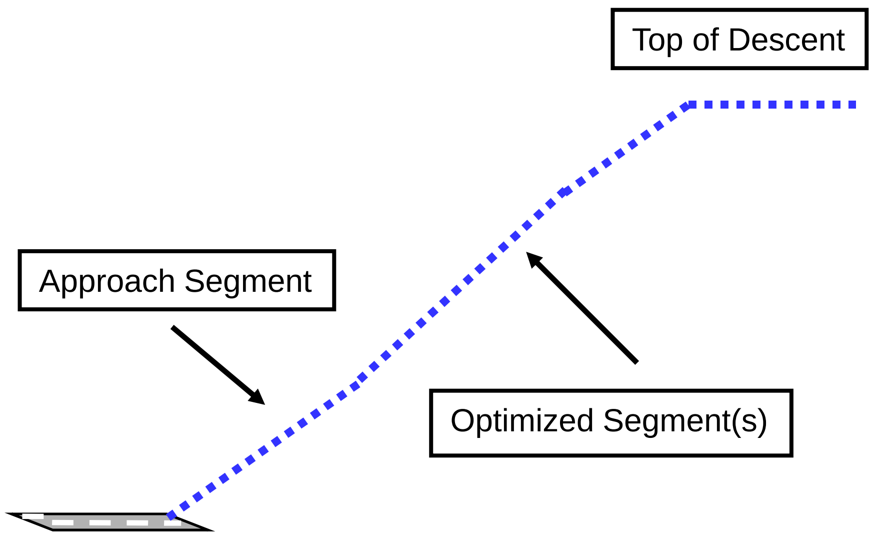
The maximum benefit is achieved by keeping the aircraft as high as possible until it reaches the optimum descent point determined by the onboard flight management computer.

Step-down vs. CDO

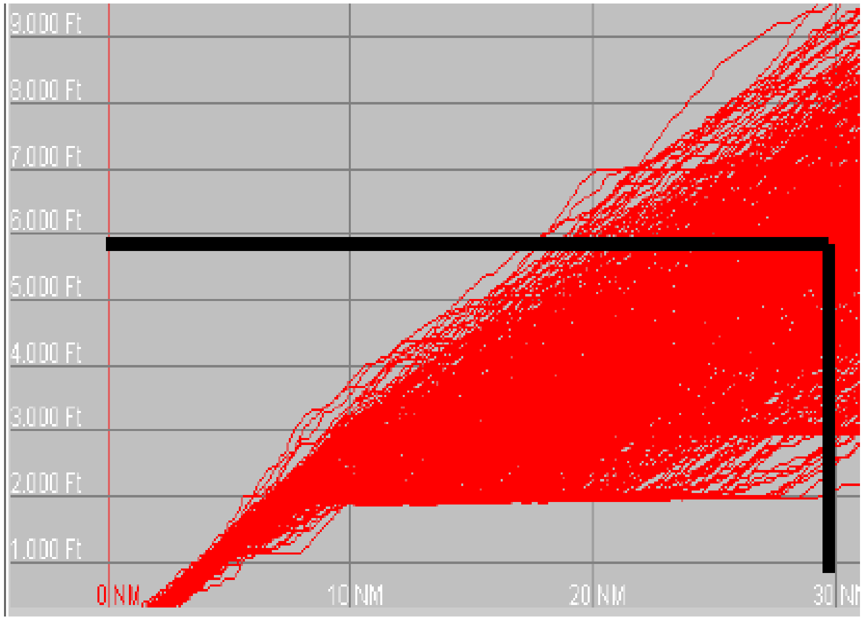
Conventional Step-down



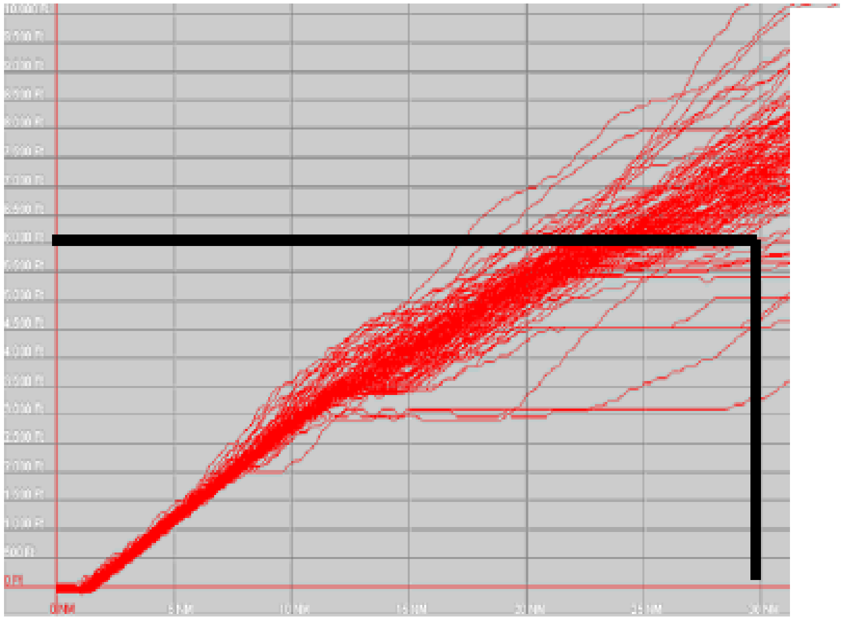
Continuous Descent Operations



Actual CDO Operation



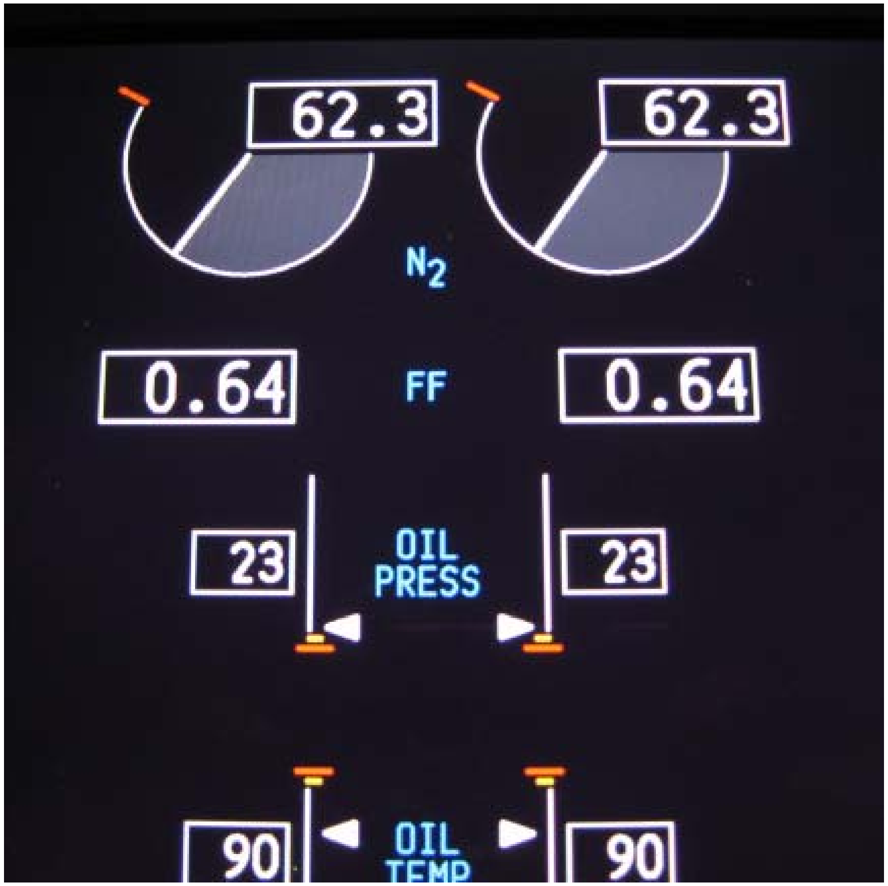
Flight tracks before CDO



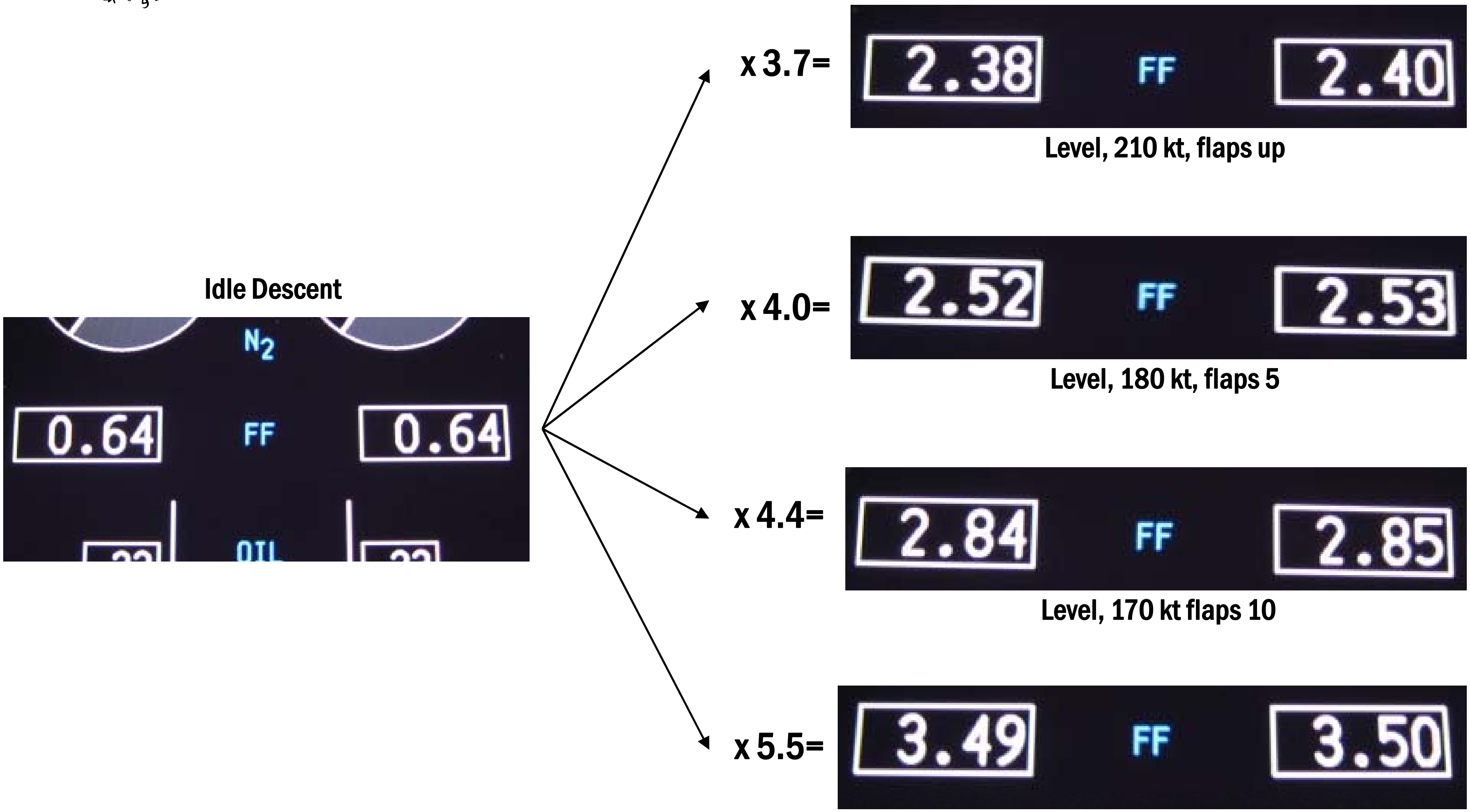
Flight tracks after CDO

Importance of an Idle Descent

- Idle Descent
- 640 lbs/hr/engine
- 1280 lbs/hr
- 3.2 gal/min



Level-offs Use 4 to 5 Times More Fuel Than a Idle Descent!



Level, 210 kt, flaps up

Level, 180 kt, flaps 5

Level, 170 kt flaps 10

Level, 160 kt, flaps 15

Selecting a CDO Design

CDO facilitation methods should be selected and designed with the goal of allowing the highest percentage of use during the broadest periods of air traffic operations.

"Open-path or Closed-path"

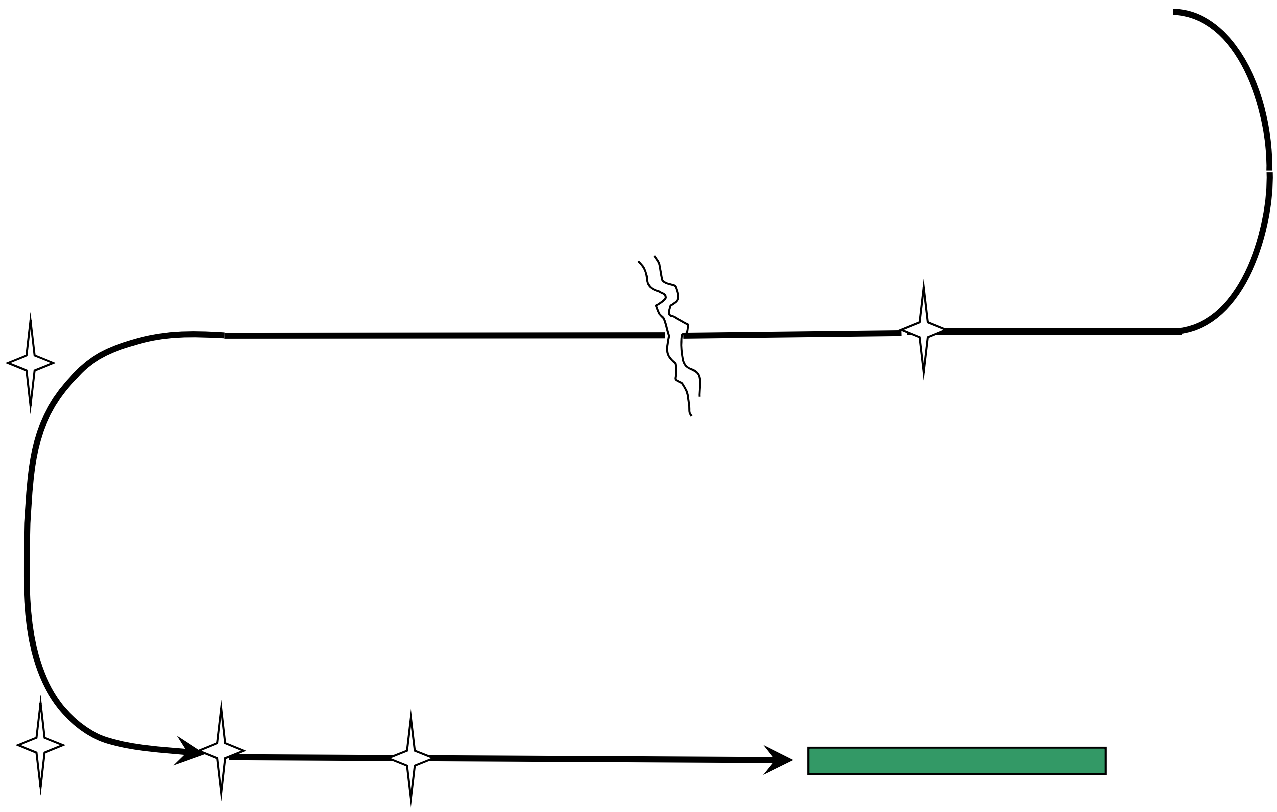
CDO Closed Path Design

Closed path designs:

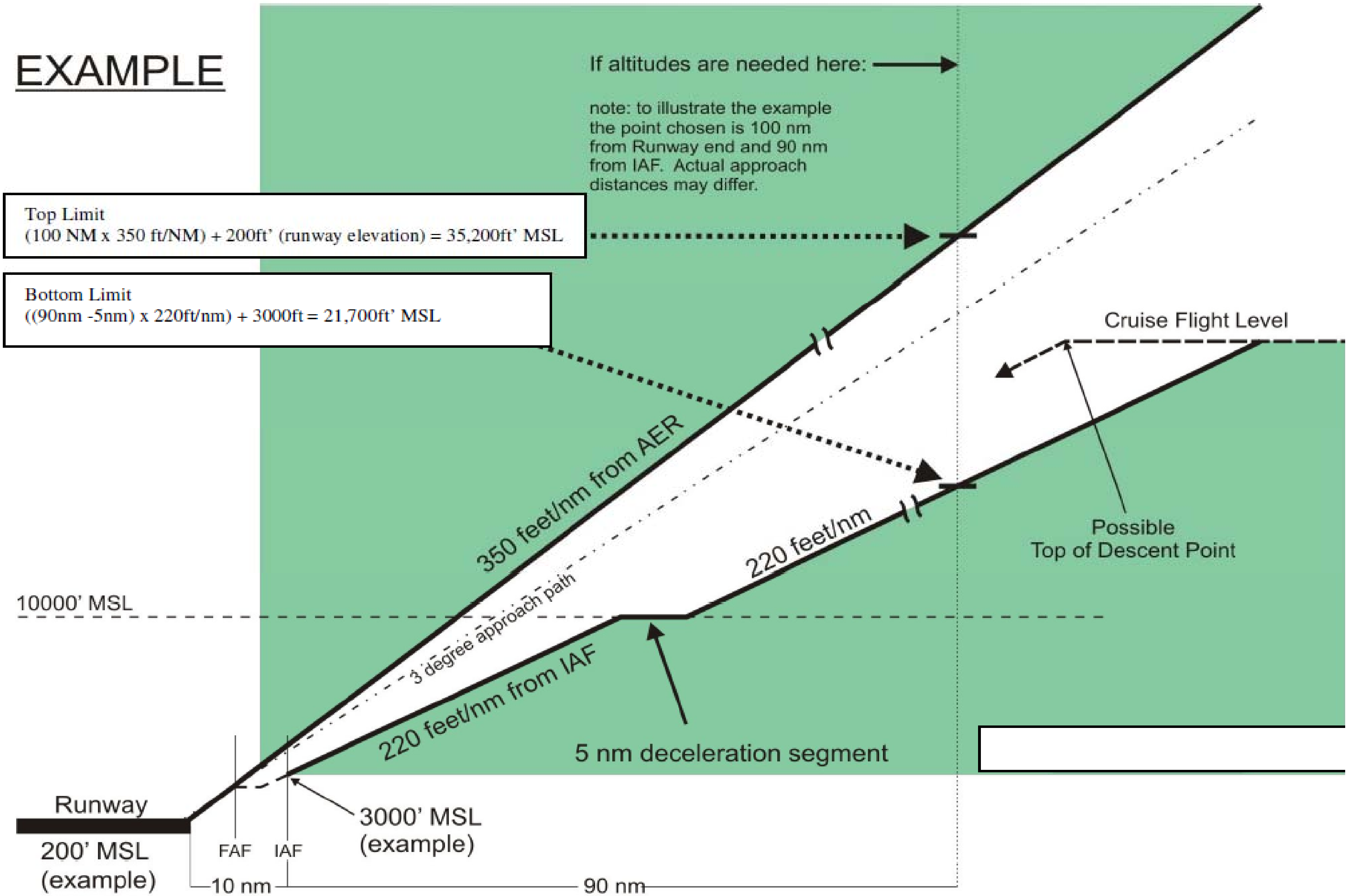
- are procedural designs
- the lateral flight track is pre-defined up to and including the Final Approach Fix
- the exact distance to runway is precisely known
- The procedure may be published with crossing levels, level windows and/or speed constraints

An example of a closed path procedure is a STAR terminating at a point that defines a part of an instrument approach and is thus directly linked to an approach procedure

STAR and (initial) approach phases of flight until the FAF



EXAMPLE


If altitudes are needed here:
note: to illustrate the example the point chosen is 100 nm from Runway end and 90 nm from IAF. Actual approach distances may differ.
Top Limit
(100 NM x 350 ft/NM) + 200ft' (runway elevation) = 35,200ft' MSL
Bottom Limit
((90nm -5nm) x 220ft/nm) + 3000ft = 21,700ft' MSL
Cruise Flight Level
350 feet/nm from AER
3 degree approach path
220 feet/nm
Possible
Top of Descent Point
10000' MSL
220 feet/nm from IAF
5 nm deceleration segment
Runway
200' MSL
(example)
FAF
IAF
3000' MSL
(example)
10 nm
90 nm

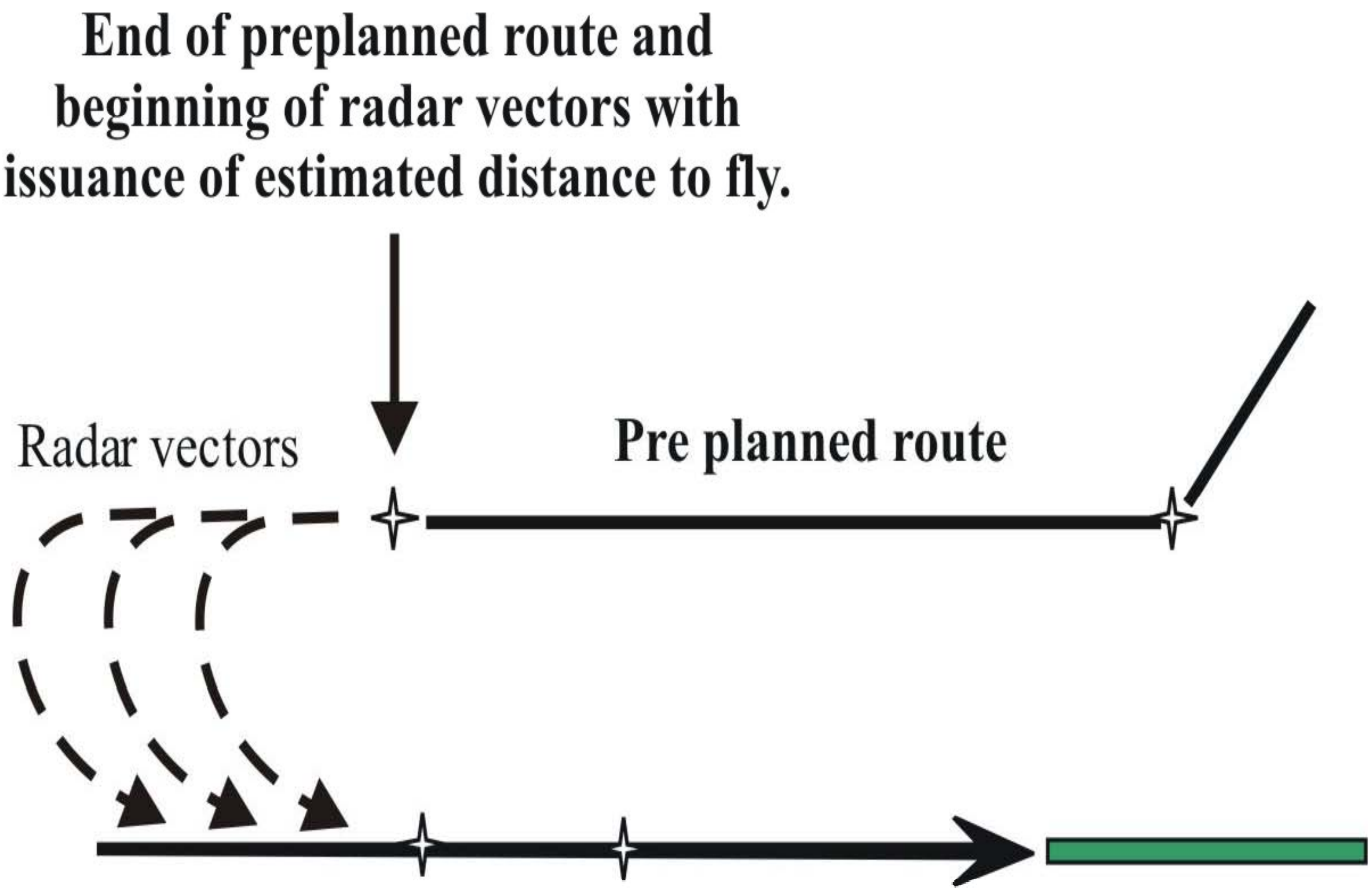
CDO Open Path Design

Open path designs are designs where the procedure does finish before the final approach Fix.

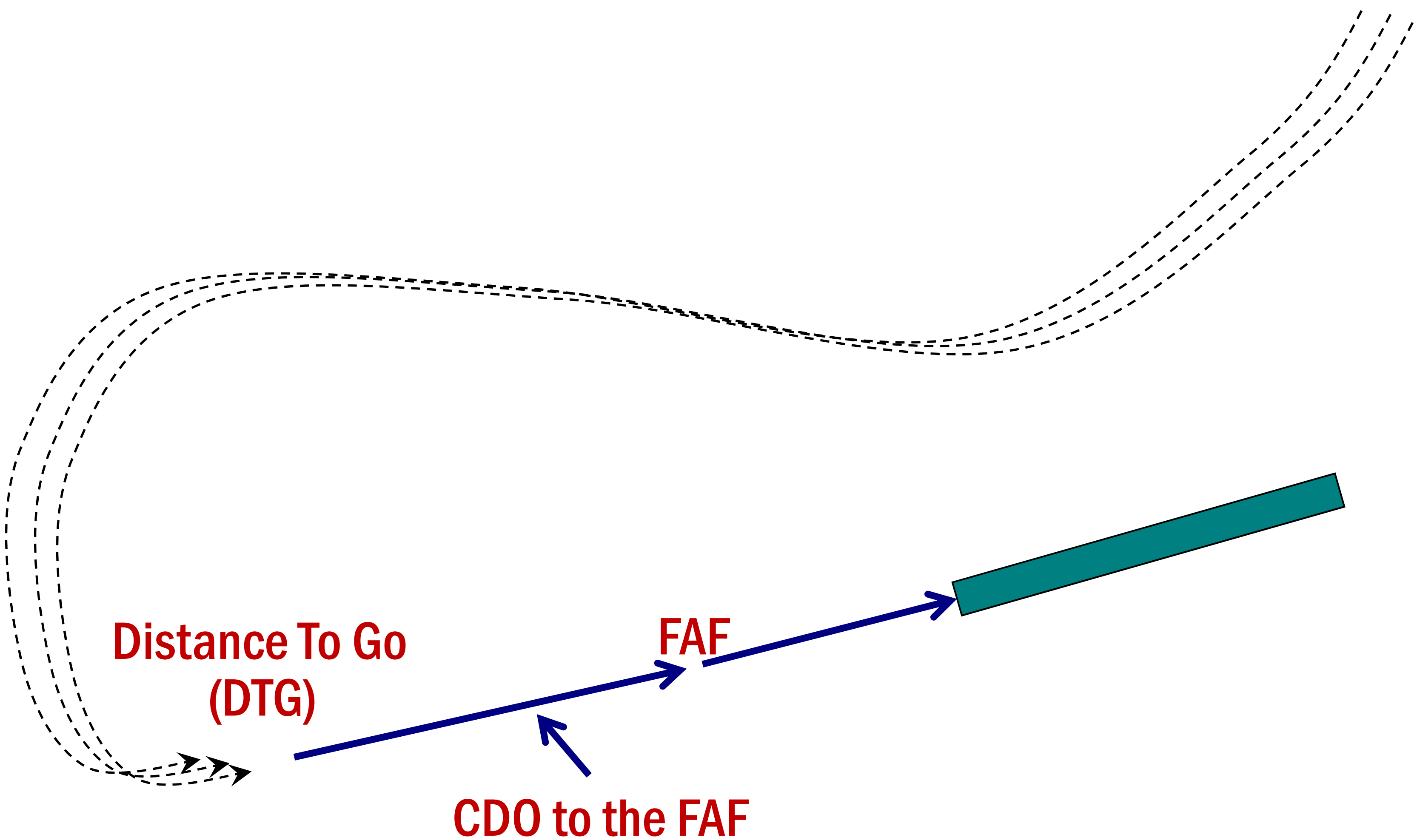
Two main types of open paths exist:

- The first ending in a downwind leg leaving the controller to clear the aircraft to final.
- The second option is where the approach sequencing is undertaken by radar vectors, here the CDO can only be planned to the metering Fix and the air traffic controller will need to communicate, to the extent possible, an estimate of Distance To Go (DTG) to end of runway to the pilot. The pilot uses ATC distance estimates to determine the optimum descent rate to achieve the CDO to the FAF.

Open CDO procedure to downwind



Vectored CDO procedure

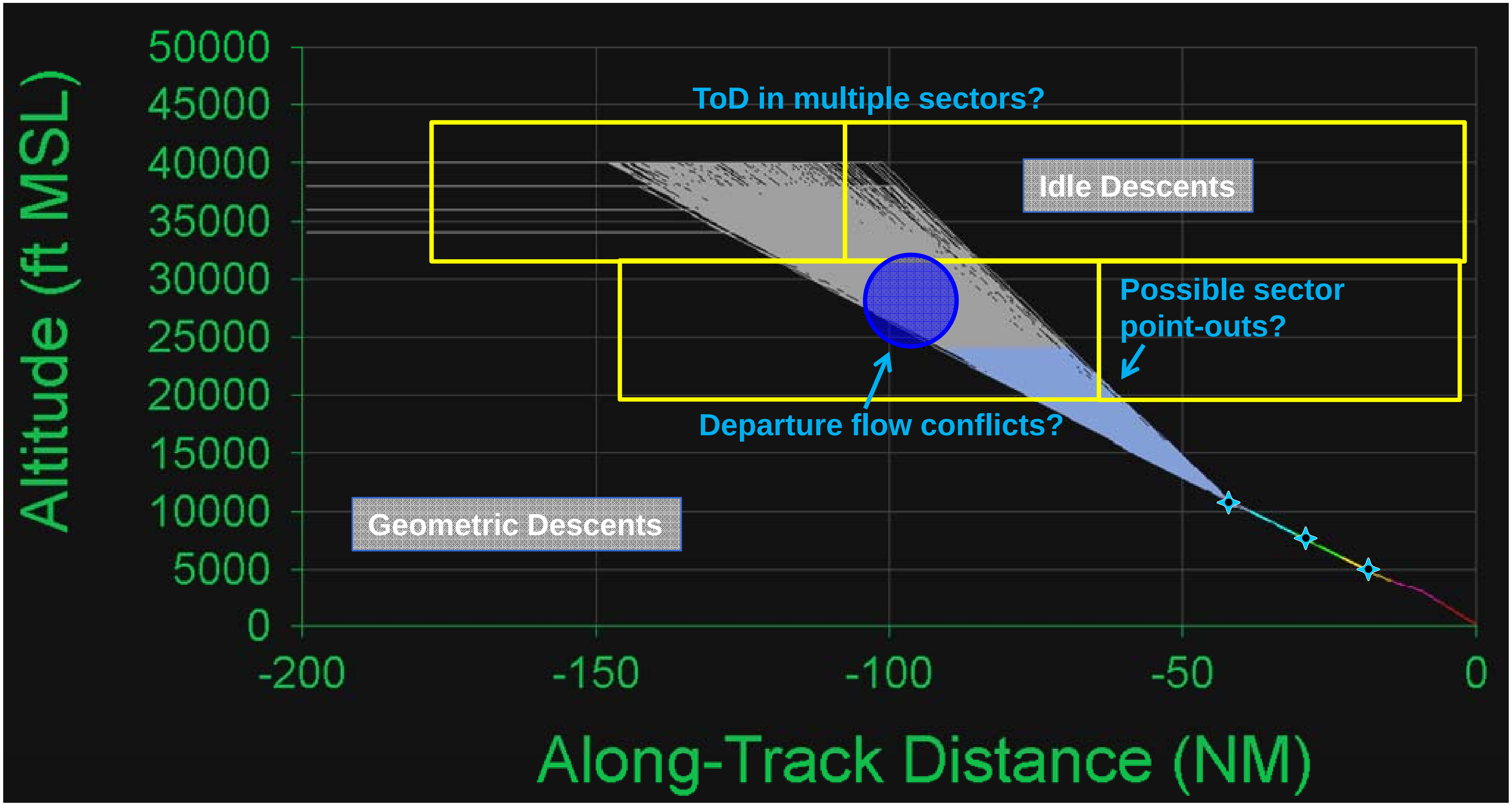


Who makes CDO possible?

Identify Impacts of a CDO

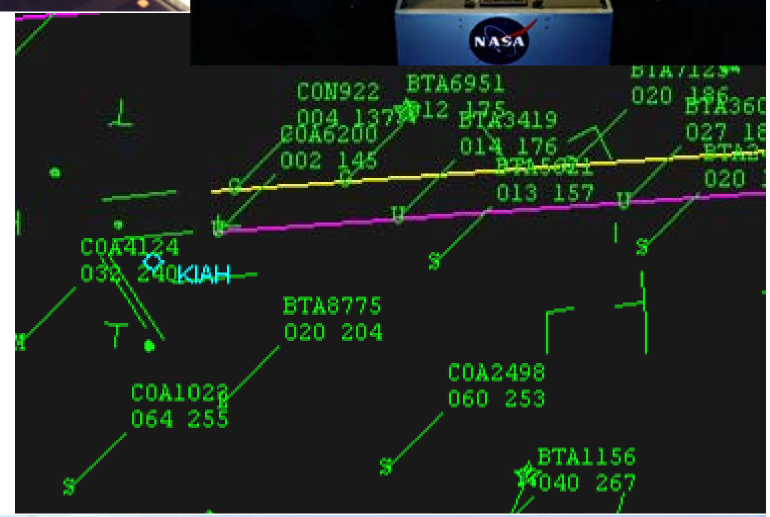
- Crossing traffic impacts sequencing/issuing descent clearance
- Departure traffic frequently uses same gates as arrivals
- Intra-facility sector point-outs for coordination of high and low airspace
- Inter-facility coordination is not automated; requires voice coordination

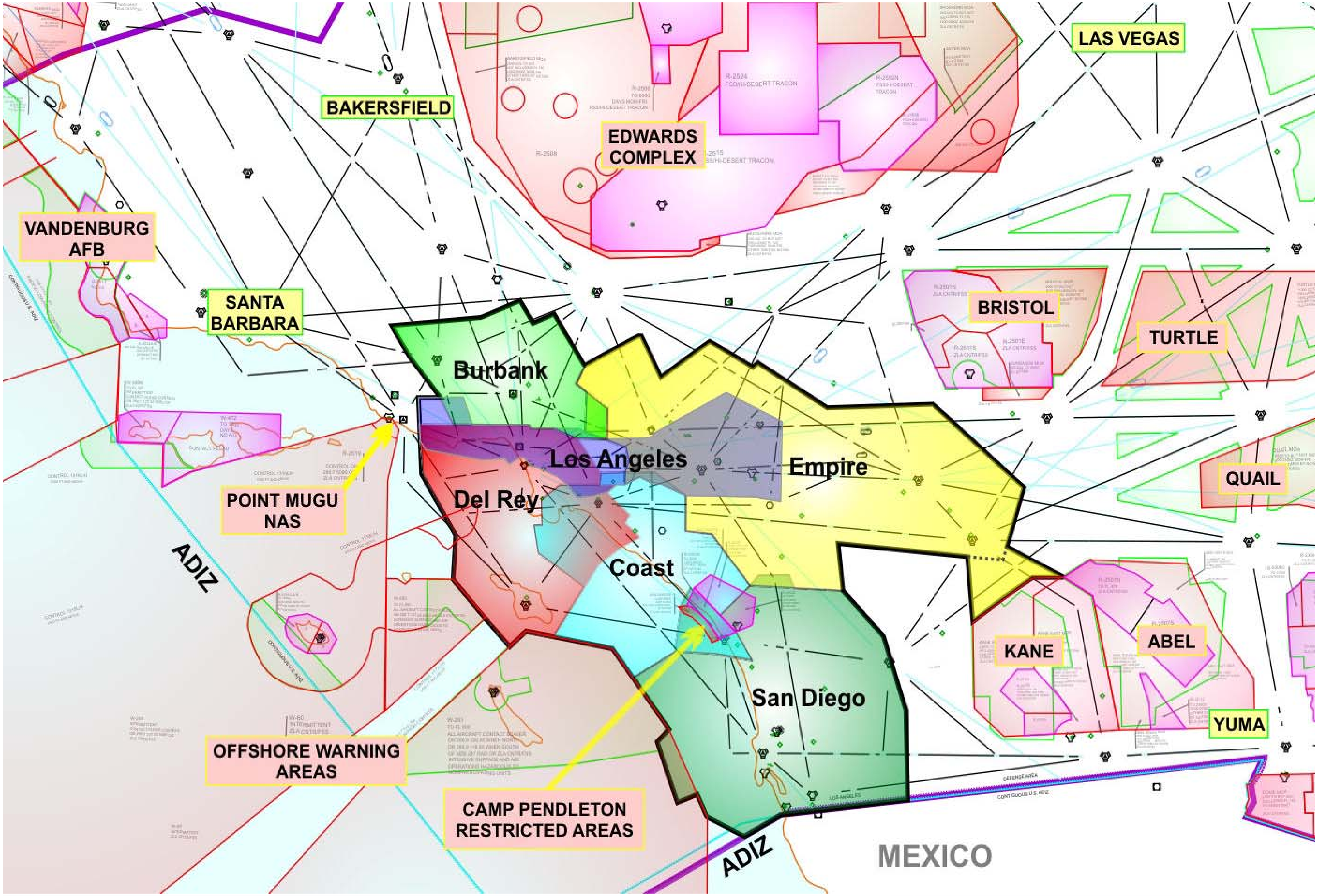
Impacts on ATC



Training and Education

- **Every implementation requires some level of information to be provided to both controllers and flight crews**
- **Complexity of implementation drives type of information needed**
  - **Awareness**
  - **Education**
  - **Training**





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BAKERSFIELD
EDWARDS COMPLEX
VANDENBURG AFB
SANTA BARBARA
BRISTOL
TURTLE
Burbank
Los Angeles
Empire
Del Rey
POINT MUGU NAS
QUAIL
ADIZ
Coast
KANE
ABEL
San Diego
YUMA
OFFSHORE WARNING AREAS
CAMP PENDLETON RESTRICTED AREAS
ADIZ
MEXICO

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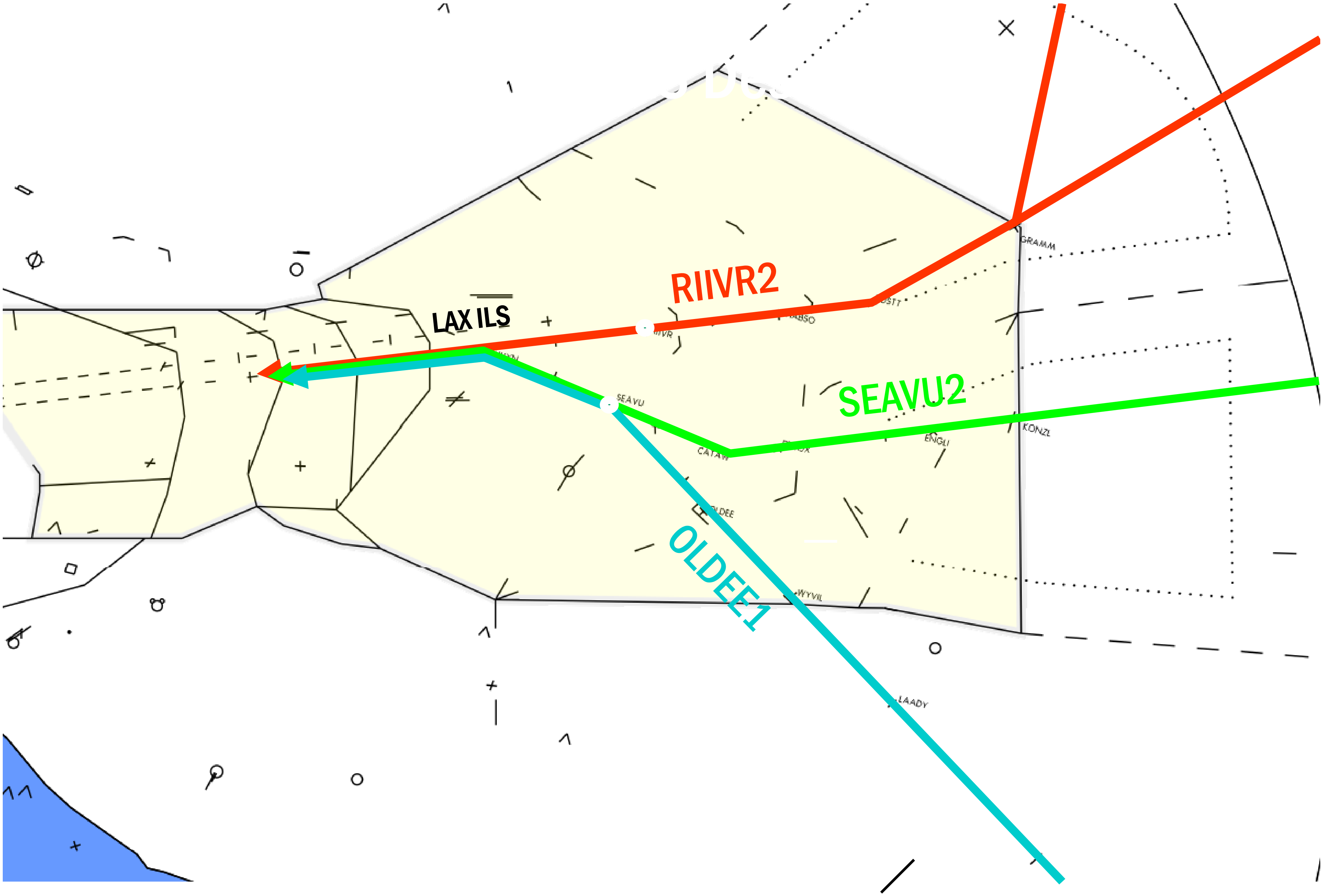
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LAX ILS
SEAVU2
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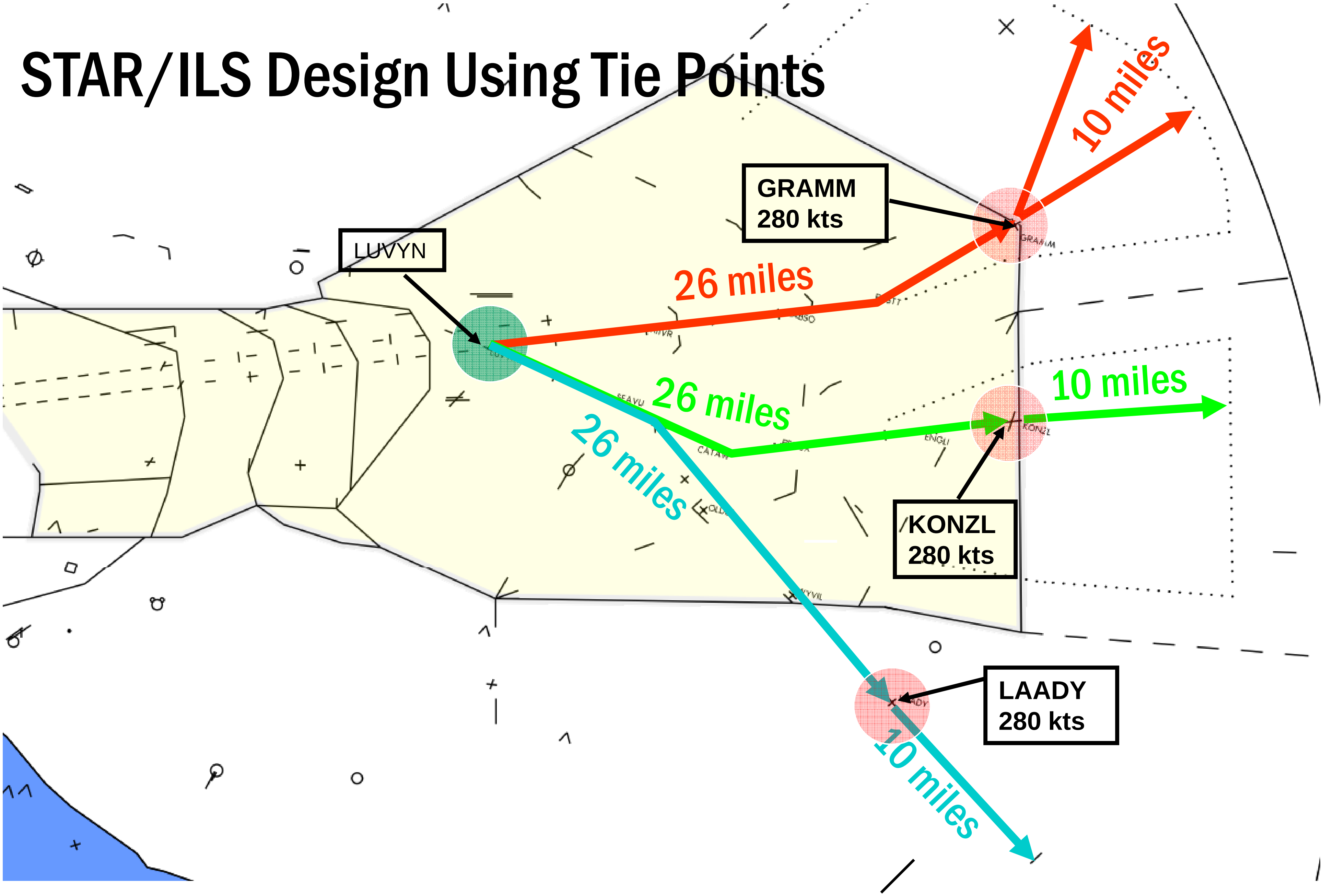
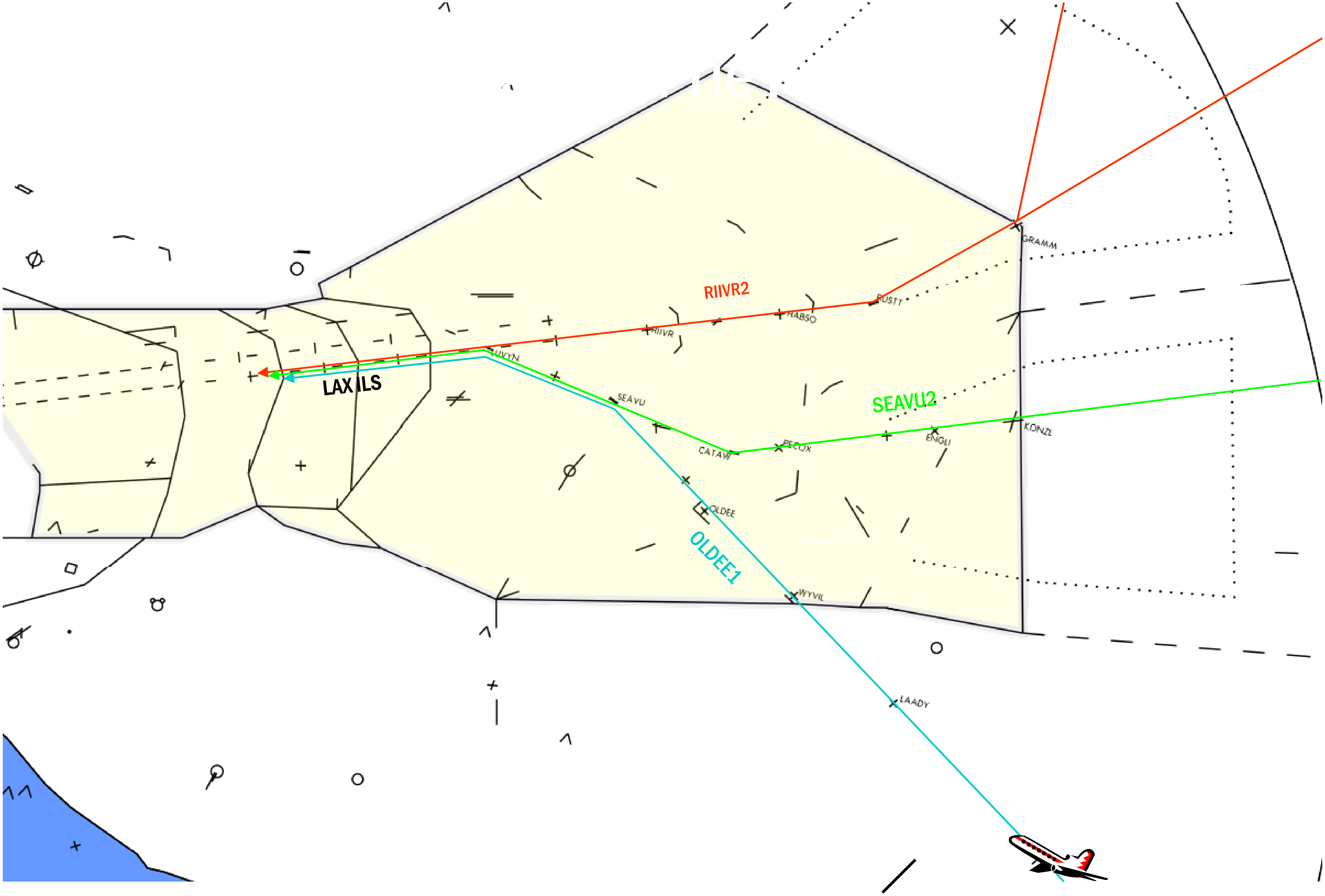
WYVIL
LAADY

STAR/ILS Design Using Tie Points

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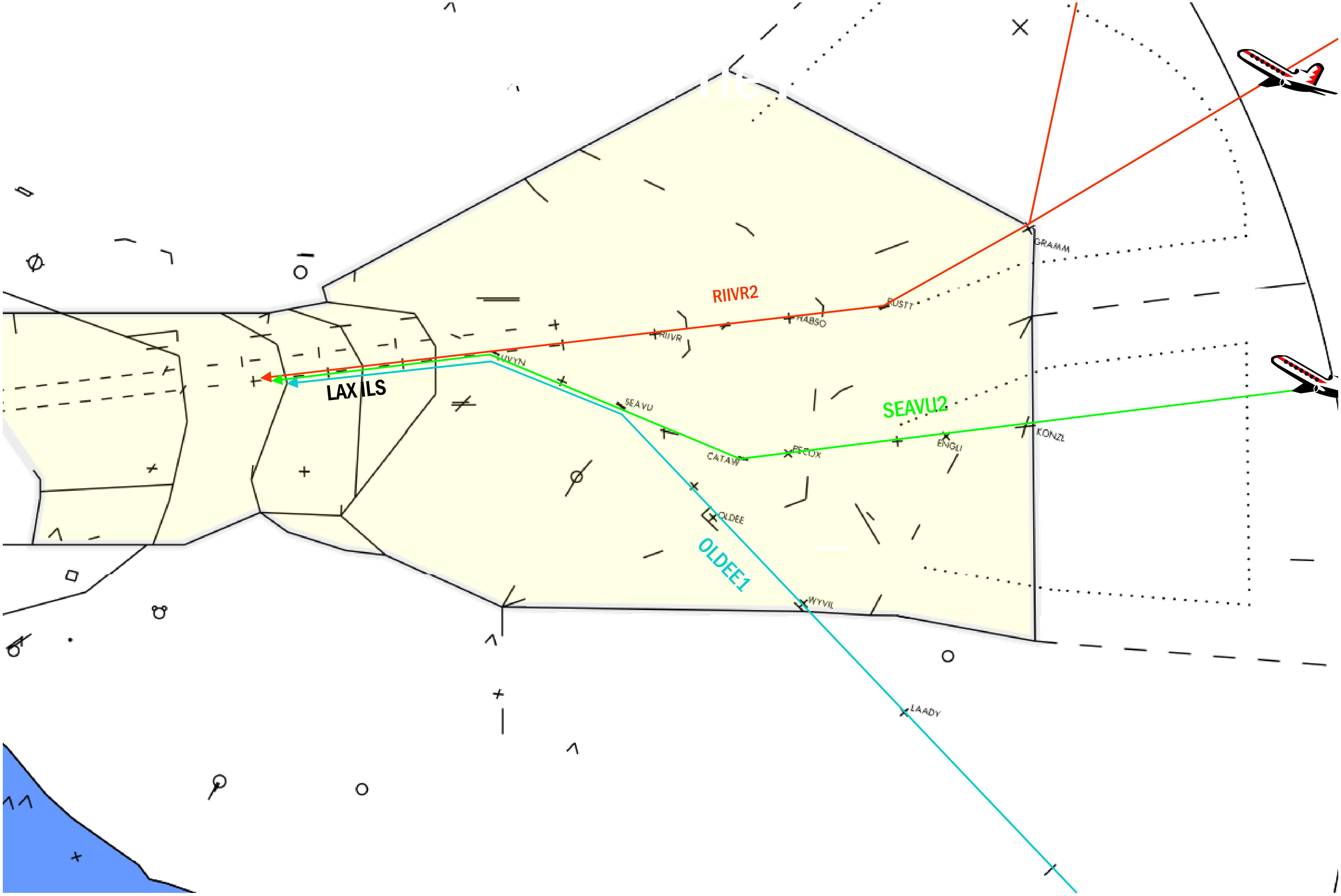
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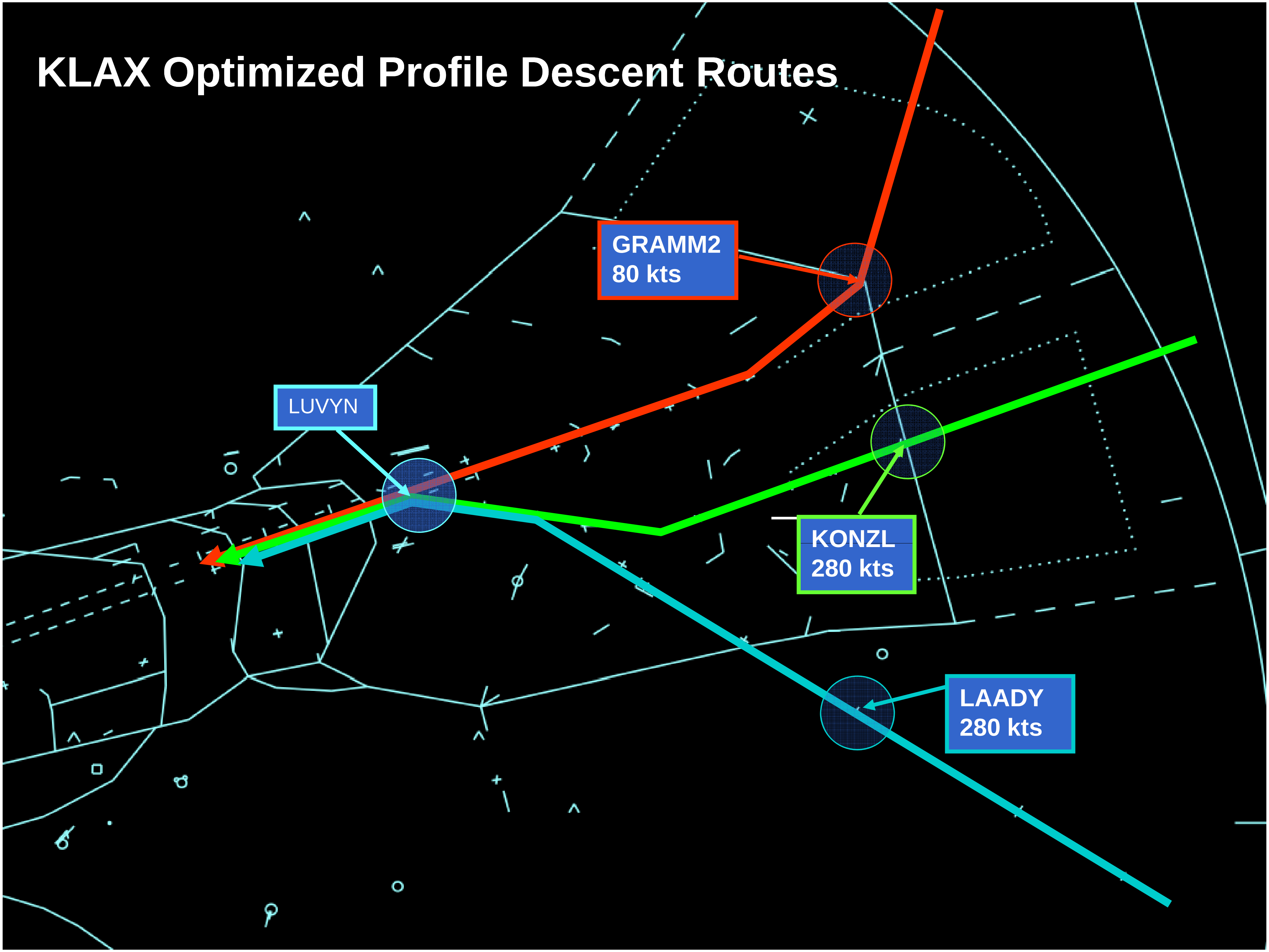
KLAX Optimized Profile Descent Routes



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http://www.icao.int/icaonet/

Questions?

PBN Programme Office

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