Workshop on PBN airspace Design

31 May - 04 June 2021

Airspace Design and CDO

(Doc. 9992, Airspace Design Manual)
Doc. 9931, CDO Manual

Outline

- Airspace design challenges
- TMA Boundaries and entry Points
- Open path and Closed Paths STARs
- STARs lateral and vertical profiles
- Continuous Descent Operations
- Data base coding

Airspace Design

CHALLENGES AND GOALS OF THE OPERATOR

Airspace design challenges

Introduction

- Other than the typical enablers and constraints, airspace design has many other challenges.
- Having done many assessments of ATC Units around the world, the more each one has claimed that they are unique, the more they are the same.
- They all pretty well face the same constraints.

Airspace design challenges

Constraints

- Restricted airspace;
- Noise sensitive areas;
- Convective weather that interferes with traffic flows;
- Peak hours;
- Choke points;
- Terrain;
- Sector/geo-political boundaries.

Airspace design challenges

Goals of the Operator/Users

- Operators want to avoid vectors as much as possible;
- They want to fly repeatable tracks:
  - ☞ For track-mile planning purposes.
- They want to be kept on the arrival (STAR) lateral and vertical profile:
  - ☞ STAR – Standard Terminal Arrival Route
- They want to fly Continuous Descent Operation (CDO) from Top-of-Descent without having a level-off:
  - ☞ This saves fuel
- Operators want to climb without altitude restrictions on departure without a level-off to get to cruising flight level as soon as possible:
  - ☞ Level-offs waste fuel and create a lot of noise

Airspace design challenges

Goals of the Airspace Planner

- Regardless of which scenario you are dealing with, your current procedures form the reference scenario.
- This reference scenario will be used to measure the improvements made by implementing the new airspace design (Ref: Doc 9992, Chapter 2.1.1)
- Don't forget to state your Strategic Objectives (Ref: Doc 9992, Chapter 1.1.4.3)
  - Safety
  - Capacity
  - Efficiency
  - Access
  - Environmental concerns (noise)
- If you don't know what you're trying to fix, how do you know that you've fixed it?

Airspace Design

TMA BOUNDARY AND ENTRY POINTS

TMA Boundary and Entry Points

- Keep the existing TMA boundary, unless there was specific direction to change it:
  - ☞Most likely the airspace, including all the airways outside of the TMA boundary is not in the scope of the PBN Implementation project.
- But we erase the old STARs and SIDs within the TMA and **start with a clean slate**.
- The **first step** is to locate new **Entry** points:
  - ☞Entry points serve as STAR origins, and
  - ☞Exit points serve as SID termination points… will discuss this later

TMA Boundary and Entry Points

Entry/Exit Points

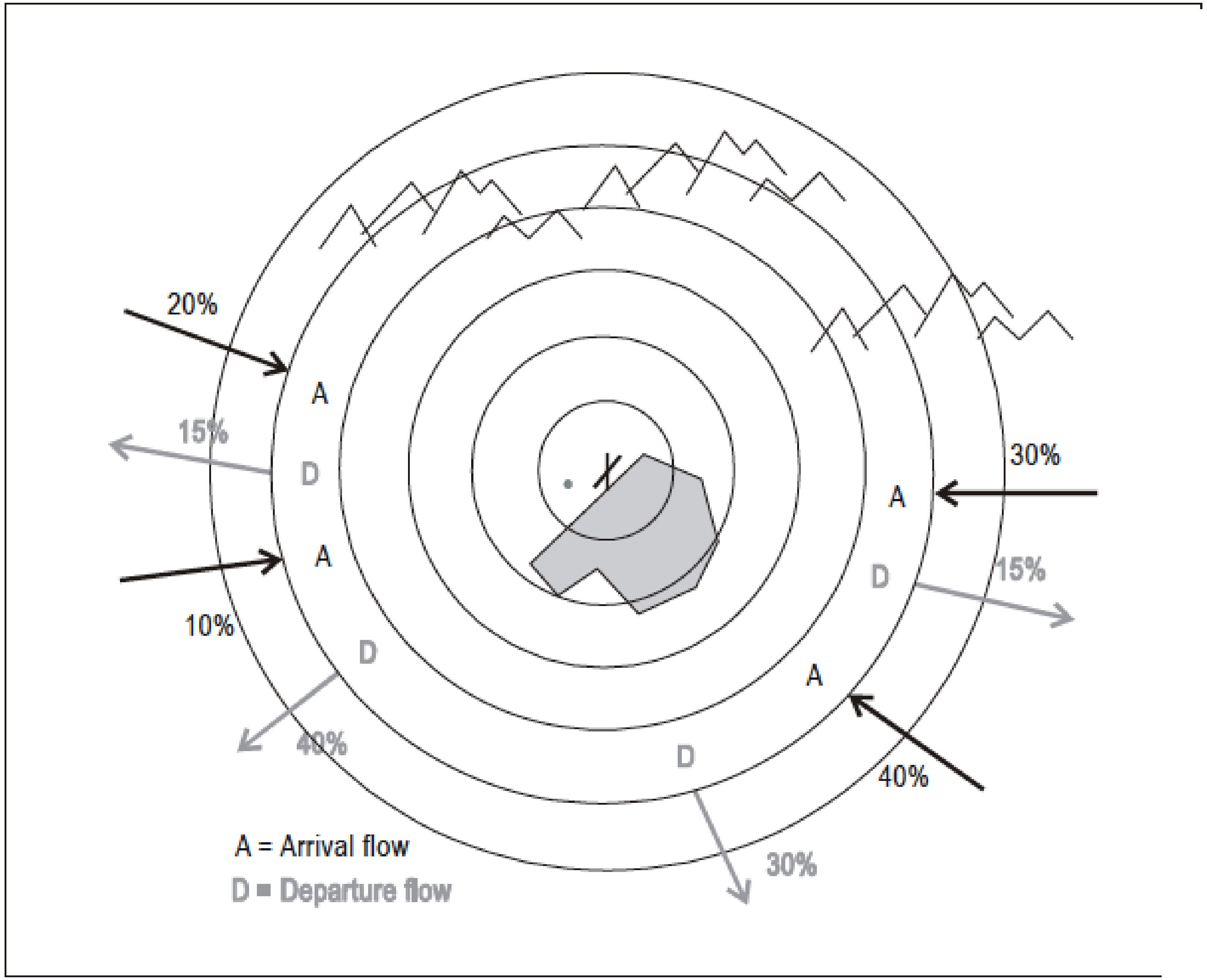
- Methodology for choosing the **number** and **location** of Ingress points.
- **Number** – as few as possible!
  - ☞When we look at some examples of reference scenarios, the TMA might have 7 STARs and 9 SIDs, or more;
  - ☞One can guess with almost 100% certainty that this cannot work.
- So let's aim for 4 STARs and 4 SIDs!

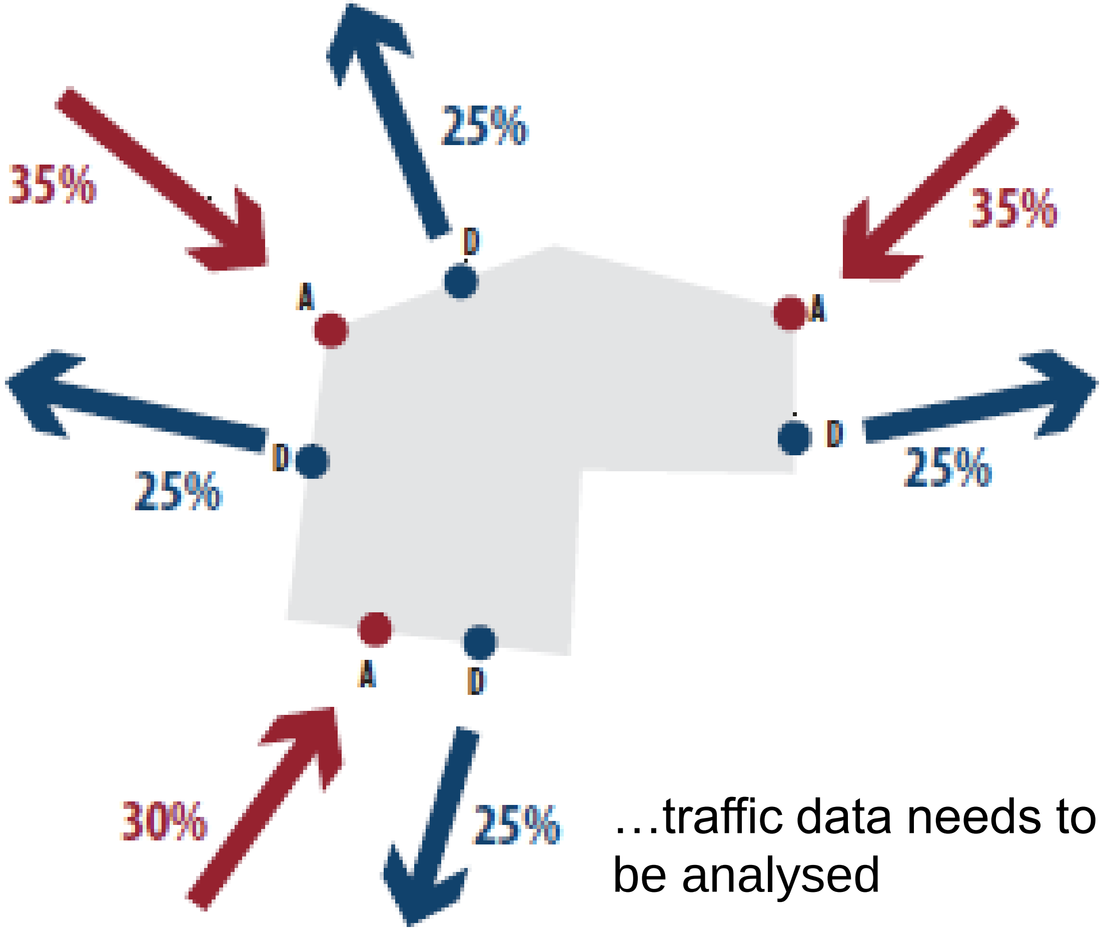
TMA Boundary and Entry Points

Placement of Entry Points

- For the placement of Entry points, you will need to carry out **traffic analysis** of the **reference scenario**, particularly **traffic flows/loads** per **sector:**
  - ☞How many daily aircraft movements ENTER/EXIT via the NNE sector for example
- The placement/location of the Entry points depends on many factors:
  - ☞Location of the airport within the country, and with respect to where other major population centres are;
  - ☞The runway orientation with respect to major traffic flows can also cause some challenges;
  - ☞And many other factors as well.

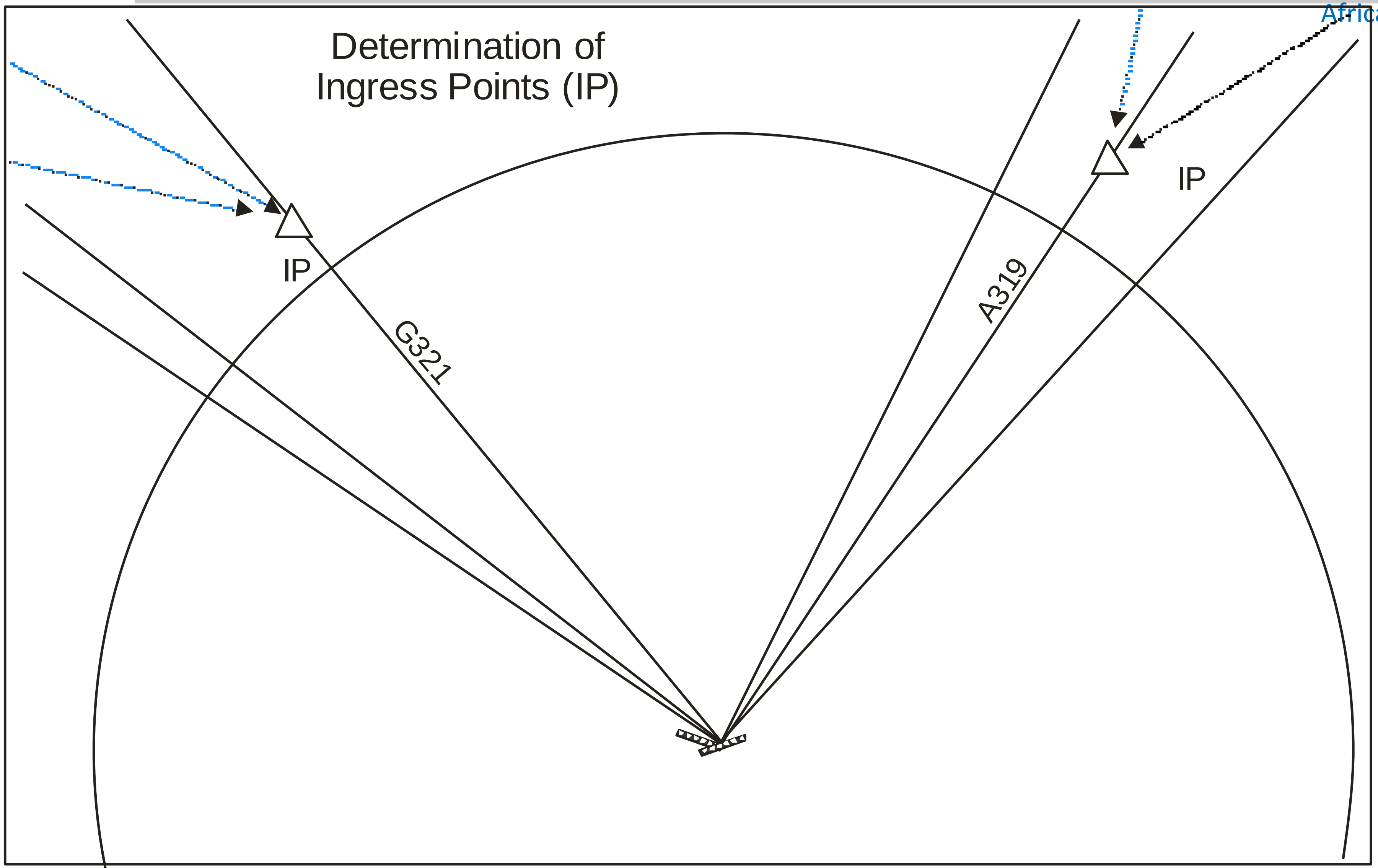
Analysis of Traffic Flows



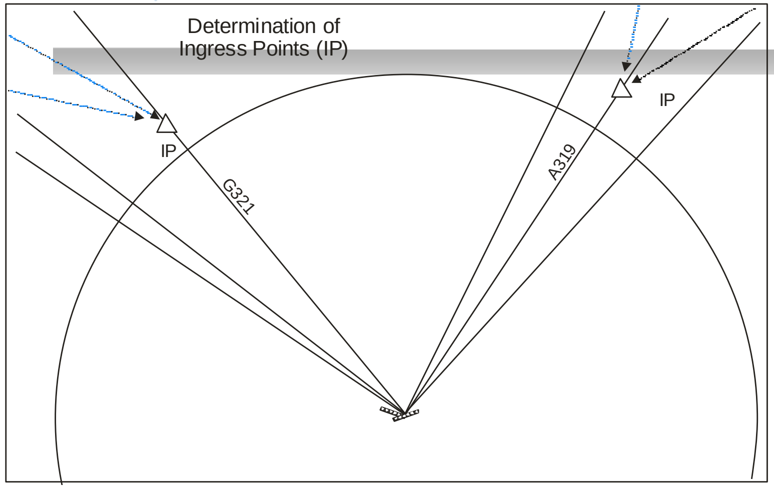


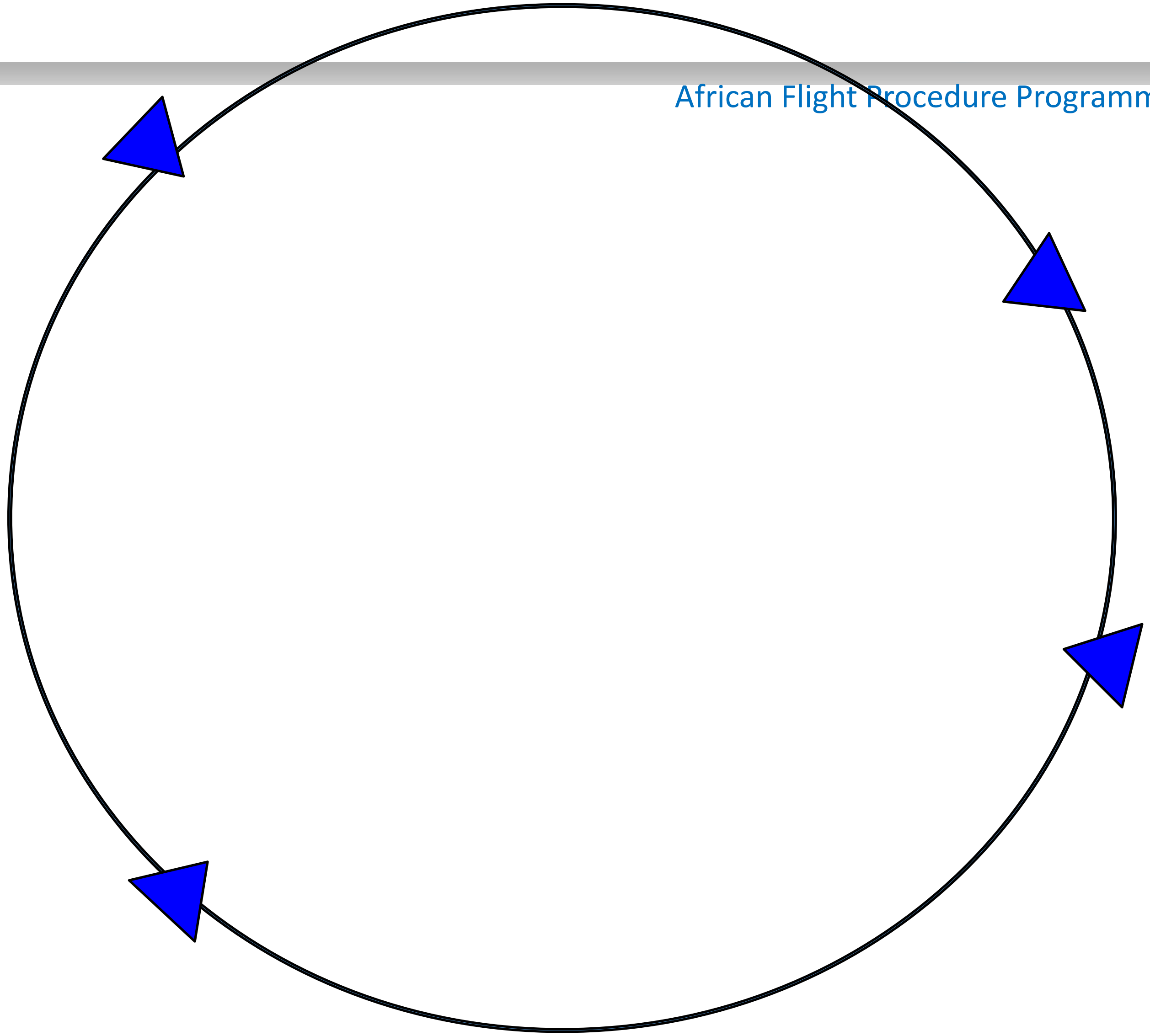
…traffic data needs to be analysed

Placement of Entry Points



Placement of Entry Points





Airspace Design

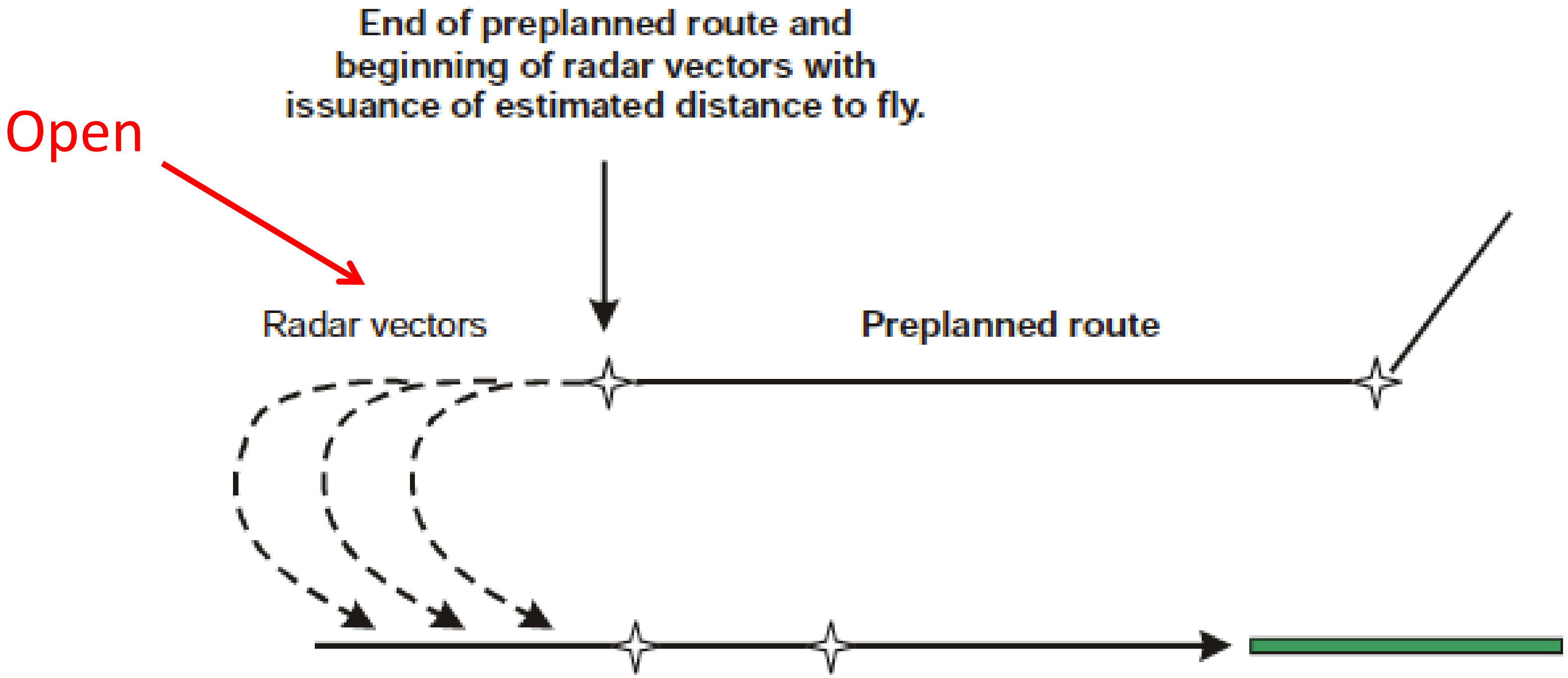
OPEN AND CLOSED PATHS STARs

Open and closed paths STARs

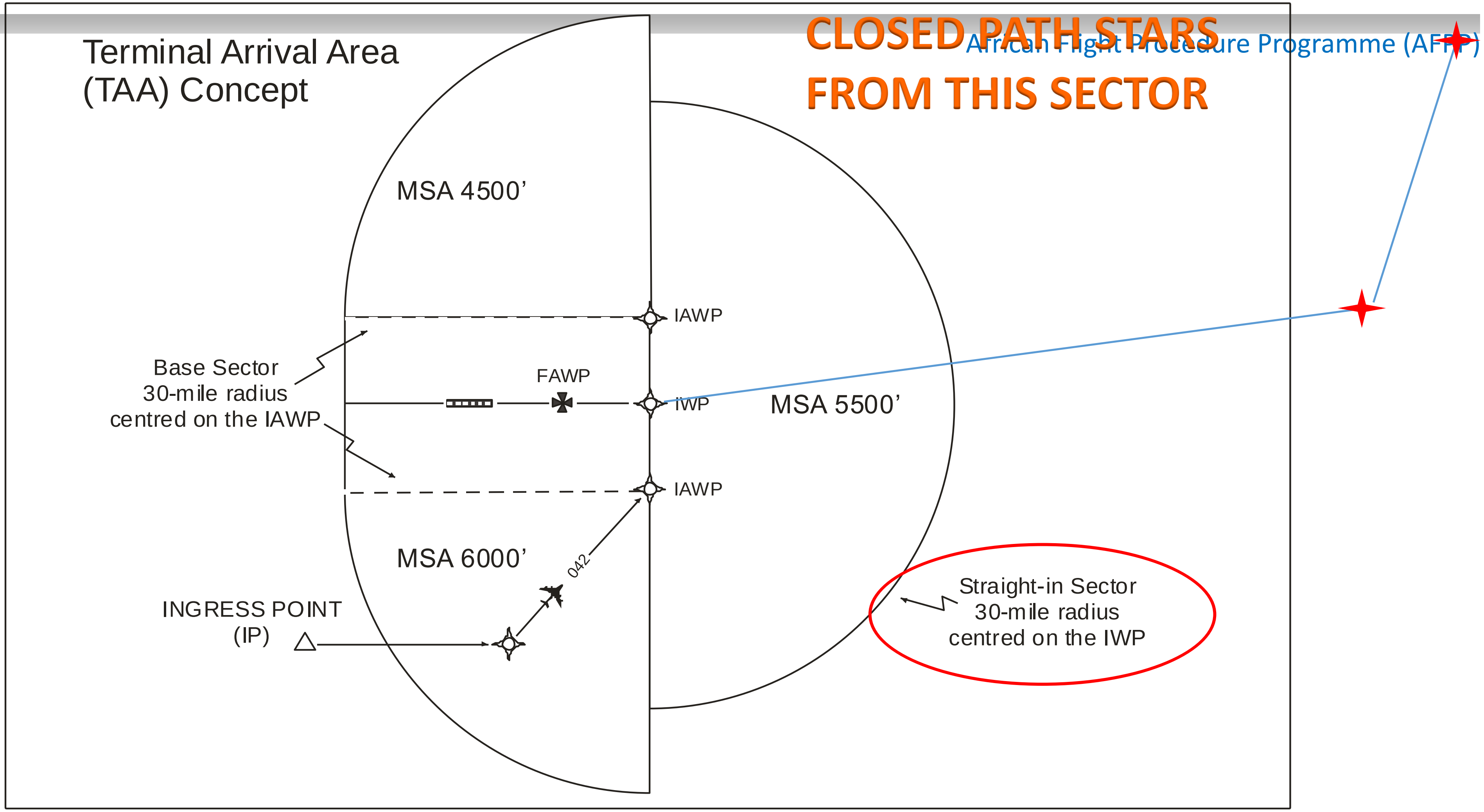
Planning the first STAR

- ❑ Start with the planning of the first STAR from the sector with the greatest traffic flow, then the second, third and fourth;
- ❑ Begins at Entry point, terminates either at:
  - ☞the FAF, if a "**Closed**" path, or
  - ☞at the "IAF" or at the Downwind Termination Waypoint (DTW), if an "**Open**" path.
- ❑ **Closed Path** exact distance to the runway is known, and **no vectors**
- ❑ **Open Path** Continuous path to the DTW … **then vectors by ATC!**

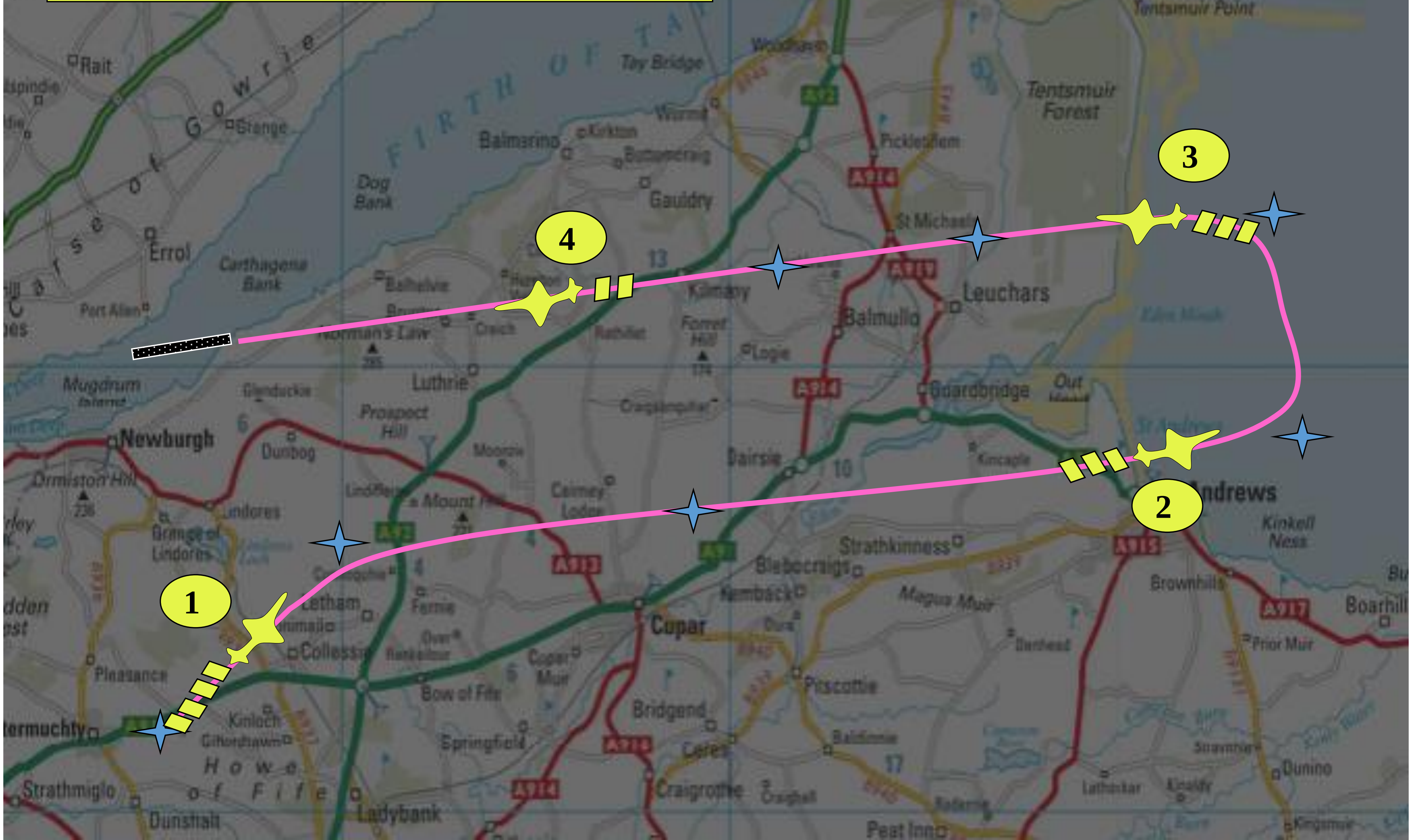
Open Path STARs



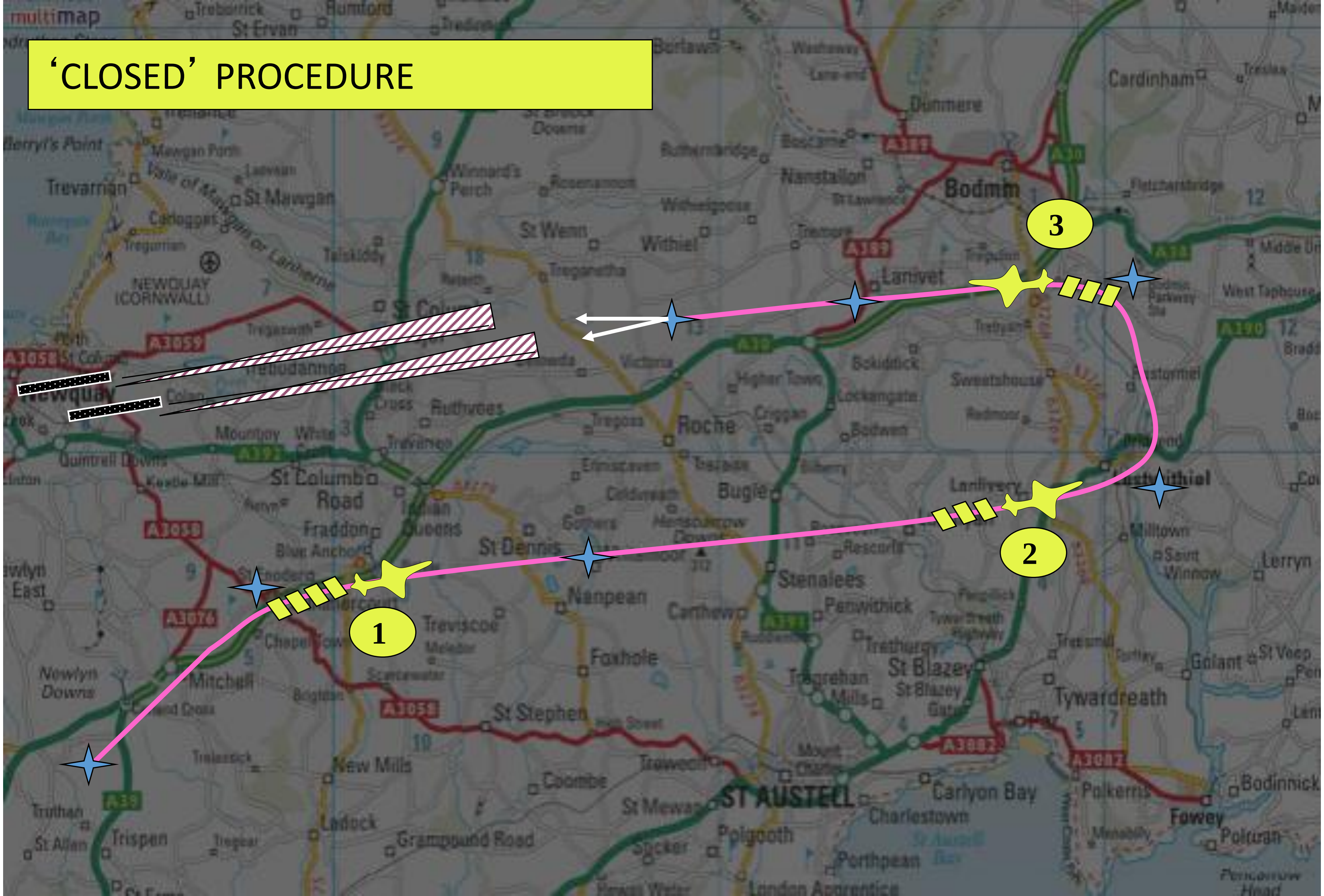
Closed Path STARs



‘CLOSED’ PROCEDURE

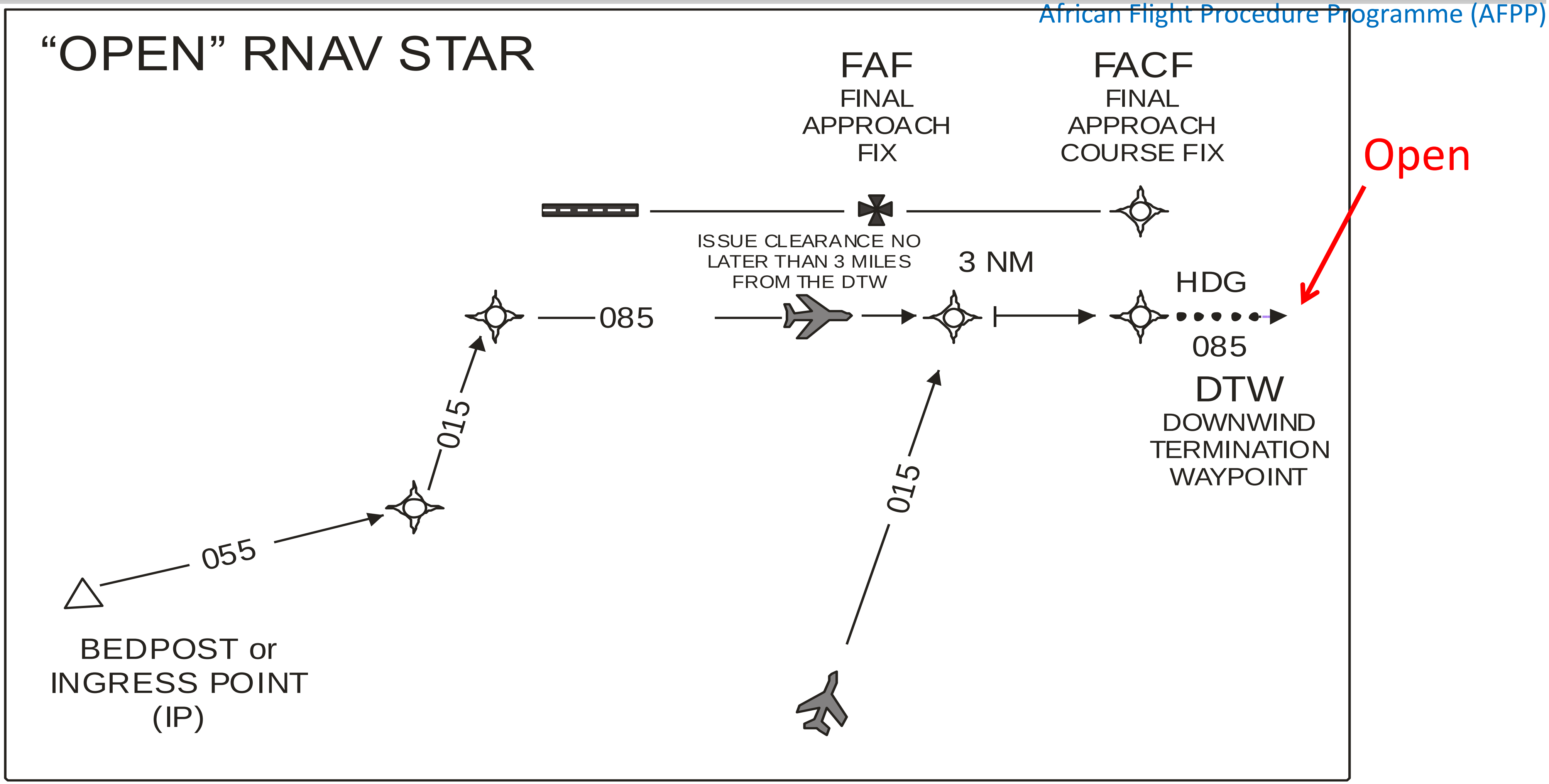


‘CLOSED’ PROCEDURE

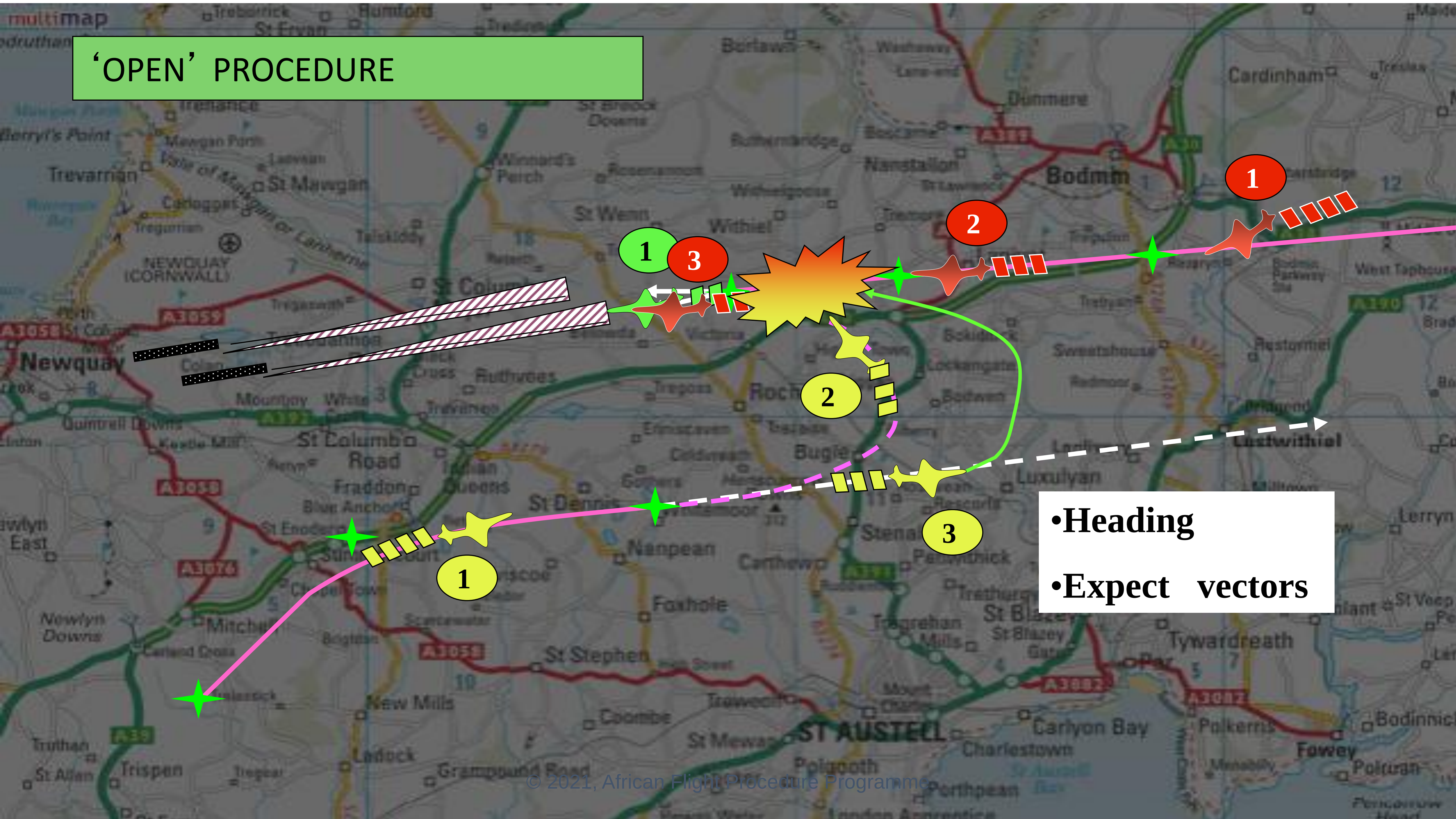


Open Path STARs

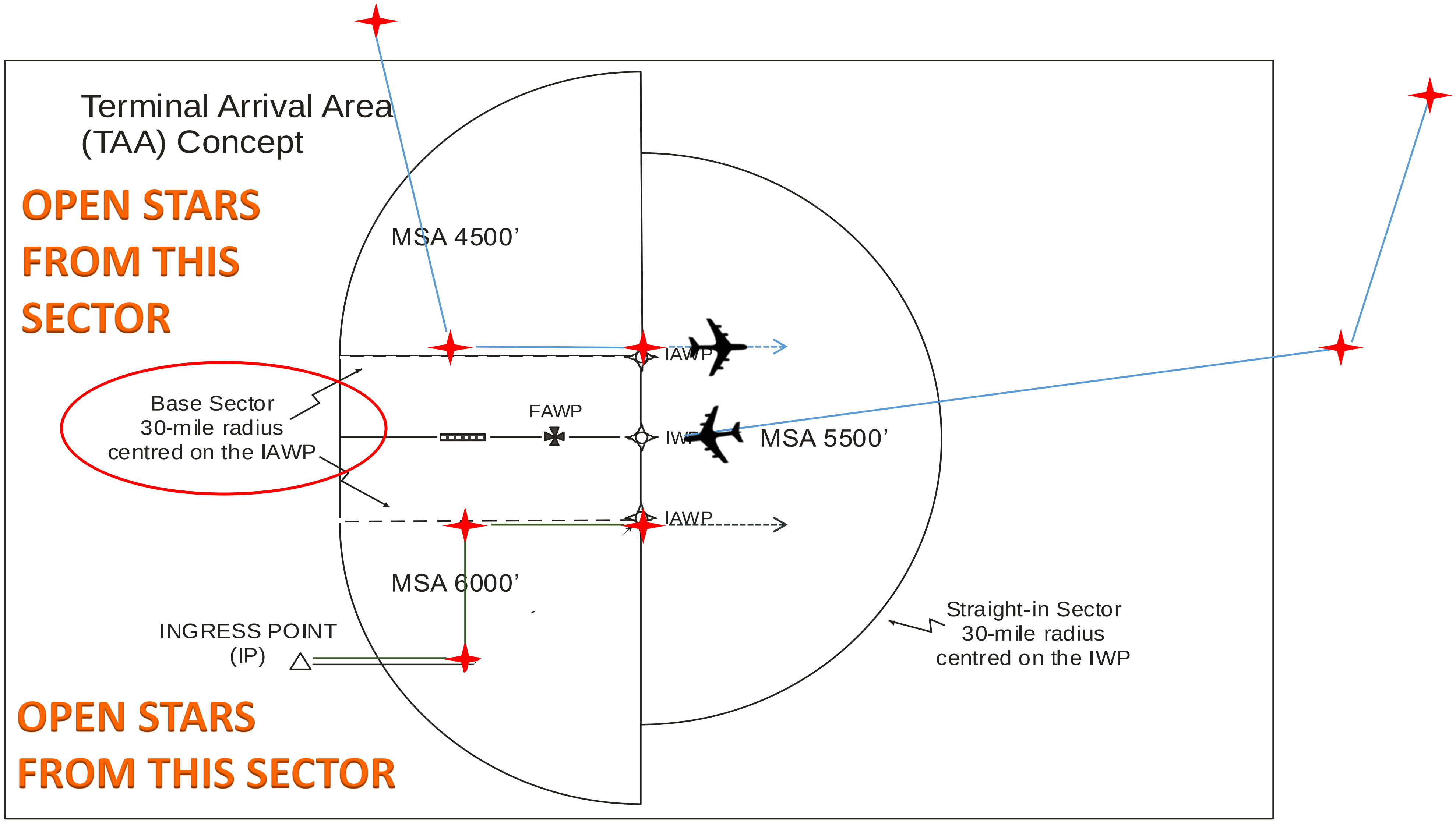
African Flight Procedure Programme (AFPP)



‘OPEN’ PROCEDURE



- **Heading**
- **Expect vectors**


Terminal Arrival Area
(TAA) Concept
OPEN STARS
FROM THIS
SECTOR
MSA 4500’
IAWP
Base Sector
30-mile radius
centred on the IAWP
FAWP
IWP
MSA 5500’
IAWP
MSA 6000’
INGRESS POINT
(IP)
Straight-in Sector
30-mile radius
centred on the IWP
OPEN STARS
FROM THIS SECTOR

Airspace Design

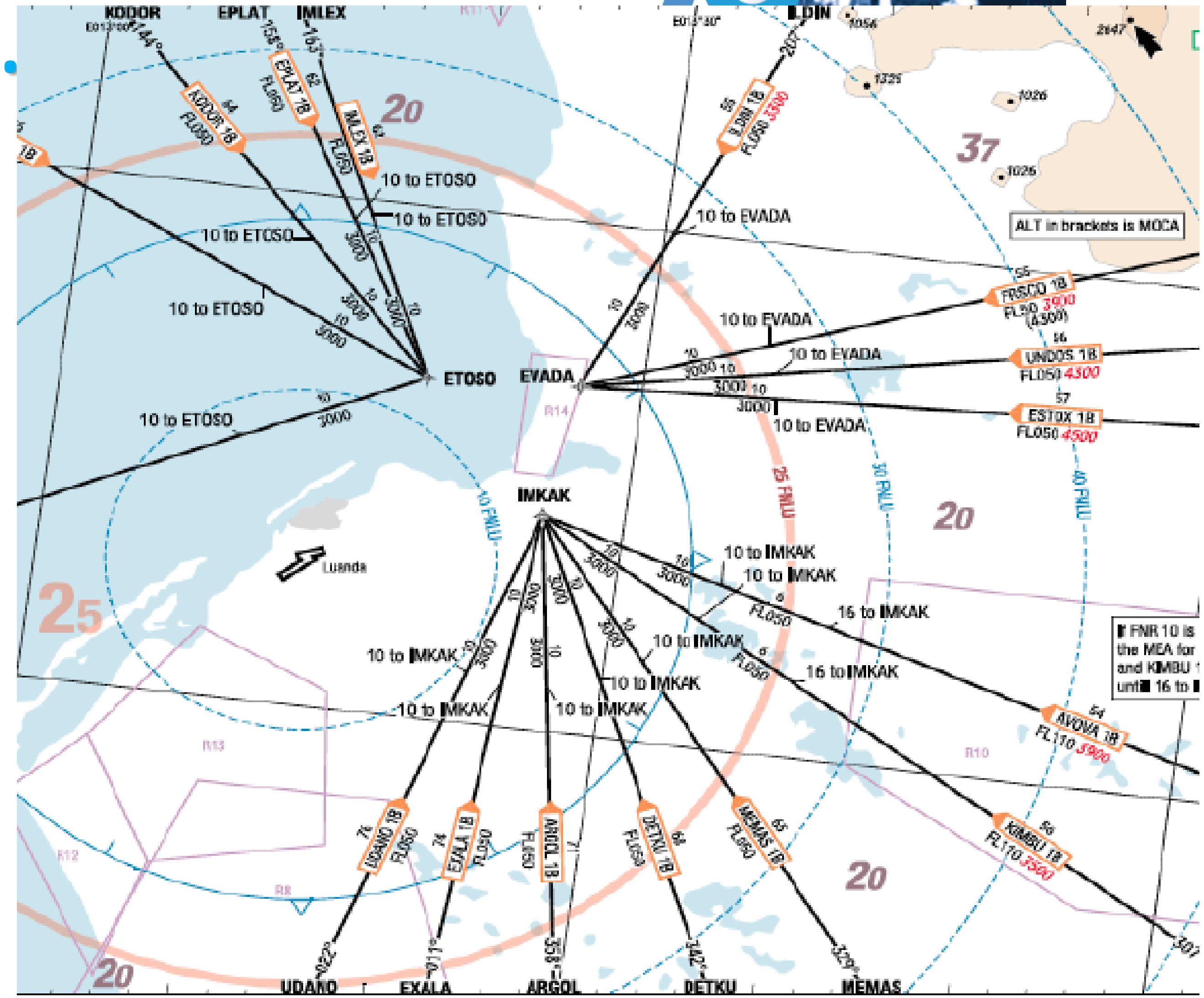
STAR LATERAL AND VERTICAL PROFILES

Lateral and Vertical Profile

- Profile – LATERAL and VERTICAL
- Lateral
  - **Not straight to IAF!**
  - Typically join to **downwind abeam airport**, or prior abeam
- Vertical
  - Even more important than the lateral profile
  - Uninterrupted continuous descents
    - Can be achieved by keeping crossing points to a minimum

PBN will save trackmiles…

- When you’ve been reading about this over and over, this is the type of design you will produce…
- You believe that you must plot a straight line from the Ingress point to the IAF!
- **But please DON’T**

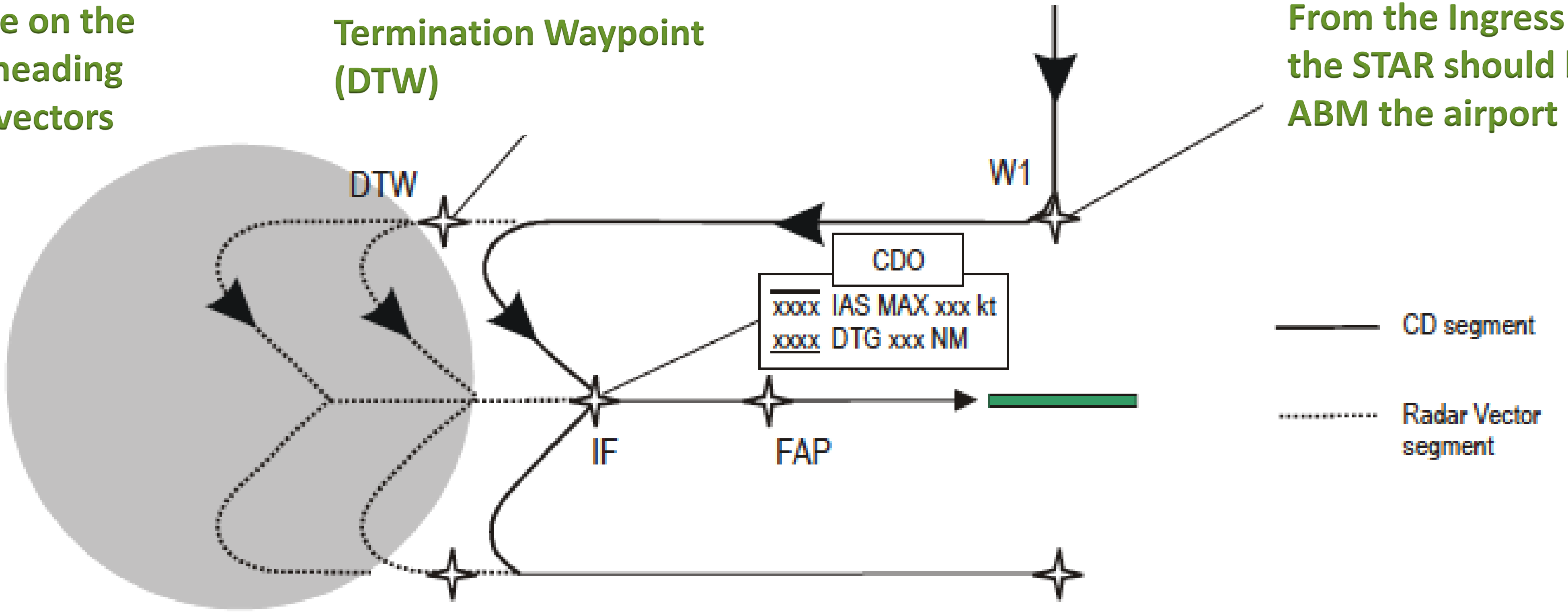


Lateral Profile

From here the aircraft will continue on the downwind heading waiting for vectors from ATC

Then to the Downwind Termination Waypoint (DTW)

From the Ingress Point the STAR should lead ABM the airport



Airspace Design

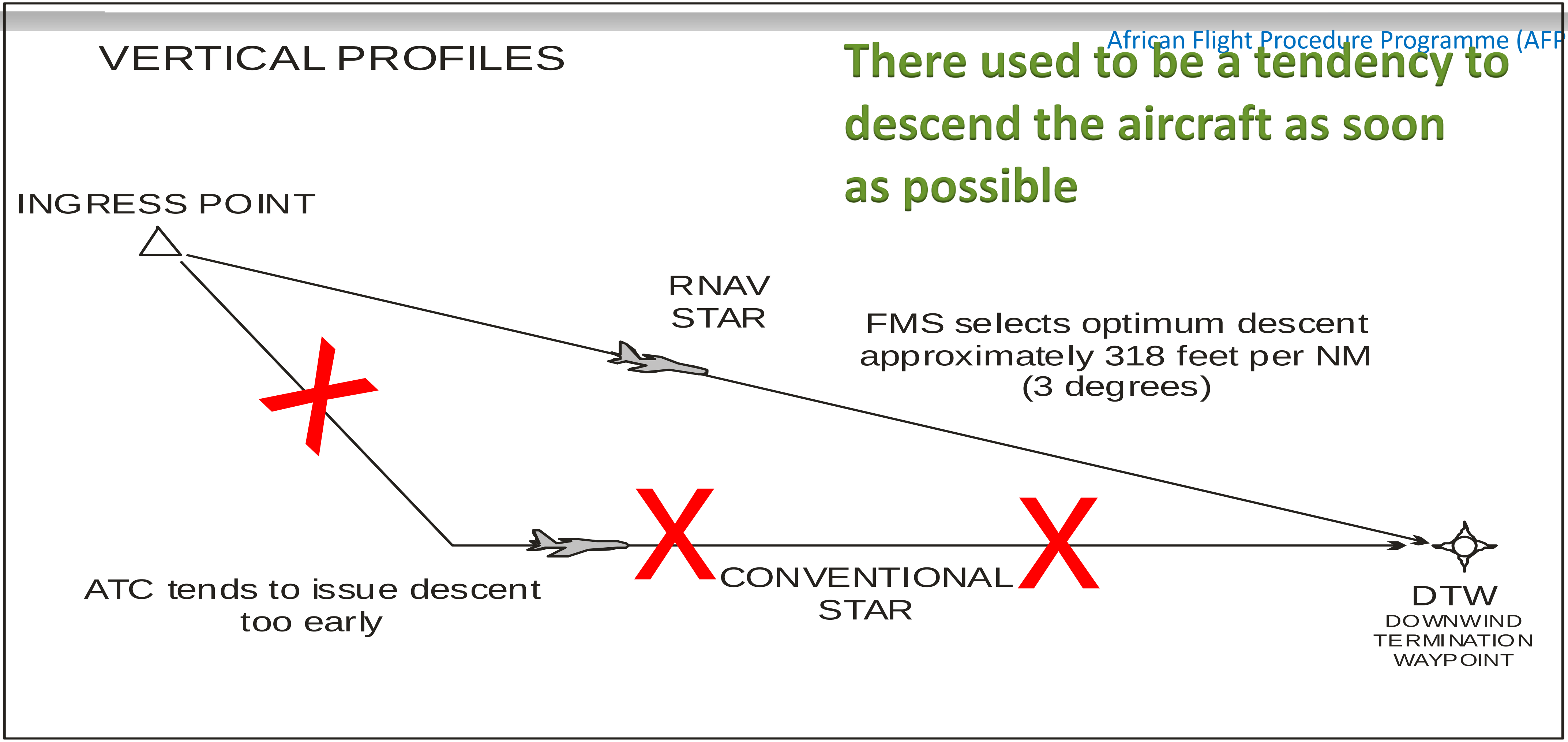
STAR VERTICAL PROFILE CONTINUOUS DESCENT OPERATIONS (CDO)

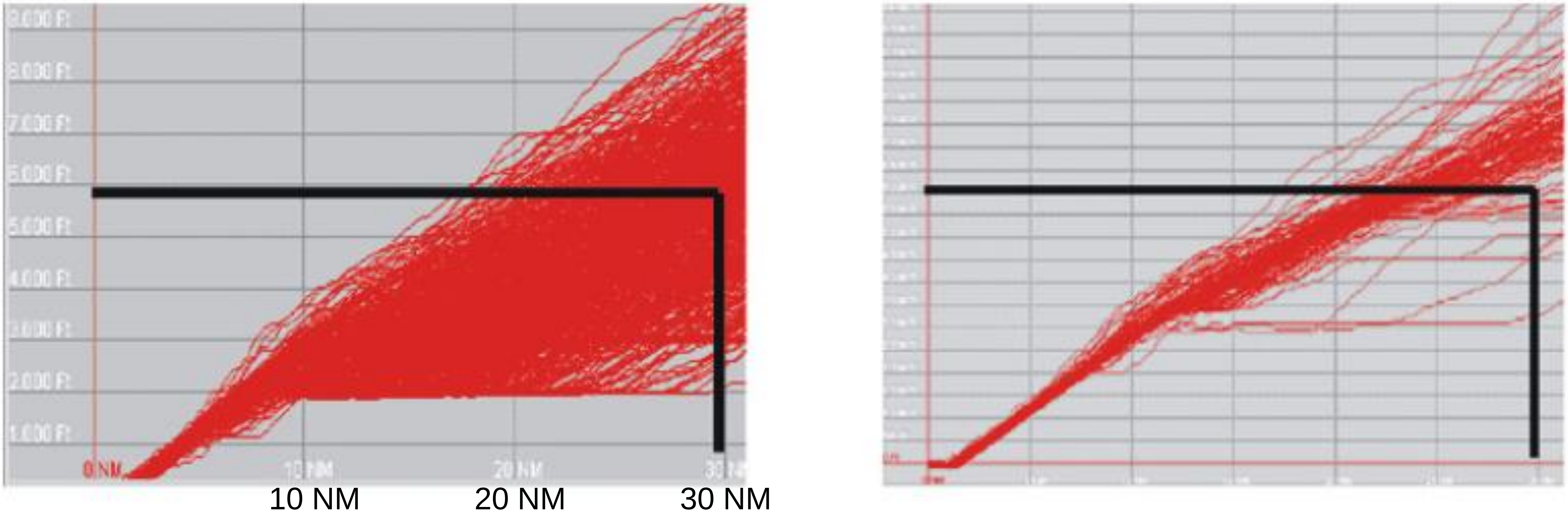
Lateral and vertical profiles

- Difference between STAR and CDO… both have the same lateral profile, but CDO has an **optimum descent profile** with published altitudes (FL) at every fix;
- Main benefits:
  - ☞Fuel savings
    - 4:1 for Cat. C, and 6:1 for Cat. D aircraft
  - ☞Reduced noise;
  - ☞Even a partial continuous descent at lower levels will still save between 50 to 100 Kgs of fuel per flight.

Lateral and vertical profiles

There used to be a tendency to descend the aircraft as soon as possible





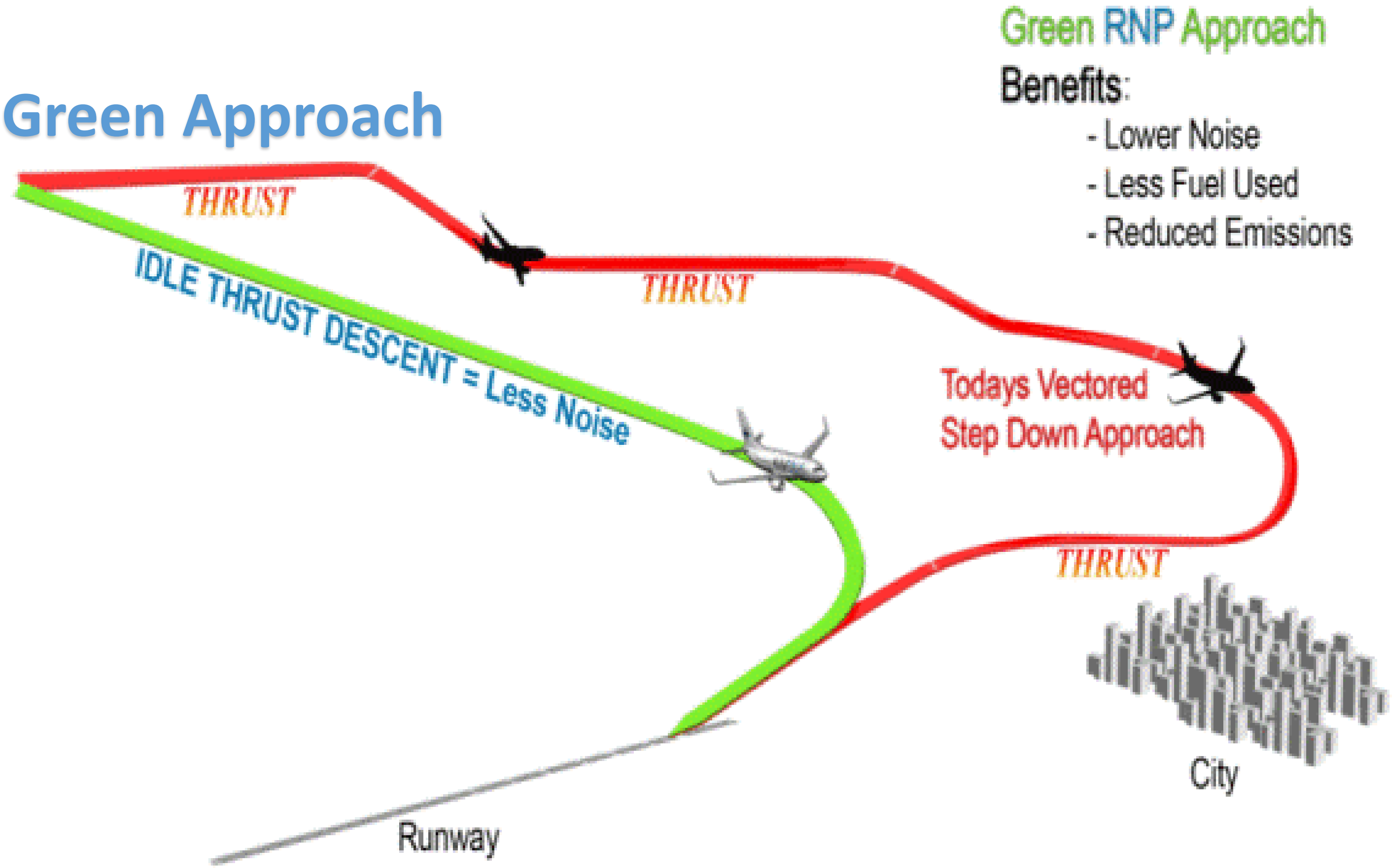
Comparison of actual aircraft profiles with and without CD Operations

Airspace Design

CONTINUOUS DESCENT OPERATIONS (CDO)

Continuous Descent Operations (CDO)

CDO or Green Approach



Objectives and Benefits

- To achieve CDOs involves:
  - Airspace Design and Flight Procedure Design
- Objectives:
  - Enable uninterrupted continuous descents:
    - without disrupting departures
- Benefits:
  - Reduction in both pilot and controller workload;
  - Reduction in the number of required radio transmissions;
  - Cost savings and environmental benefits through reduced fuel burn;
  - Authorization of operations where noise limitations would otherwise result in operations being curtailed or restricted.

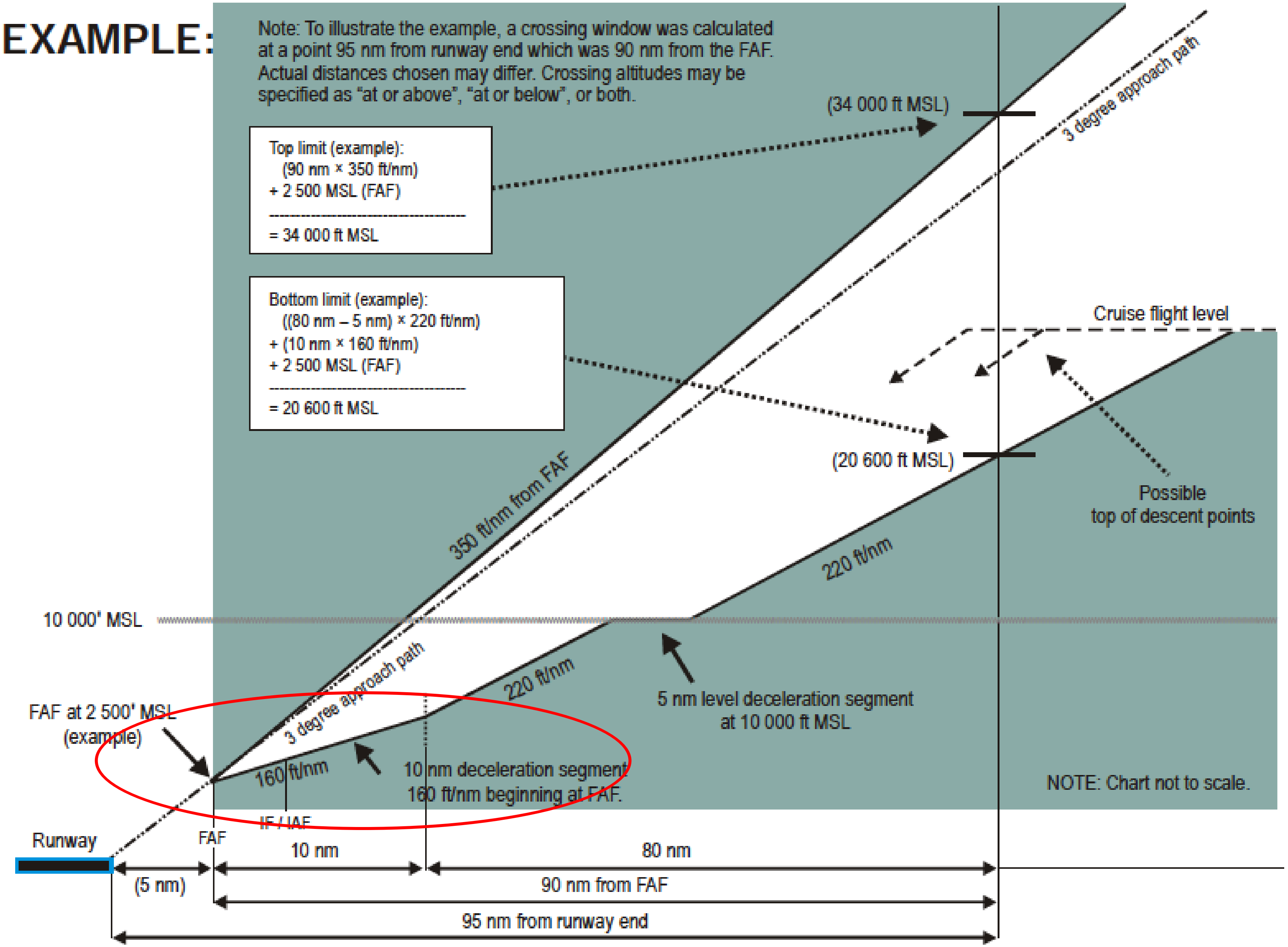
Continuous Descent Operations (CDO)

- How do we get the maximum fuel efficiency?
  - ☞Need to take advantage of the potential energy of the aircraft at TOD:
    - B737 glide ratio 17:1 ~ 360’/NM
- By employing **minimum engine thrust**, preferably in a **low-drag configuration;**
- This is dependent on **aircraft performance** but what would be the typical descent profile (angle)?
- 2.0 to 3.3° the industry mean is 3° or 320’/NM (5.24%);
- The optimum vertical path will vary depending on the **type of aircraft**, **actual weight**, **the wind**, **air temperature**, **icing conditions**, etc.

Continuous Descent Operations (CDO)

- A CDO is usually flown with VNAV:
  - ☞With the support of a computer-generated vertical flight path…
  - ☞But it can be flown without VNAV as well.
    - Pilot calculates the descent rate based on next fix altitude.
- The trick is to keep aircraft **as high as possible** before it reaches the optimum descent path, which starts at **Top-of-Descent (TOD):**
  - ☞The total energy of the aircraft at high altitude can be used most efficiently during descent with **minimum thrust** and **drag**.
- The pilot should have the maximum flexibility to manage the aircraft's speed and rate of descent.

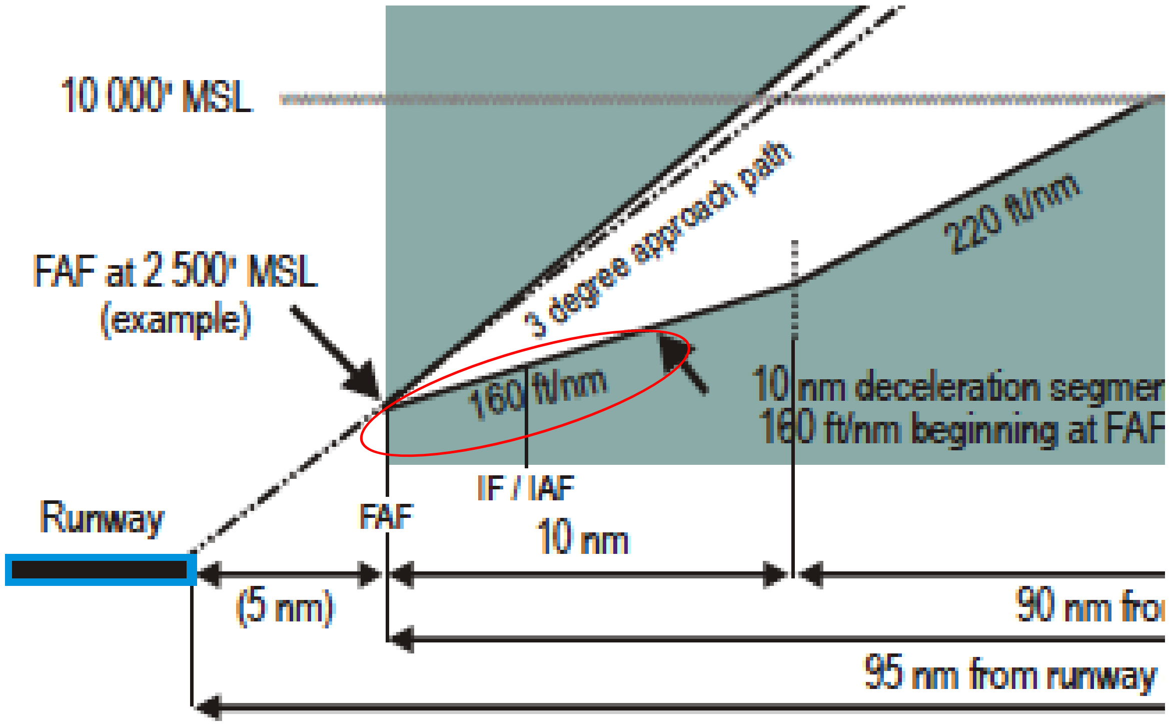
EXAMPLE:



This example shows a STAR linked to **an instrument approach** in an optimized CDO procedure and should allow most FMSs to perform fully automated lateral navigation/vertical navigation (LNAV/**VNAV**) descent.

Continuous Descent Operations (CDO)

- A closed-path STAR terminates at an FAF:
  - ☞This allows the FMS to link the STAR with the approach procedure.
- Instrument approach altitudes from the runway threshold (50’ AGL) are generally designed to allow:
  - ☞for a **3°descent path** (approximately 320’/NM), and
  - ☞have a **shallower segment 1.5° in the intermediate segment** (160’/NM) to allow the aircraft to **stabilize** and to **decelerate**.



Continuous Descent Operations (CDO)

Speed Control

- Speed constraints reduce the flexibility of the CDO but can help with traffic sequencing.
- Proposed speed restrictions need to be coordinated between all stakeholders prior to finalizing them.
- In general, speeds from higher levels should not be less than 280–290 K.
- An example chart notation could be "… maintain 280 K until leaving 10,000' MSL".
- Pilots are expected to program their FMS to set speeds at 280 K as the aircraft changes from the Mach regime… 0.83 etc.

Continuous Descent Operations (CDO)

Transition Level/Altitude

- ❑ If a CDO starts above the transition level (TL), a buffer should be established by the procedure designer and added to the minimum levels along the path.
  - ☞2 992 as opposed to station pressure will affect the altitudes along the CDO
- ❑ This buffer will be calculated based upon the aerodrome historical pressure altitude range.
  - ☞2 998 – 3005
- ❑ In order to optimize CDO performance, it is recommended that **transition altitudes** (TA) be established **as high as possible**, for example, **10,000’ or higher**.

Database Coding

- **Closed path** CDO procedures: These procedures should be coded with **track to fix** (TF) legs and **fly-by waypoints**.
  - ☞STARs that terminate with a link to an instrument approach procedure should terminate at a **fly-by waypoint**.
- STARs that terminate with vector-based legs may be coded with **fix to manual termination** (FM) or **heading to manual termination** (VM) path terminators.

Continuous Descent Operations (CDO)

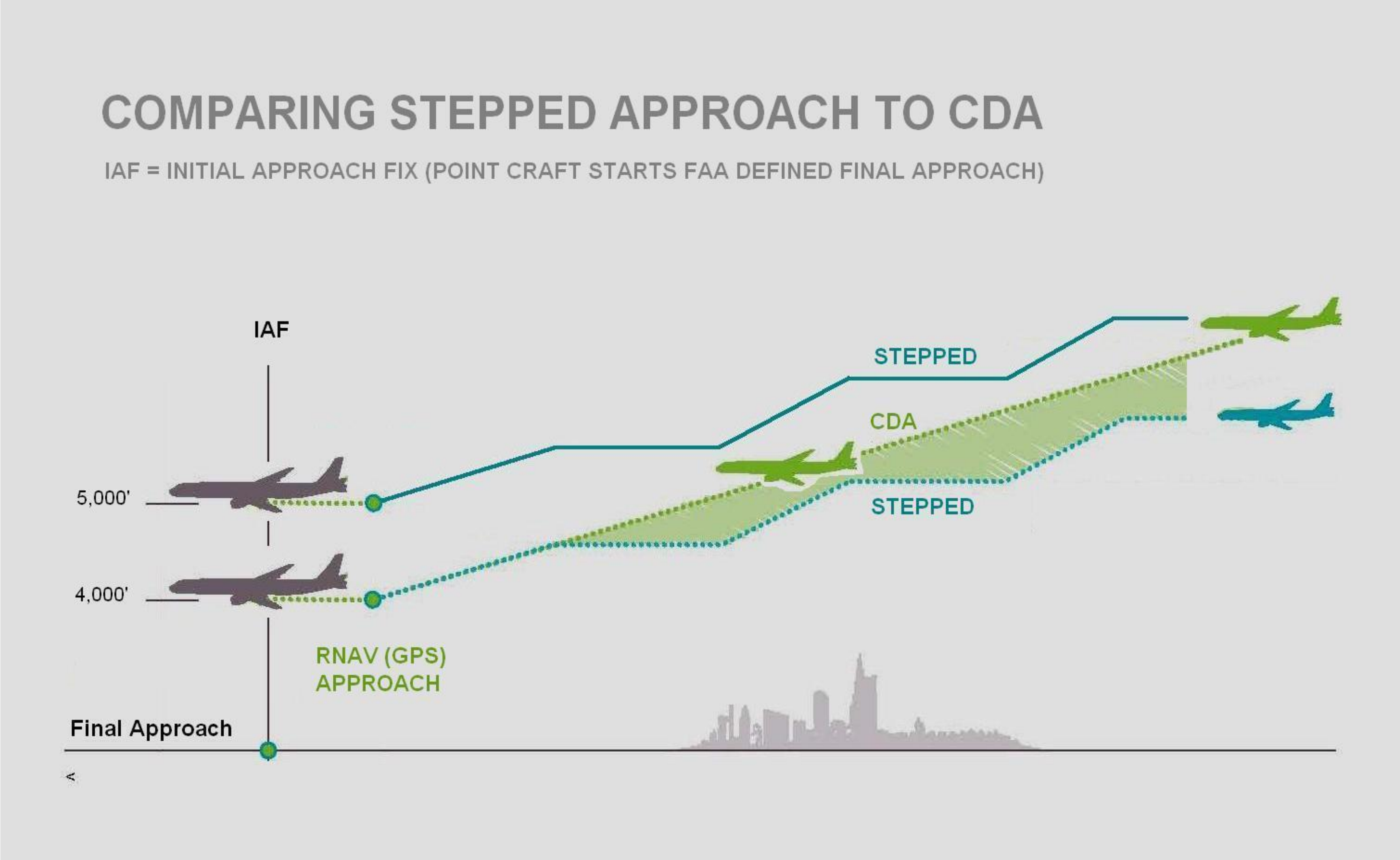
Level/Altitude Windows

- Unless specifically required as a part of the procedure design, there is no need to provide specific level windows or speed restrictions for CDO on STAR charts:
  - ☞ But we will annotate these during our exercises so you will know how to calculate these.
- Any speed and altitude restrictions applicable at or beyond the IAF should be clearly depicted on the chart.

Continuous Descent Operations (CDO)

Level/Altitude Windows

- Level restrictions should be expressed using level windows by "at or above" or "at or below" constraints.
- *If CDO is only applicable to a part of a procedure, this should be depicted in an obvious manner, indicating the beginning and the end of the CDO:*
  - *The CDO may be indicated with appropriate text on the chart or by the procedure designation, for example KARLAP (CDO)… more about STAR naming later.*



STAR altitude windows and procedure height constraints should be designed to allow most aircraft to descend unimpeded.

Continuous Descent Operations (CDO)

The right balance

- CDO is one of many tools available to aircraft operators and ATC to increase safety, flight predictability, while reducing noise, fuel burn, emissions, and controller-pilot communications
- Several attempts have been made to strike a balance between ideal **fuel-efficient** and **environmentally** (noise) **friendly** procedures and the **capacity requirements** of a specific airport or airspace

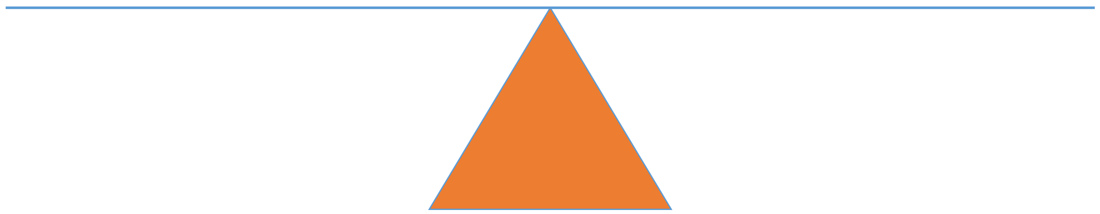
Continuous Descent Operations (CDO)

The Right Balance

Striking the right balance

Fuel efficient
Quiet
Controller-Pilot reduced communications

Capacity
Efficiency



Airspace Design (CDO)

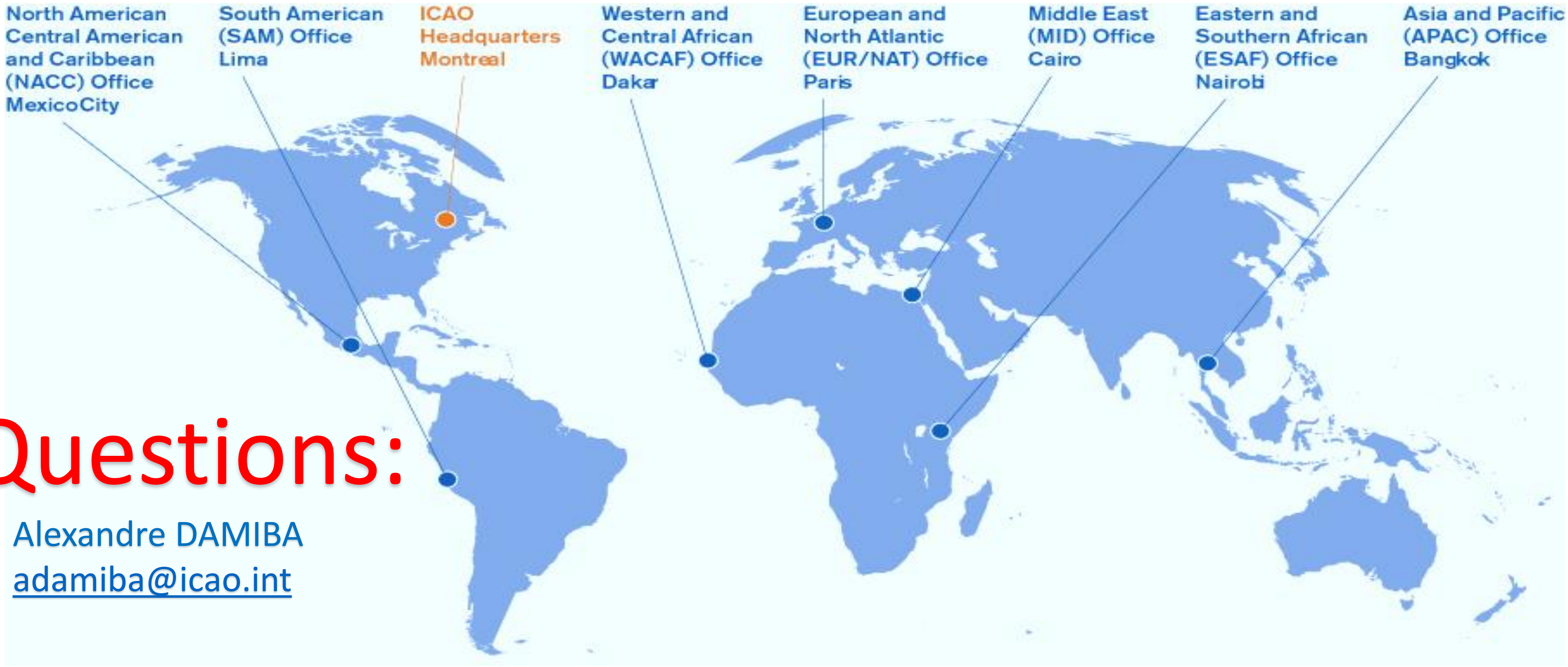
SUMMARY

Summary

- Airspace design challenges
  - What are we transitioning from?
  - Old airspace serves as the reference scenario
- Organizing TMA flows
  - Based on analysis of traffic flows per sector
- Entry Points… keep to a minimum (4 – 5)
- STAR Open and Closed Paths
  - Open from Base Sector, Closed from Straight-in Sector
- CDO
  - 250 – 350’/NM

Comprehension Check

1. State goals of the operator
2. What are the 3 documents recommended for airspace design?
3. Why is the ”Reference” scenario important?
4. List 5 strategic objectives.
5. What is the ideal number of STARs and SIDs?
6. What determines the location of Entry points?
7. Where does an OPEN path STAR terminate?
8. What is the TAA and what is it used for during TMA airspace design?
9. What is the industry mean angle for an optimum vertical path?



Questions:

Alexandre DAMIBA
adamiba@icao.int