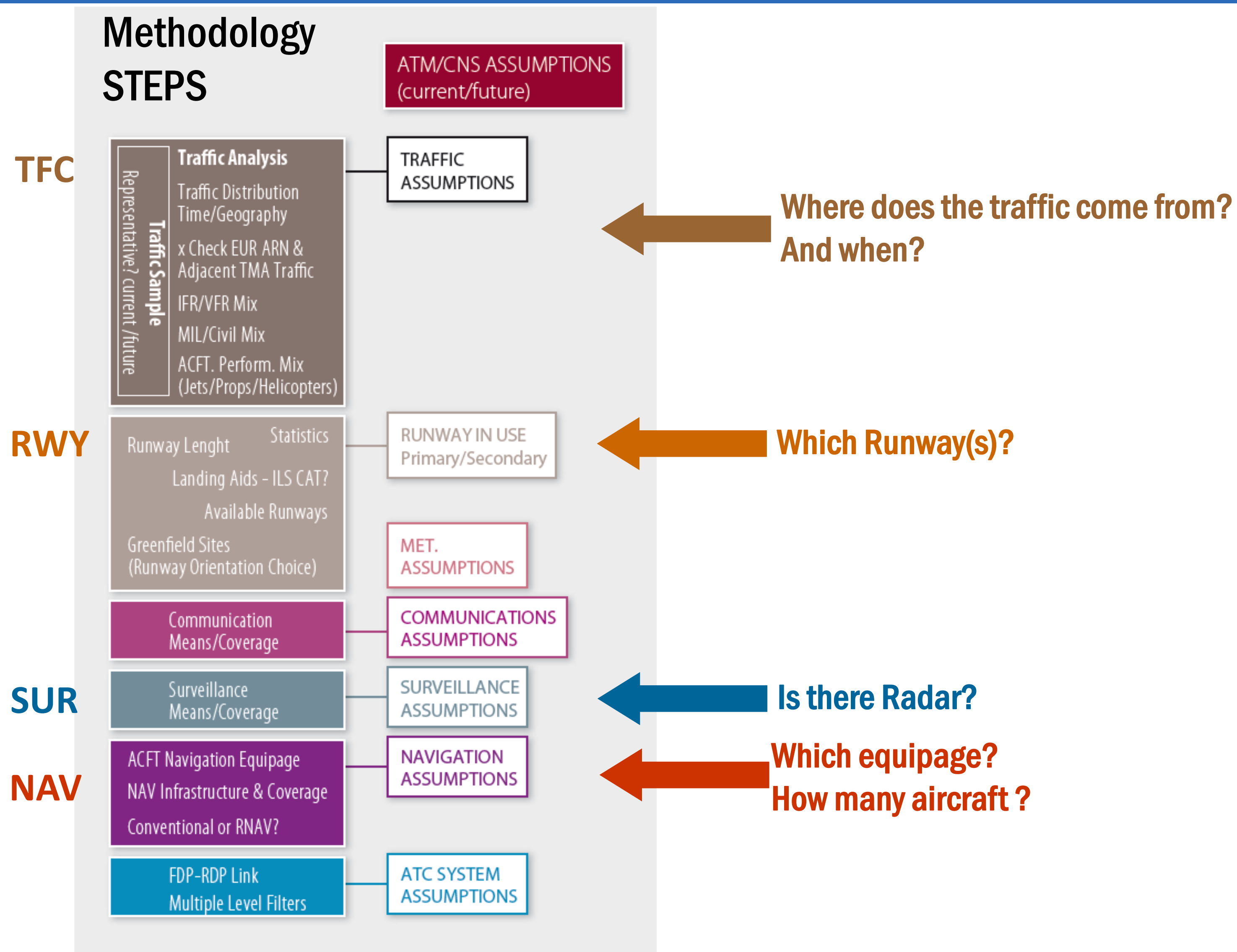
International Civil Aviation Organization

PBN
AIRSPACE CONCEPT WORKSHOP

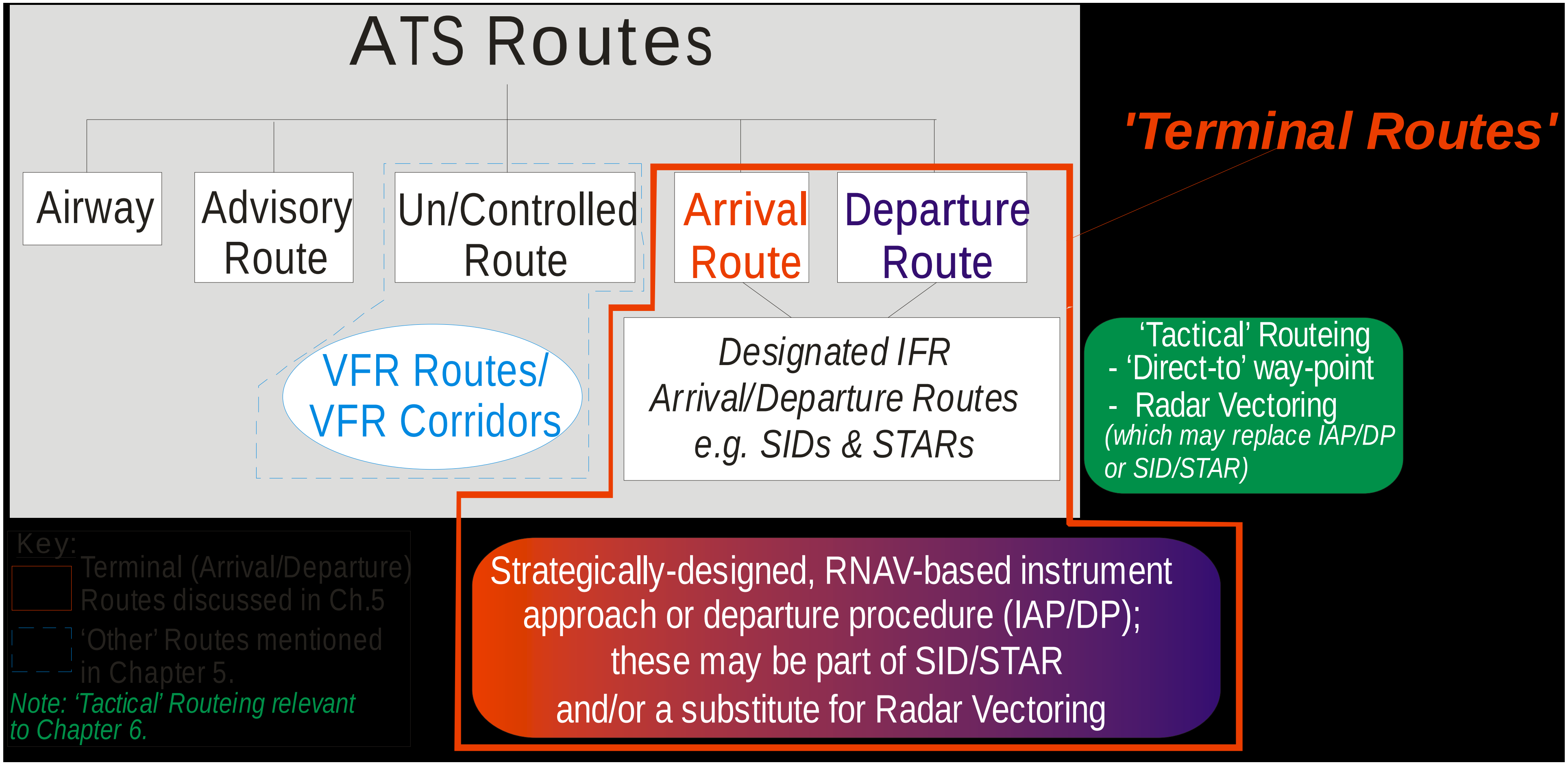
SIDs/STARs/HOLDS

Continuous Descent Operations (CDO)
ICAO Doc 9931

Design in context



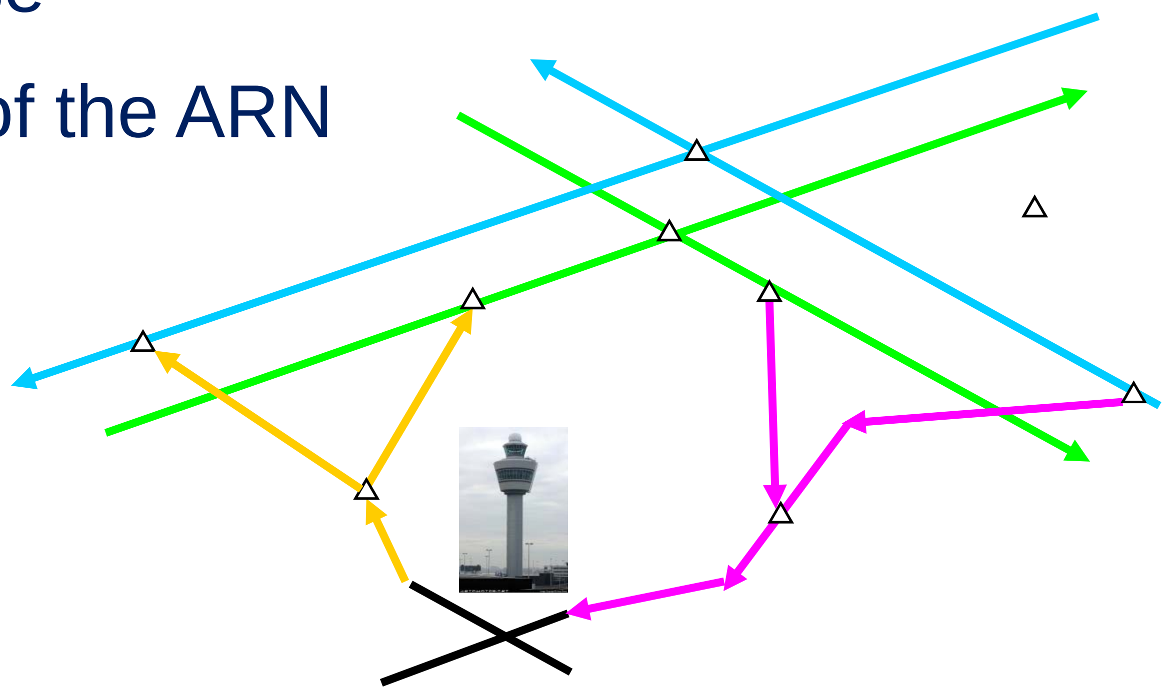
Routes


ATS Routes
Airway
Advisory Route
Un/Controlled Route
Arrival Route
Departure Route
'Terminal Routes'
VFR Routes/ VFR Corridors
Designated IFR Arrival/Departure Routes e.g. SIDs & STARs
'Tactical' Routeing
- 'Direct-to' way-point
- Radar Vectoring
(which may replace IAP/DP or SID/STAR)
Strategically-designed, RNAV-based instrument approach or departure procedure (IAP/DP); these may be part of SID/STAR and/or a substitute for Radar Vectoring
Key:
Terminal (Arrival/Departure) Routes discussed in Ch.5
'Other' Routes mentioned in Chapter 5.
Note: 'Tactical' Routeing relevant to Chapter 6.

Terminal Routes

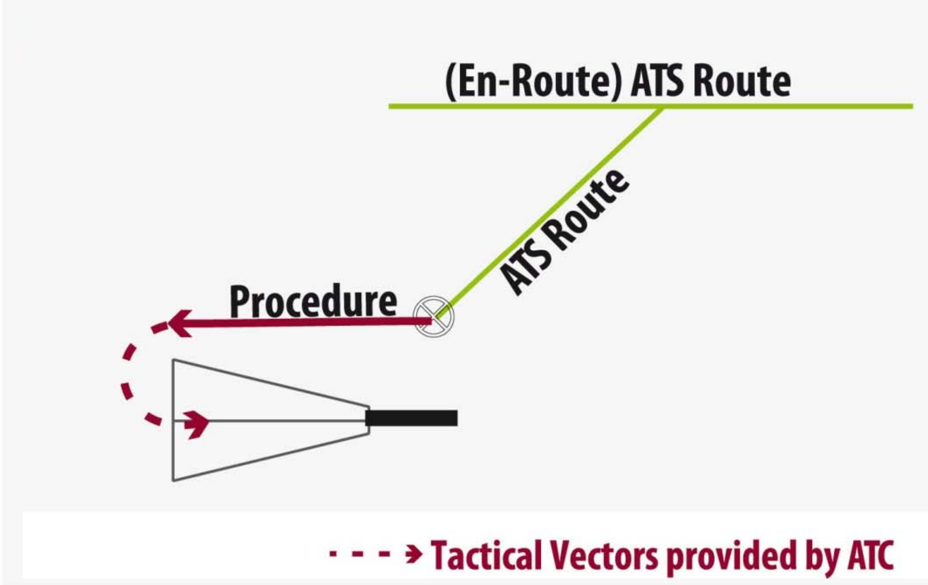
Routes in Terminal Airspace link…

- Raw demand
- Runway in use
- ATS Routes of the ARN

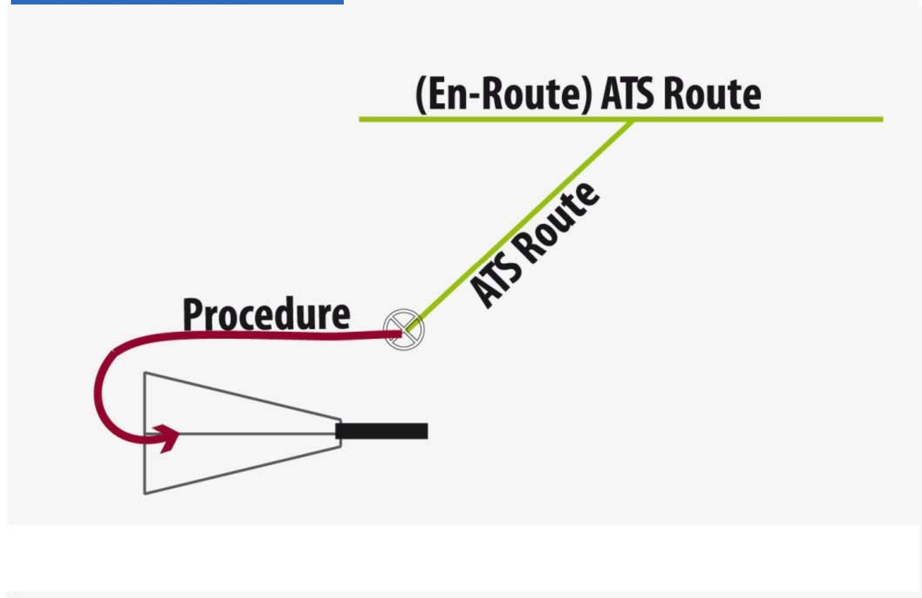


Different kinds of IFP

Open Path



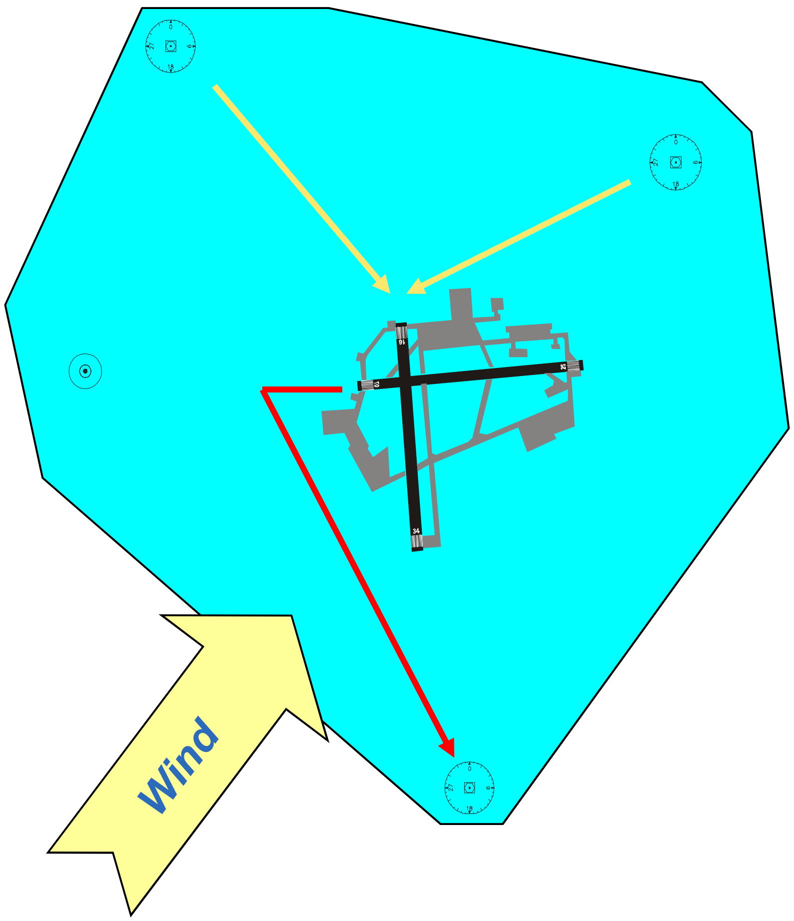
Closed Path



Tactical Vectors provided by ATC

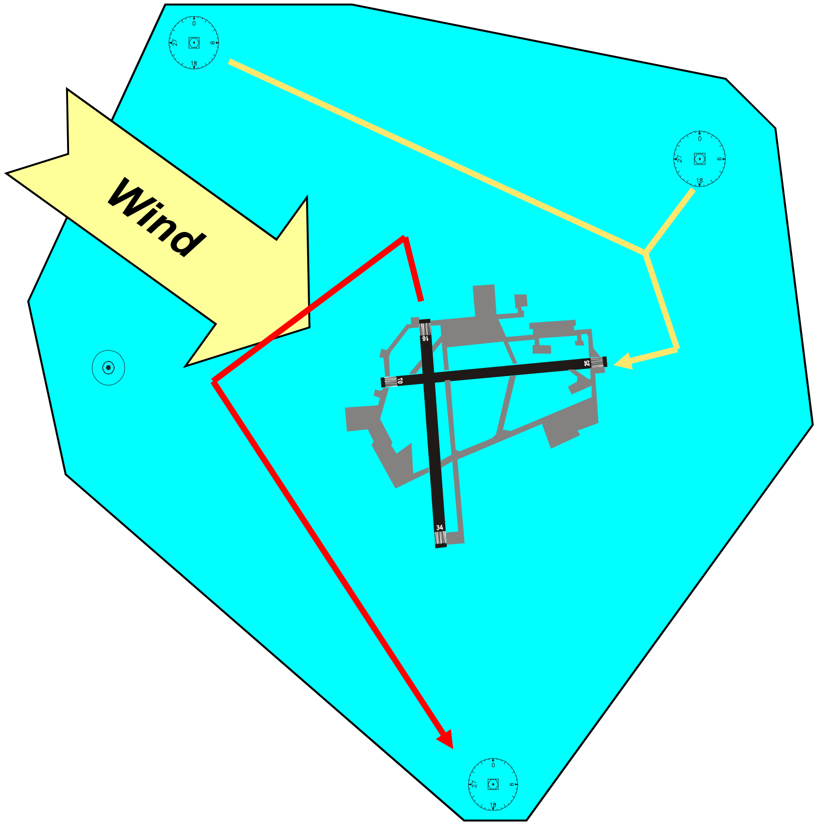
SID/STAR Dependence on

- RWY orientation is given
- Direction of RWY in use depends on wind



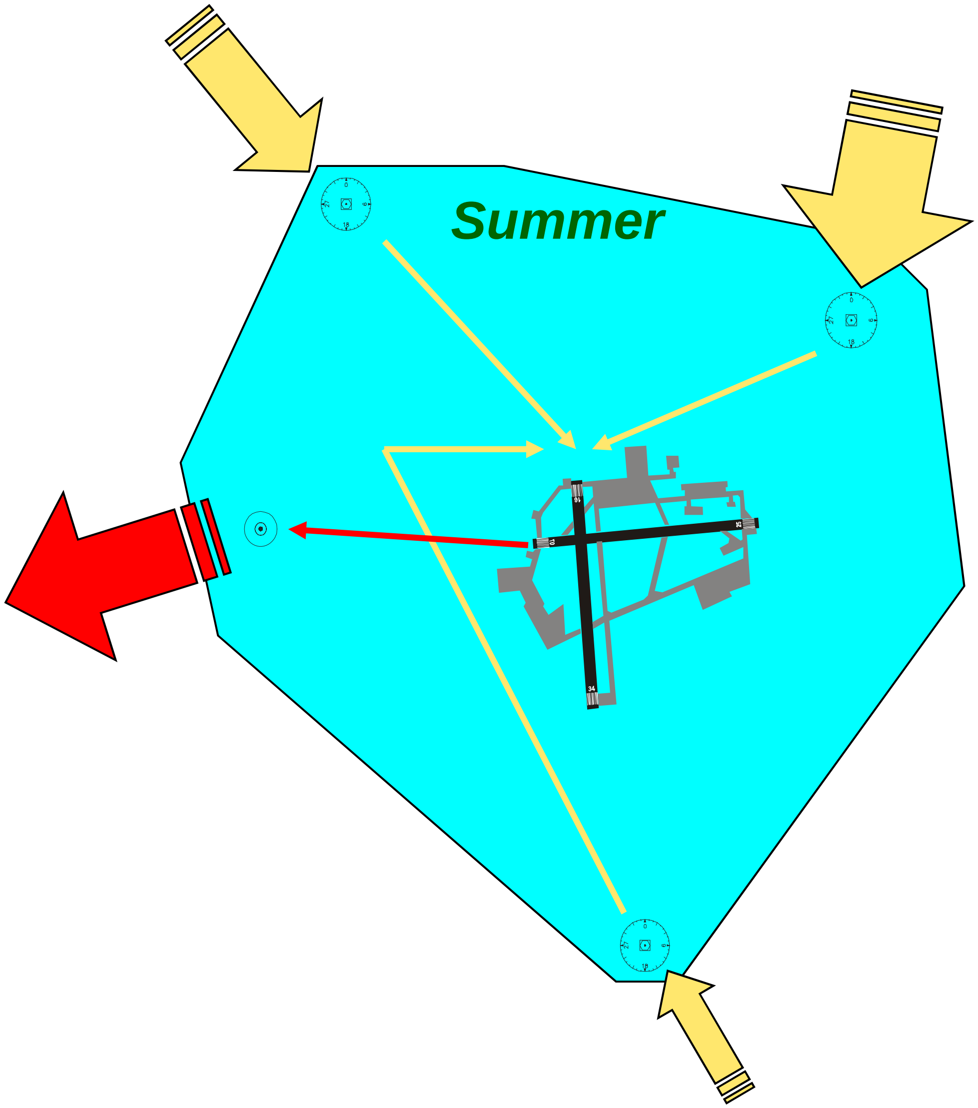
SID/STAR Dependence on RWY (2)

- Different set of SIDs and STARs for different Runway in use



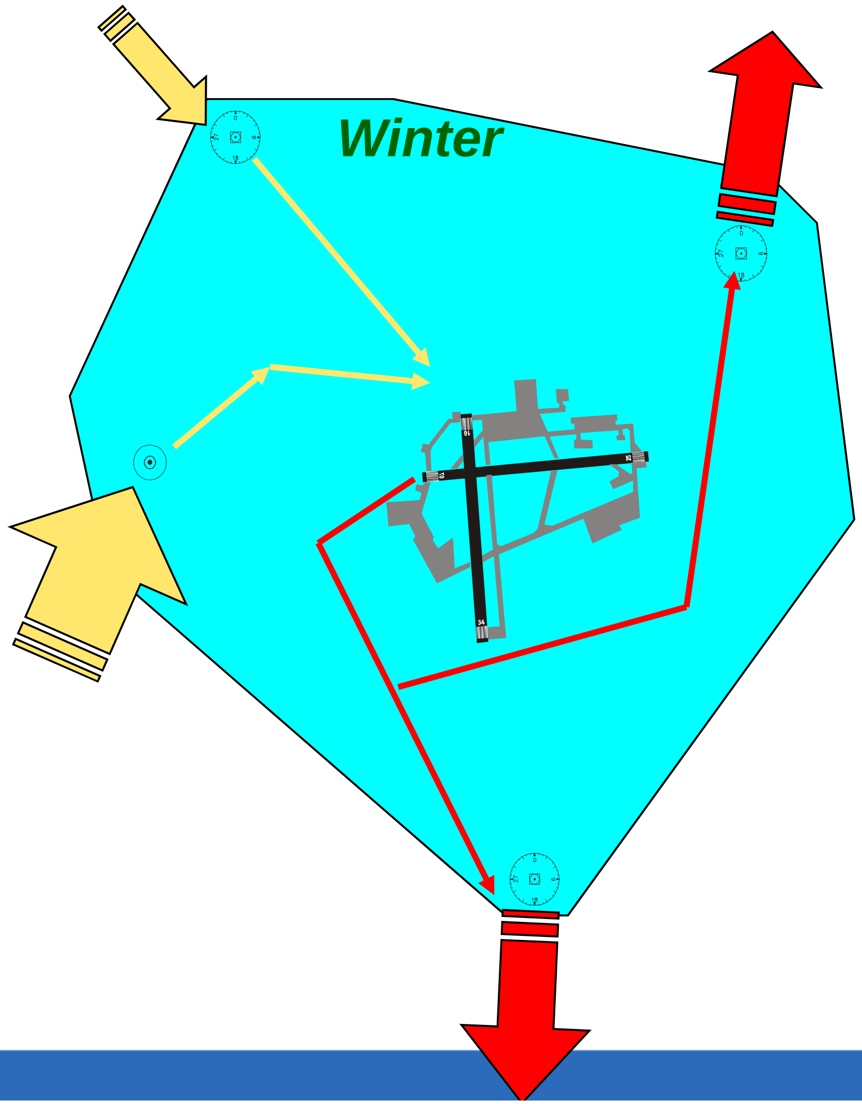
Seasonal Effect (1)

- Demand and route placement can vary for different seasons



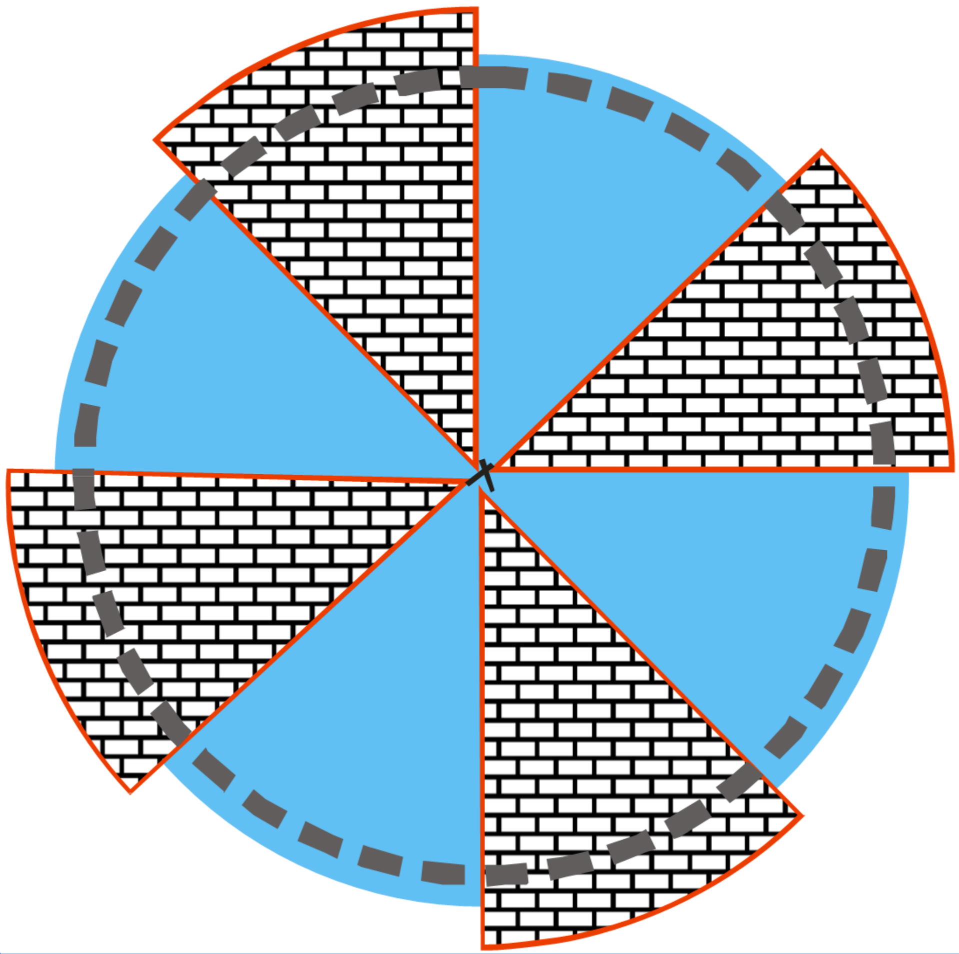
Seasonal Effect (2)

- Different set of SIDs and STARs per season

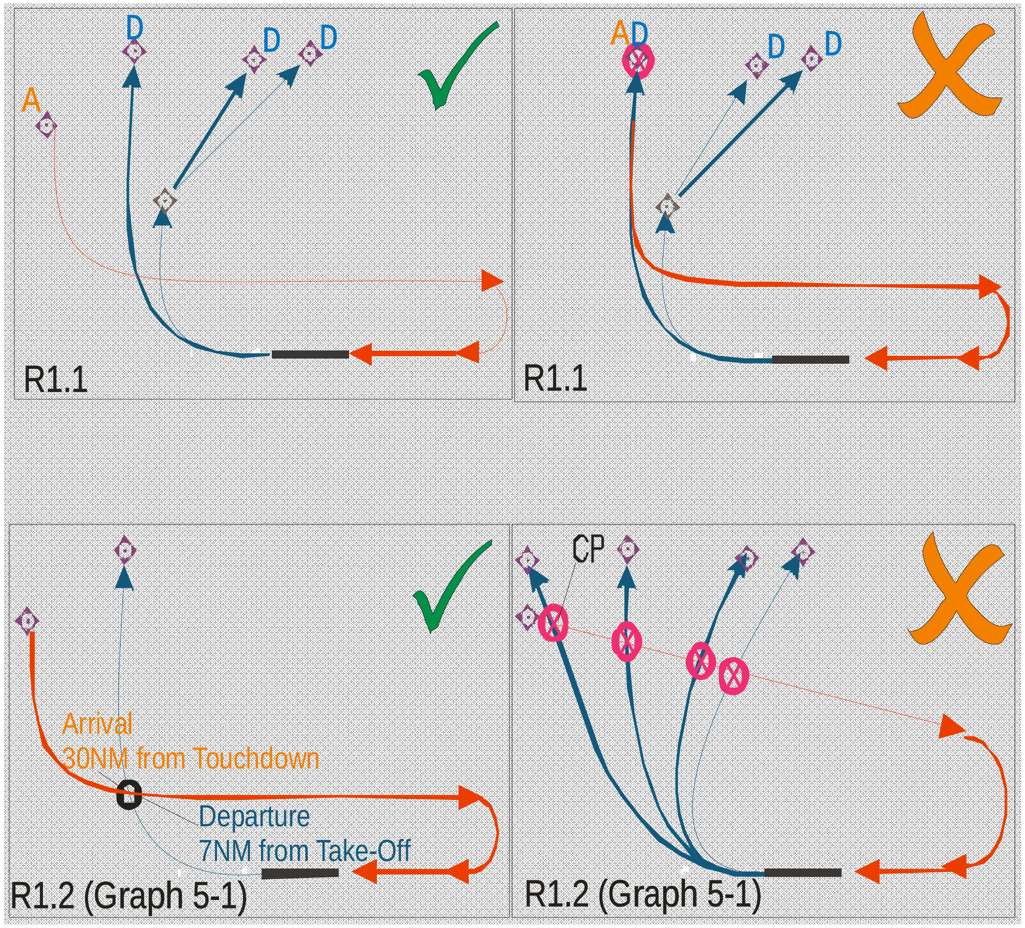


Good design practice

Segregate Arrivals from Departures
Both laterally and Vertically



Good design practice

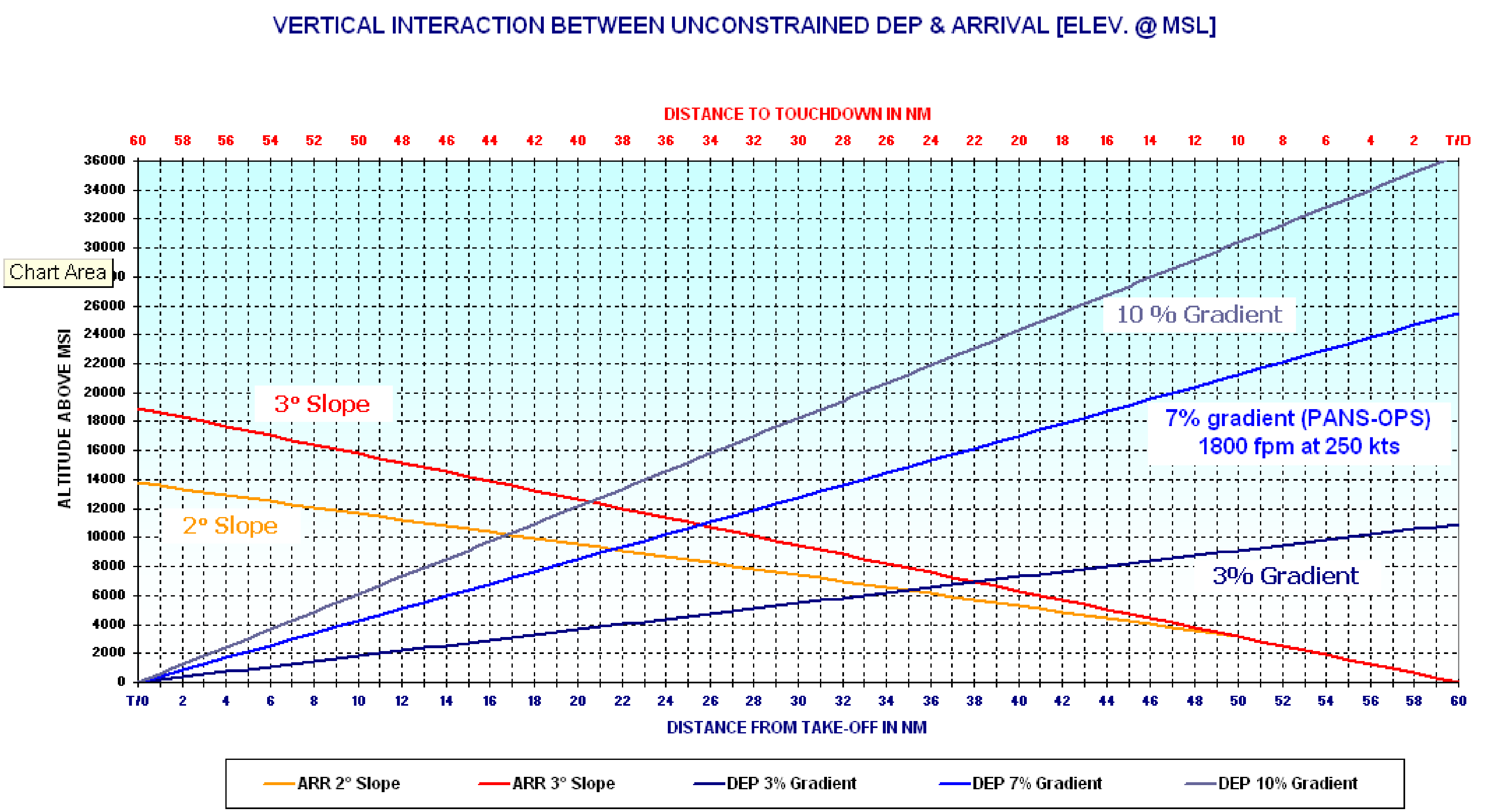


Segregation of Routes and Entry/Exit point

Minimise the number of crossing points

Plan for vertical separation

Good design practice

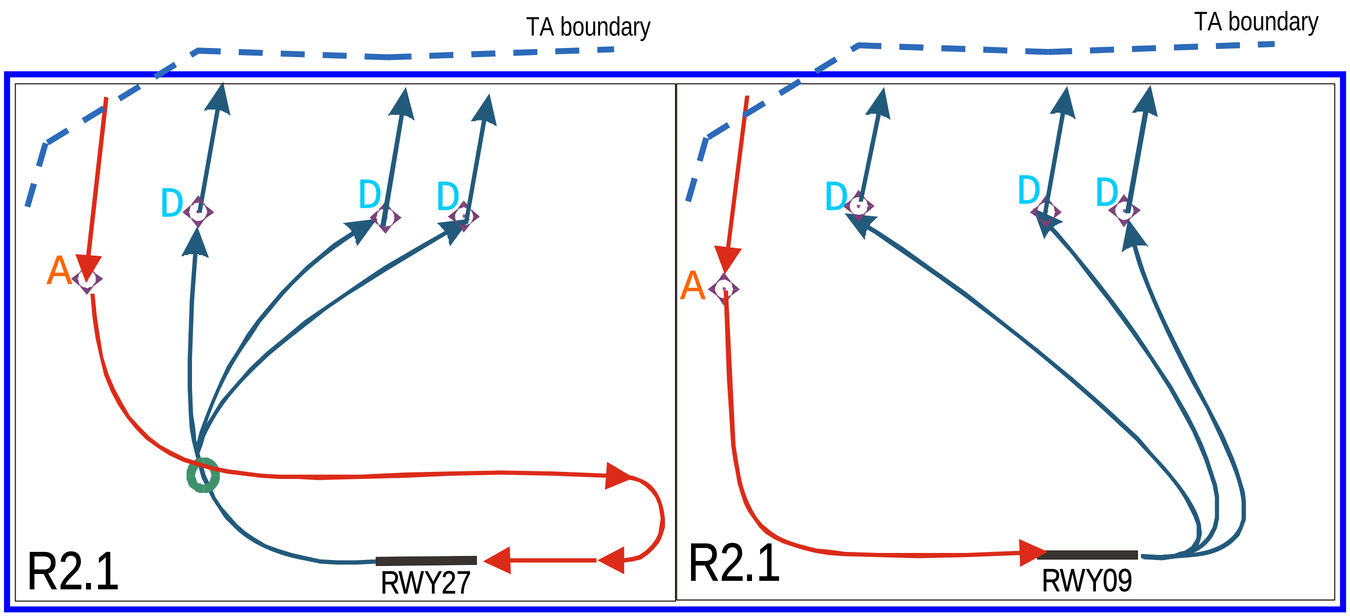


SAMPLE CHART ONLY: SIMILAR GRAPHS SHOULD BE DEVELOPED FOR EACH IMPLEMENTATION DEPENDING ON FLEET

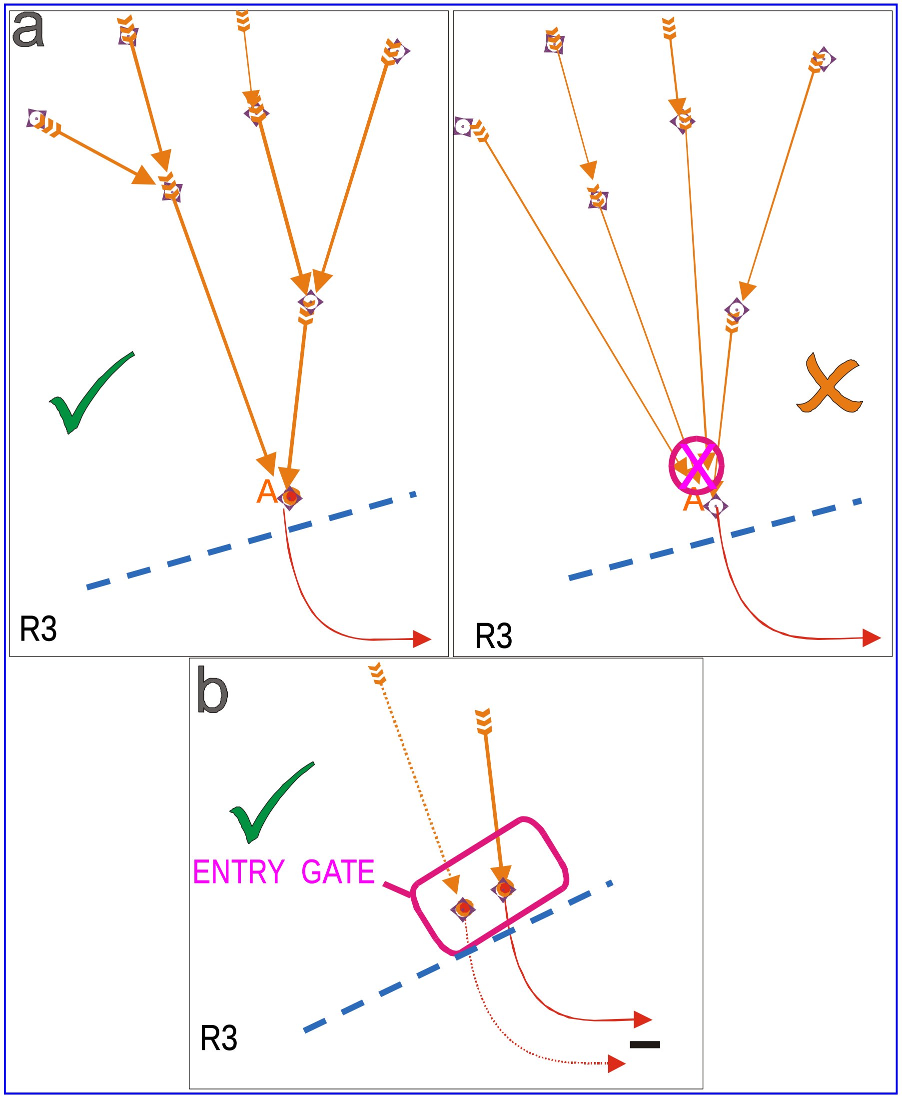
Good design practice

Fix the same Exit/Entry points for different RWY configurations

(handoff between ACC and APP should not change with RWY configuration)



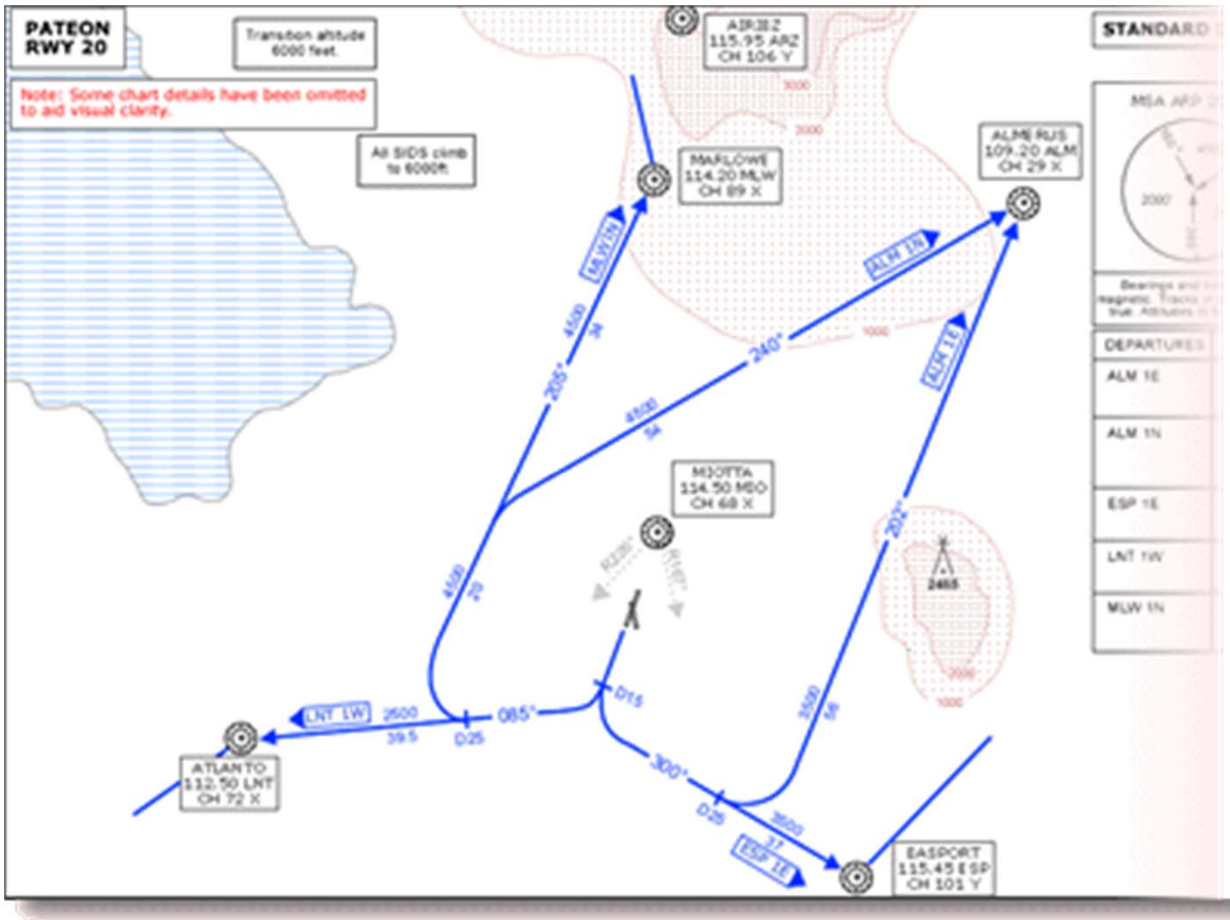
Good design practice



Gradually converge inbound flows

Group similar inbound flows in Entry Gates

Conventional SID



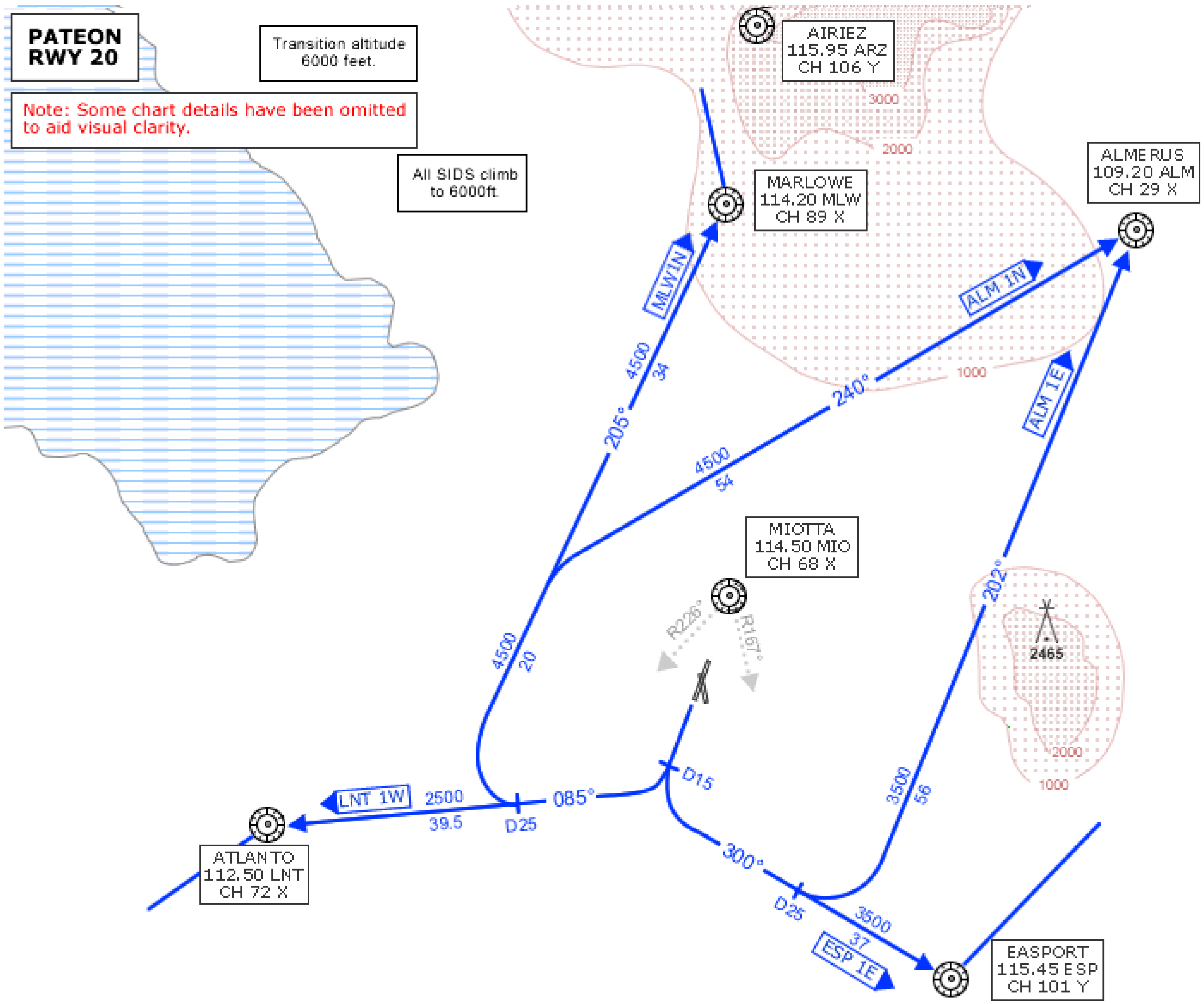
Limitations:

- Inflexible SID/STAR design: constraint to airspace optimisation
- Track accuracy performance cannot be stipulated
- Inconsistent track-keeping performance
- Require the use of VOR/DME and/or NDB

Advantages:

- All aircraft operating under IFR are suitably equipped
- Defined by waypoints

The Benefits of RNAV



STANDARD INSTRUMENT DEPARTURES

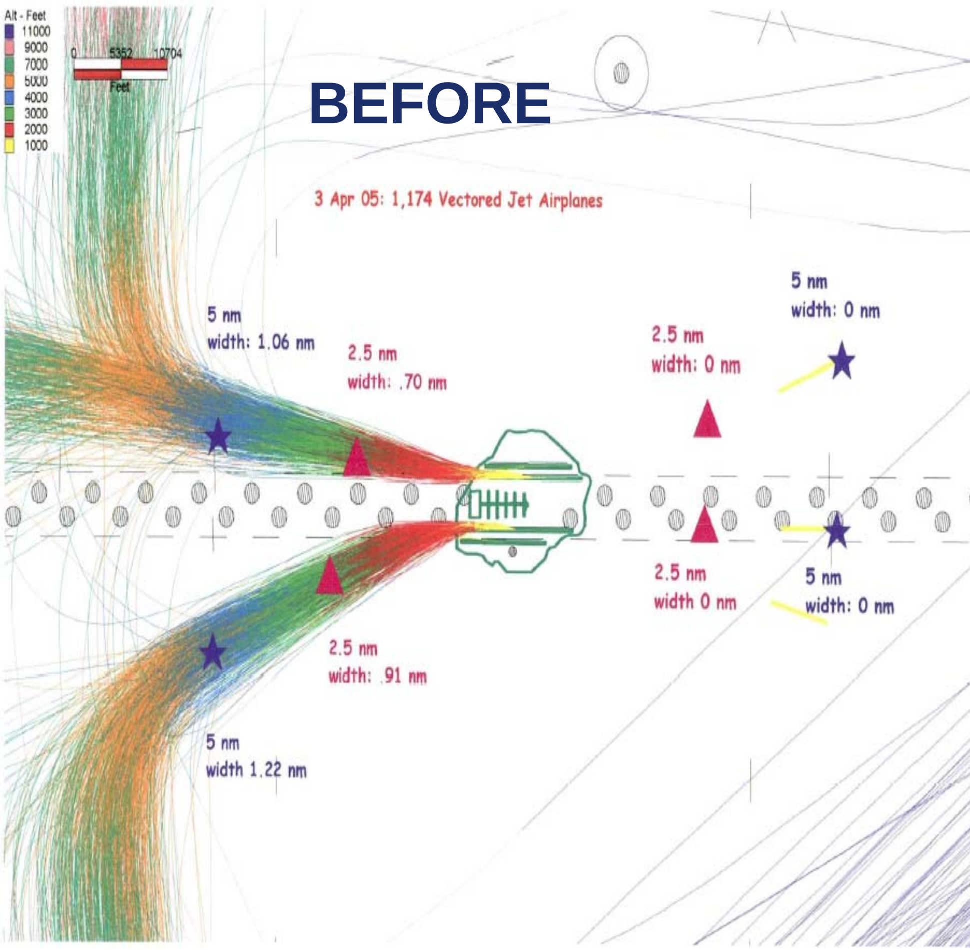
MSA ARP 25 NM

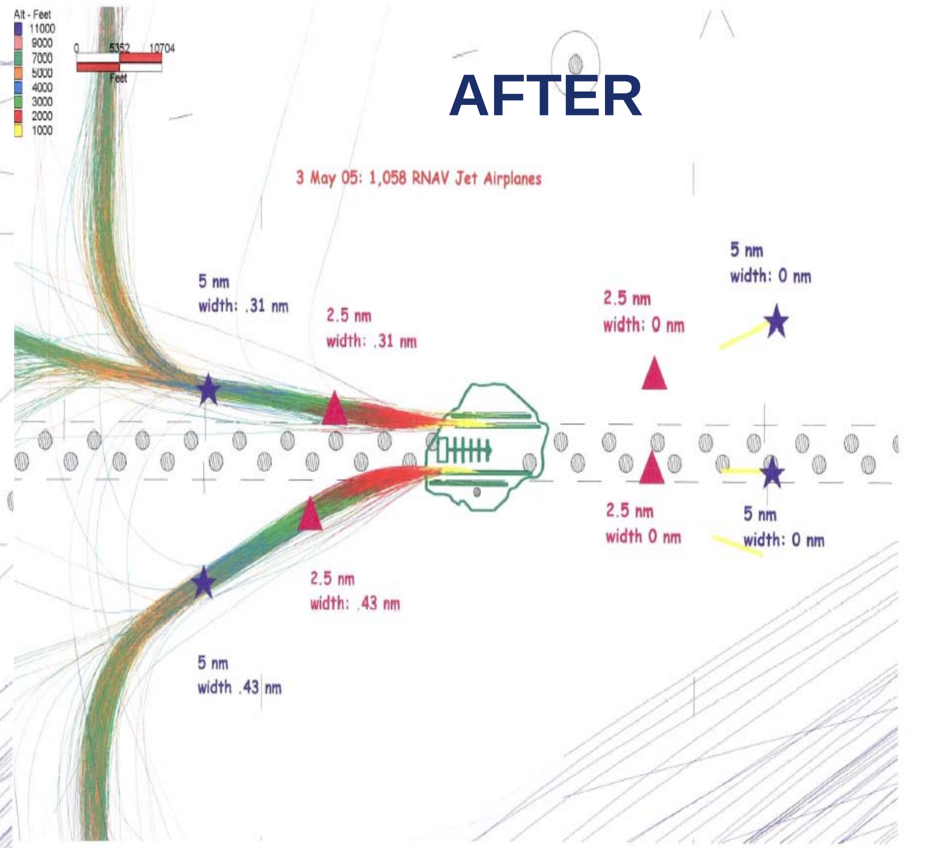
Bearings and tracks are magnetic. Tracks in brackets are true. Altitudes in feet AMSL.

VOR/DME	Latitude	Longitude
AIRIEZ	N54º 01'	E003º 03.1'
ALMERUS	N53º 48.9'	E003º 25.1'
ATLANTO	N53º 14.3'	E002º 34.8'
EASPORT	N53º 05.2'	E003º 14.2'
MARLOWE	N53º 50.5'	E003º 01.2'
MIOTTA	N53º 27.7'	E003º 01.6'

DEPARTURES	ROUTEING
ALM 1E	Climb on track 203, at 15D MIO turn left to intercept ESP R300. At 25D MIO turn left to intercept ALM R202 to ALM.
ALM 1N	Climb on track 203, at 15D MIO turn right to intercept LNT R085. At 25D MIO turn right to intercept MLW R205. Intercept ALM R240 to ALM.
ESP 1E	Climb on track 203, at 15D MIO turn left to intercept ESP R300 to ESP.
LNT 1W	Climb on track 203, at 15D MIO turn right to intercept LNT R085 to LNT.
MLW 1N	Climb on track 203, at 15D MIO turn right to intercept LNT R085. At 25D MIO turn right to intercept MLW R205 to MLW.

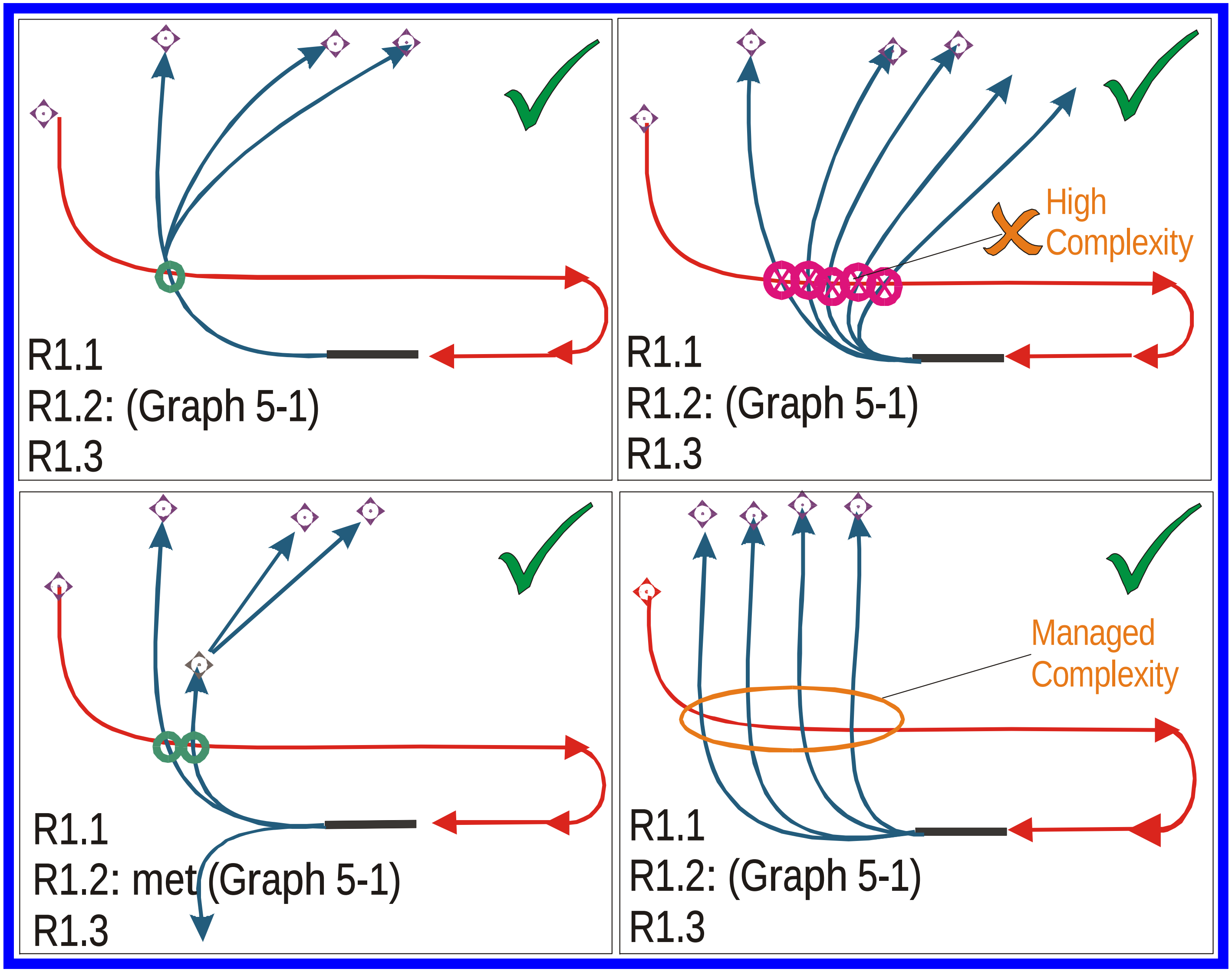
RNAV Departures at Atlanta



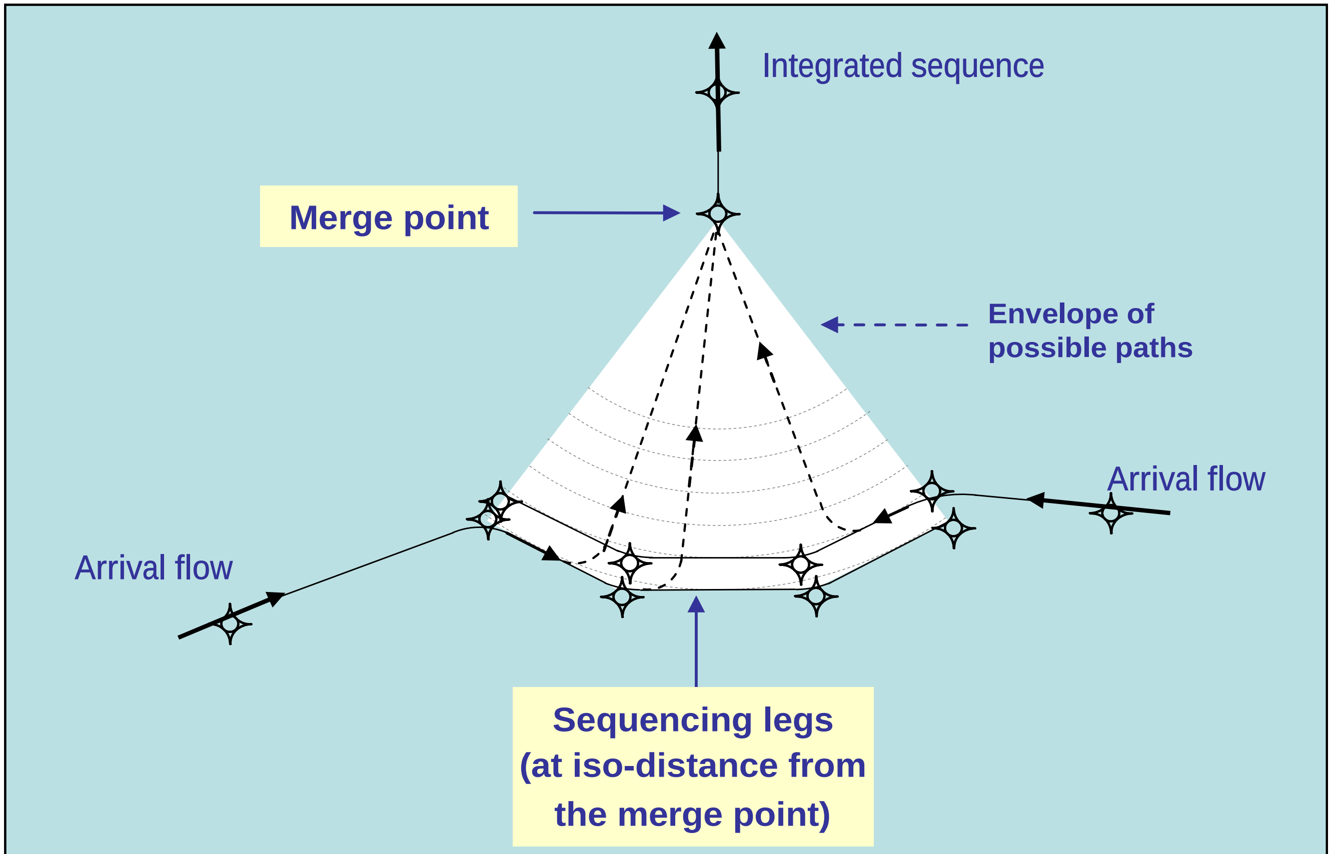


Good design practice

Minimise Crossing Complexity

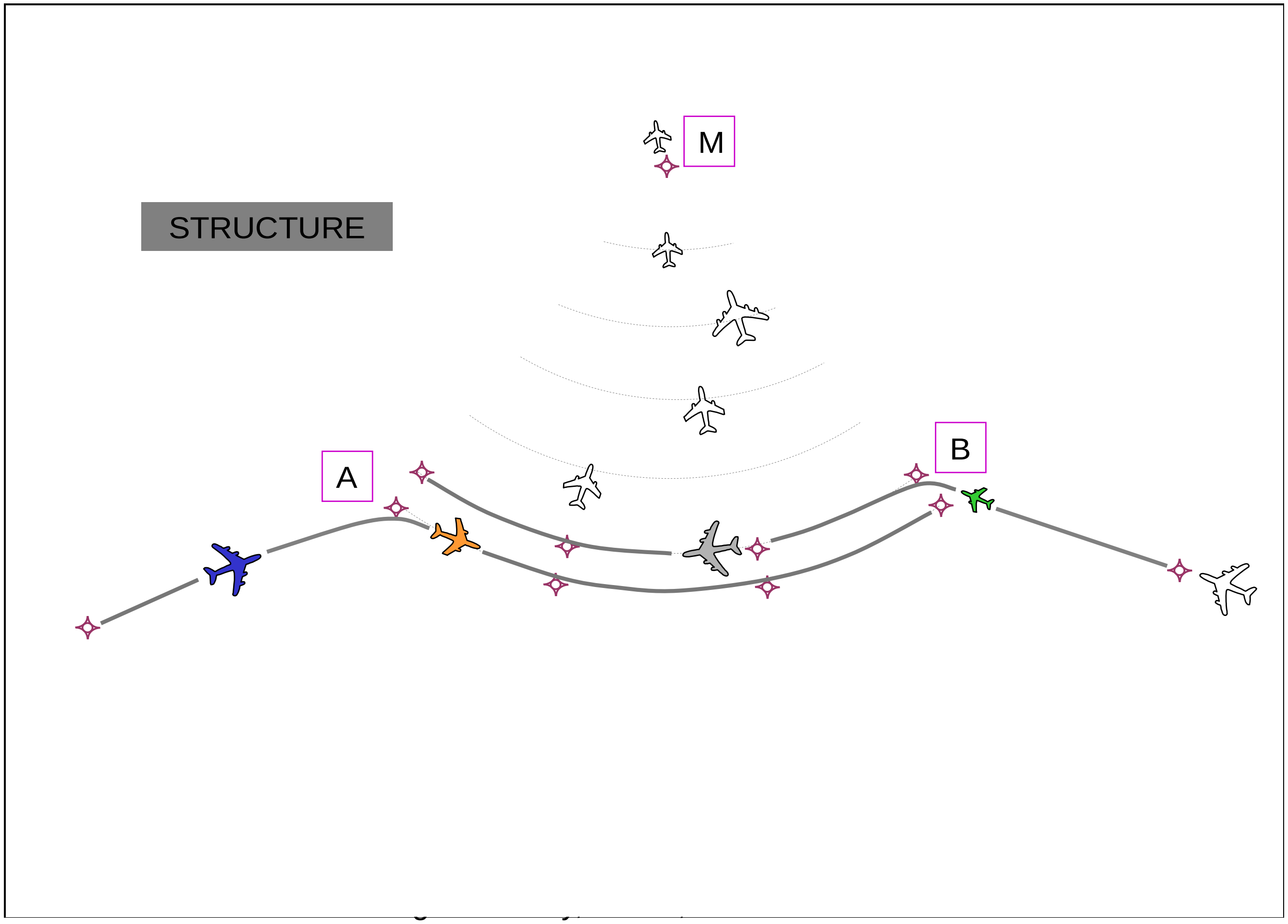


Point Merge System (PMS)

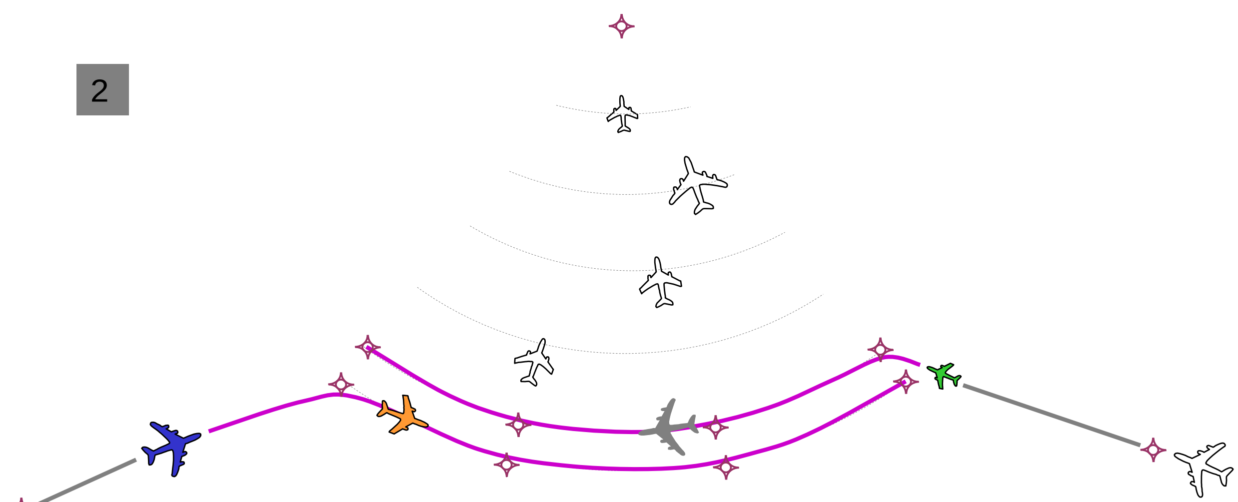


Point merge system - example with two inbound flows

Scenario “talk-through” (1/5)

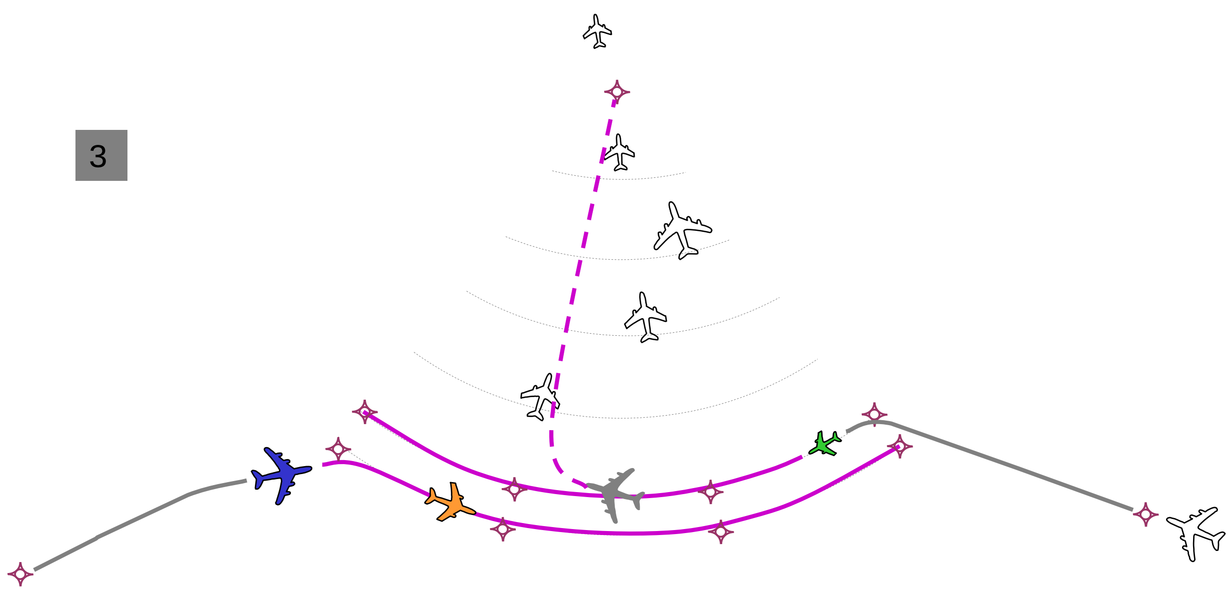


Scenario “talk-through” (2/5)



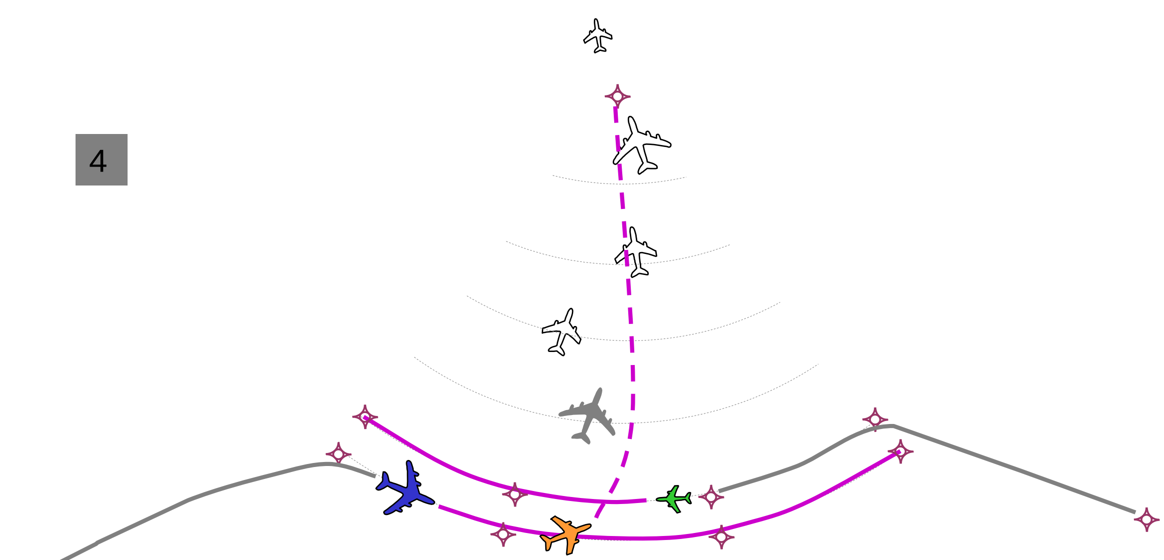
Initial situation with a busy flow of traffic to the merge point

Scenario “talk-through” (3/5)



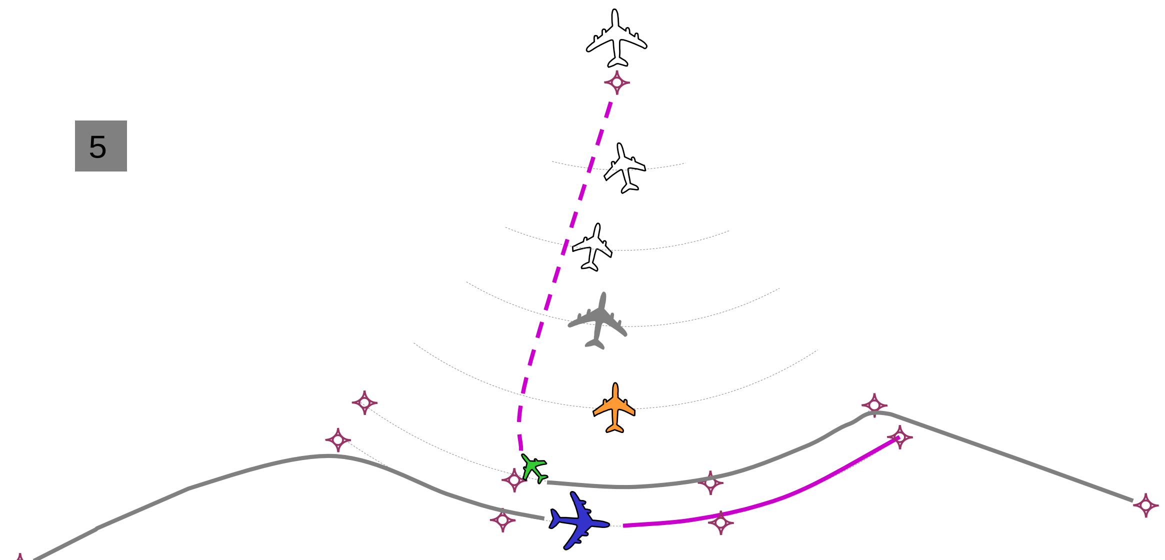
Grey heavy jet turns to the merge point.
Controller determines when to issue the “Direct to merge point” instruction to the Gold aircraft to ensure that the required WTC spacing behind the preceding aircraft will be achieved.

Scenario "talk-through" (4/5)



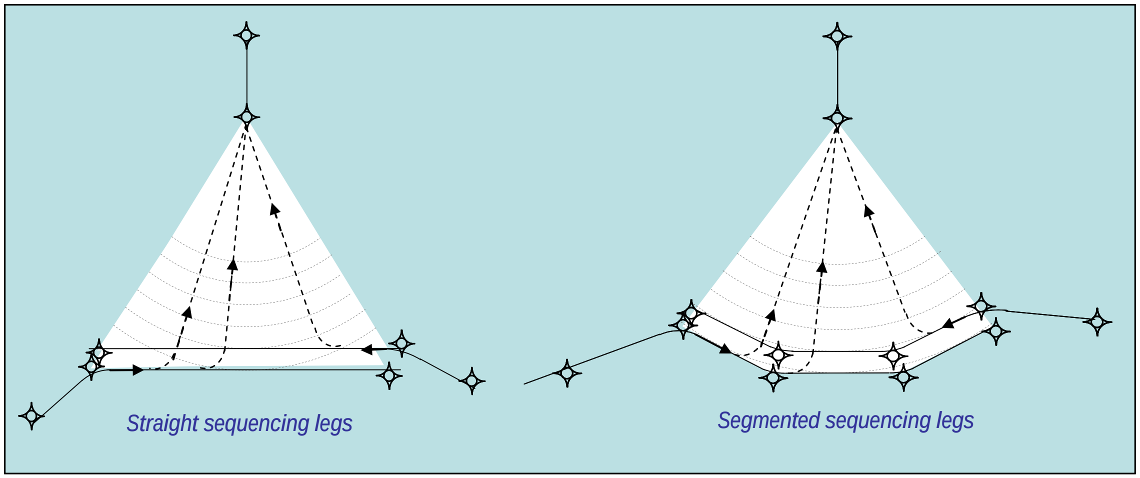
Controller issues the "Turn left direct to merge point" instruction
to the Gold aircraft using the range ring arcs to assess
the appropriate WTC spacing from the Grey aircraft.

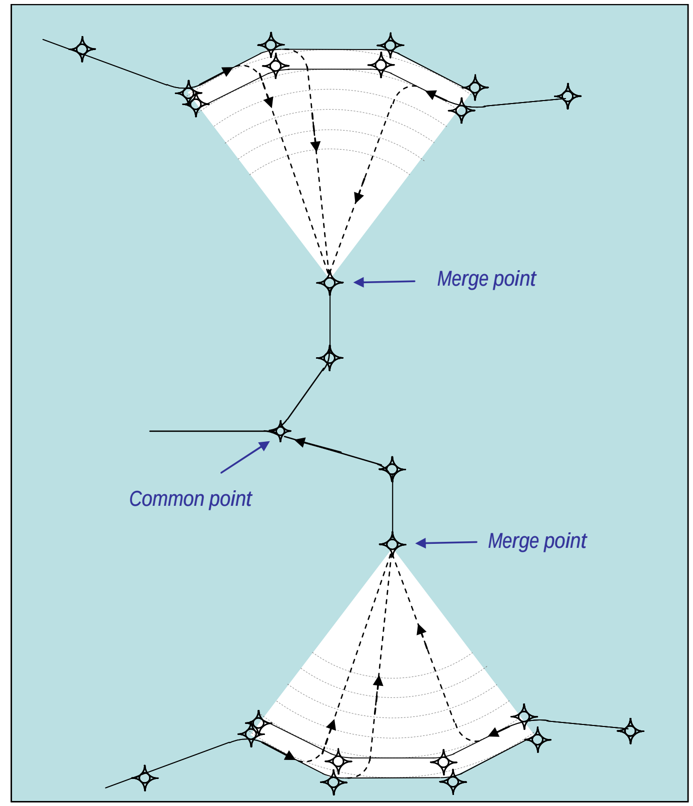
Scenario “talk-through” (5/5)

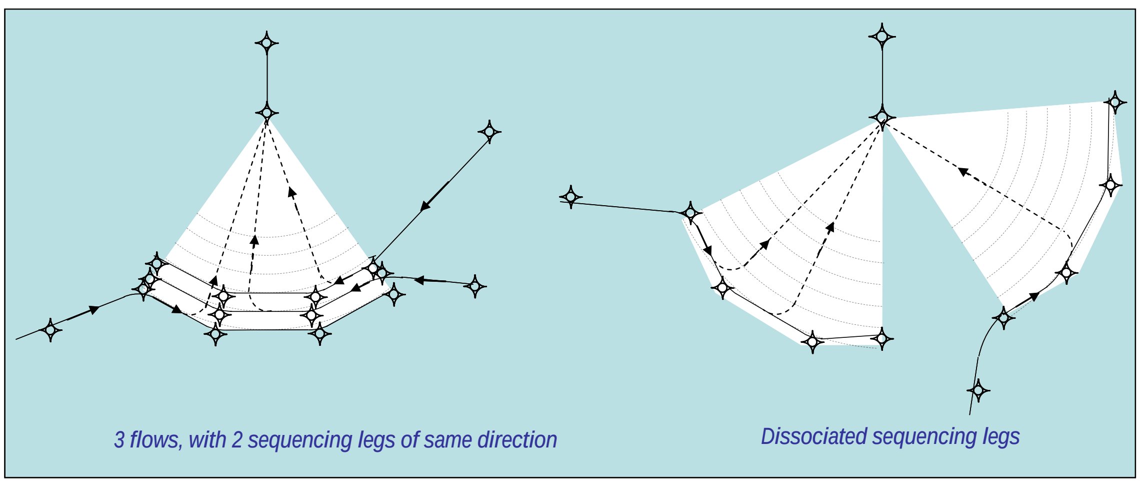


The same technique is repeated for the Green aircraft

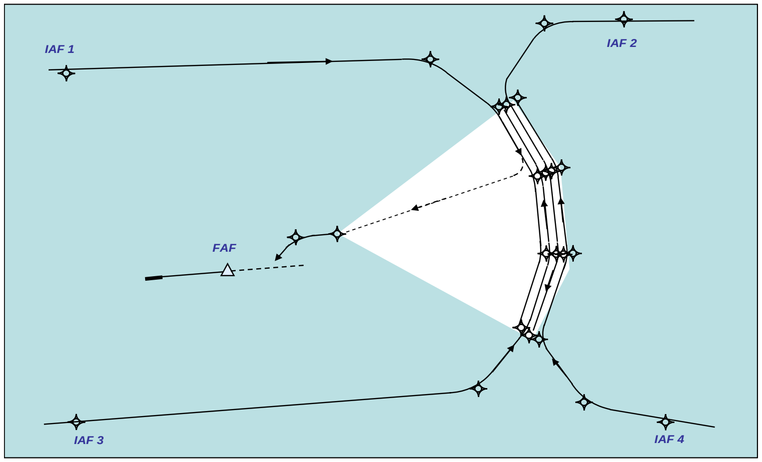
Configurations tested (1/2)

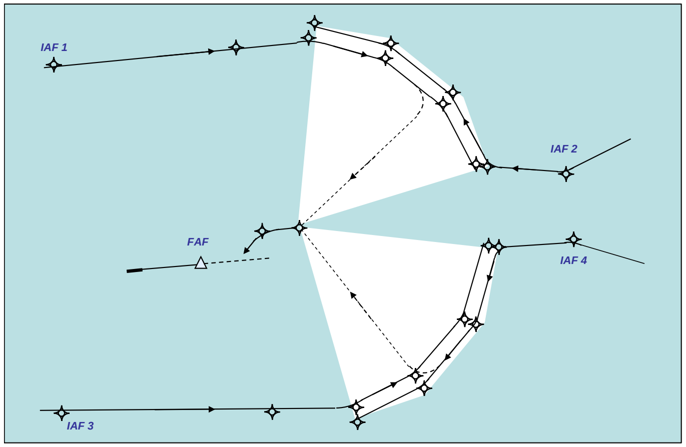


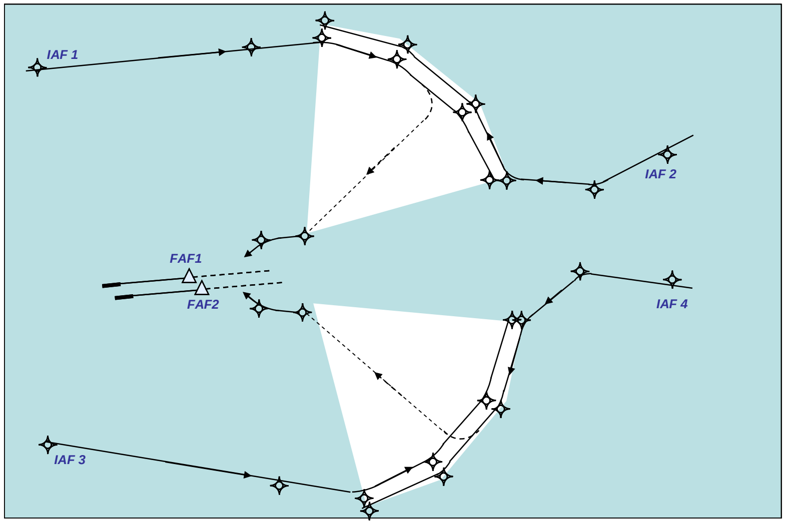




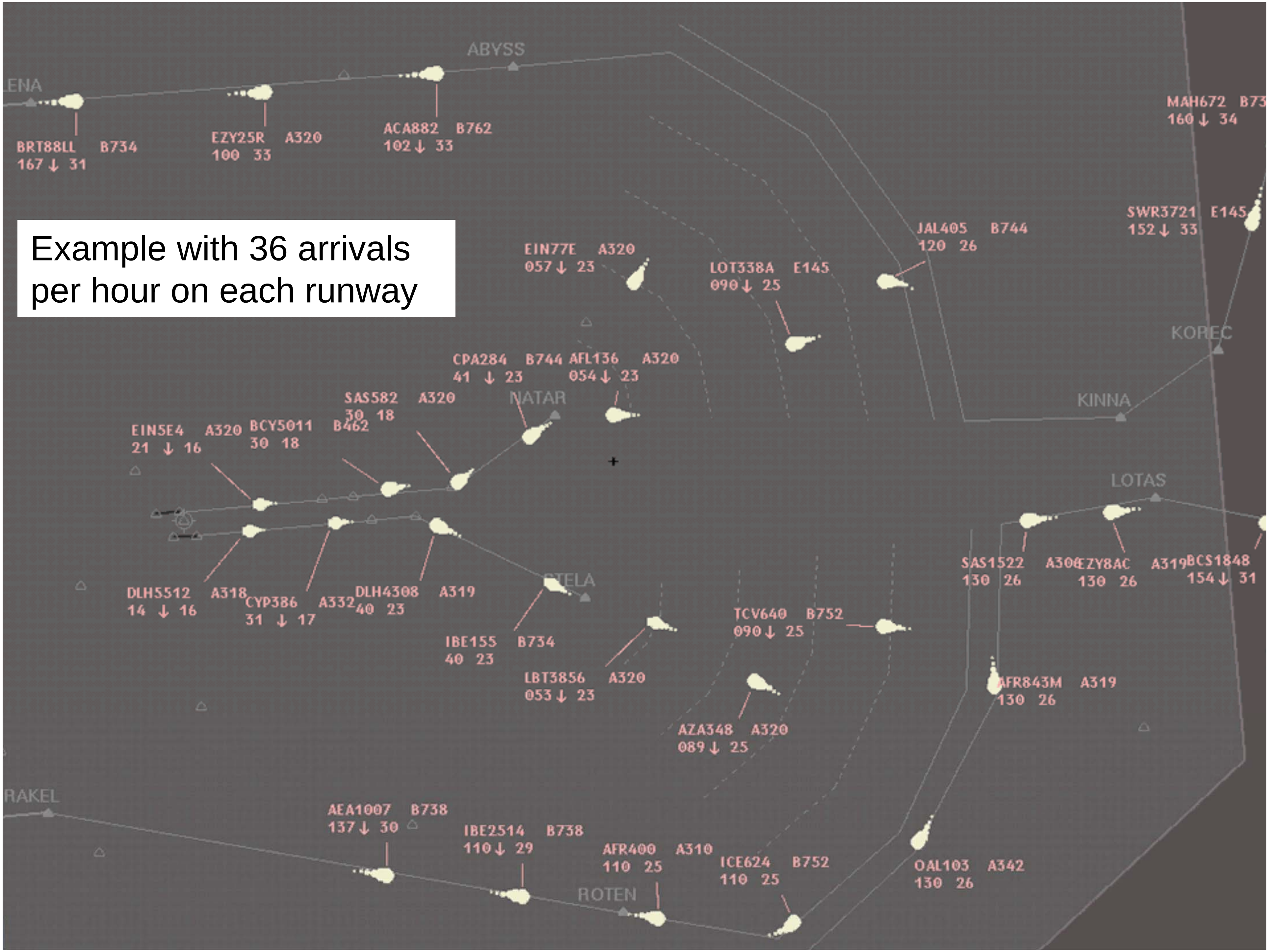
Configurations tested (2/2)







Example with 36 arrivals per hour on each runway



CDO

A CDO should always be considered when implementing new PBN STARS.

Who makes CDO possible?

Understanding Continuous Descent Operations (CDO)

Continuous Descent Operations:

- Are enabled by airspace design, procedure design and ATC facilitation
- Allows the aircraft to descend continuously
- Employing minimum engine thrust, in a low drag configuration
- Usable by 85% of the aircraft, 85% of the time

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

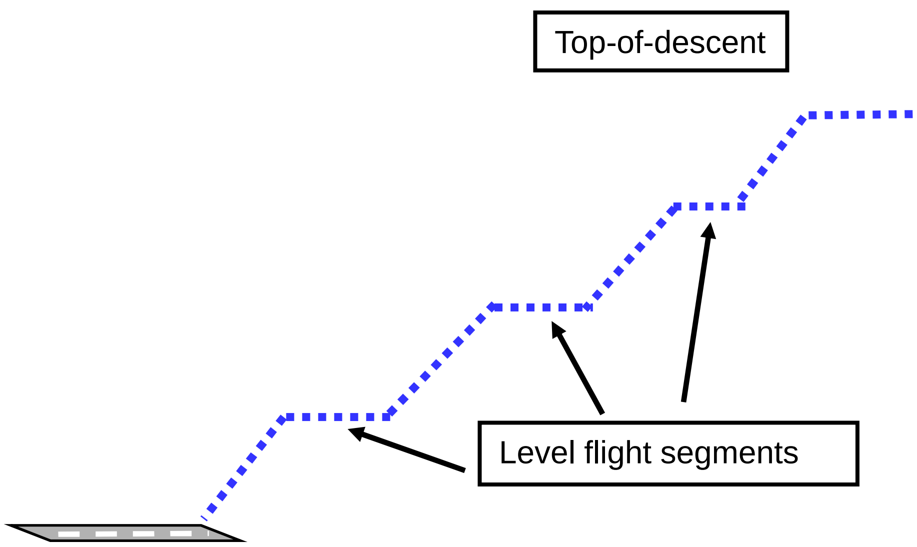
The optimum vertical path angle will vary depending on:

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

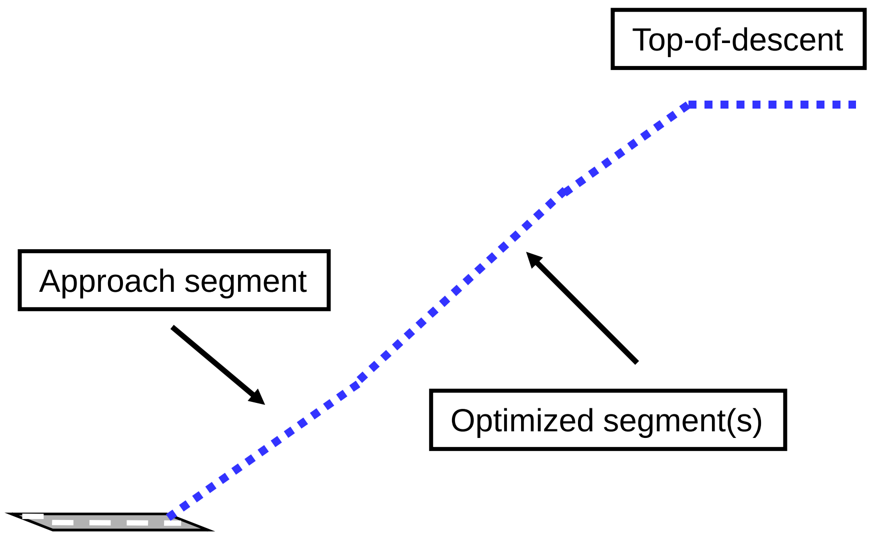
The maximum benefit is achieved by keeping the aircraft as high as possible until it reaches the optimum descent point determined by the on-board flight management computer.

Step-down vs. CDO

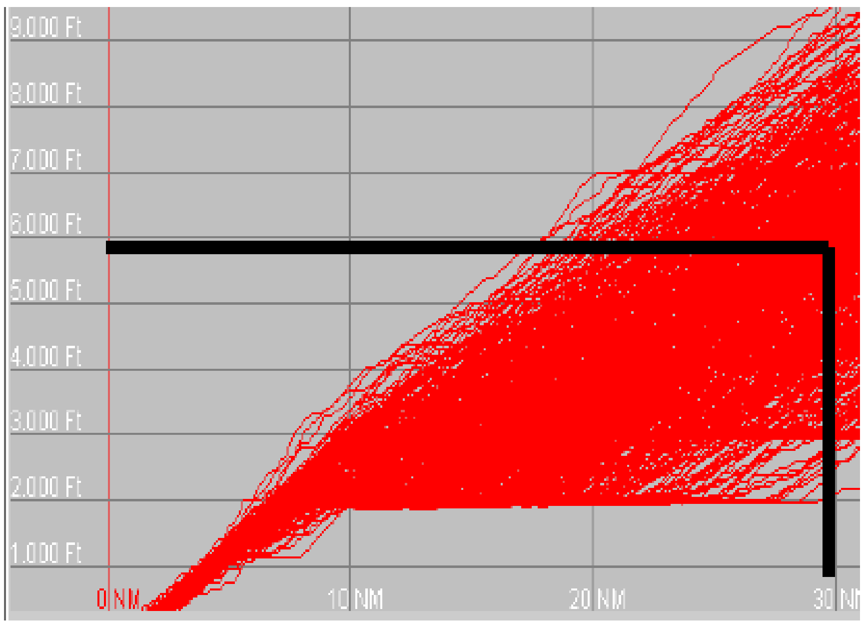
Conventional step-down



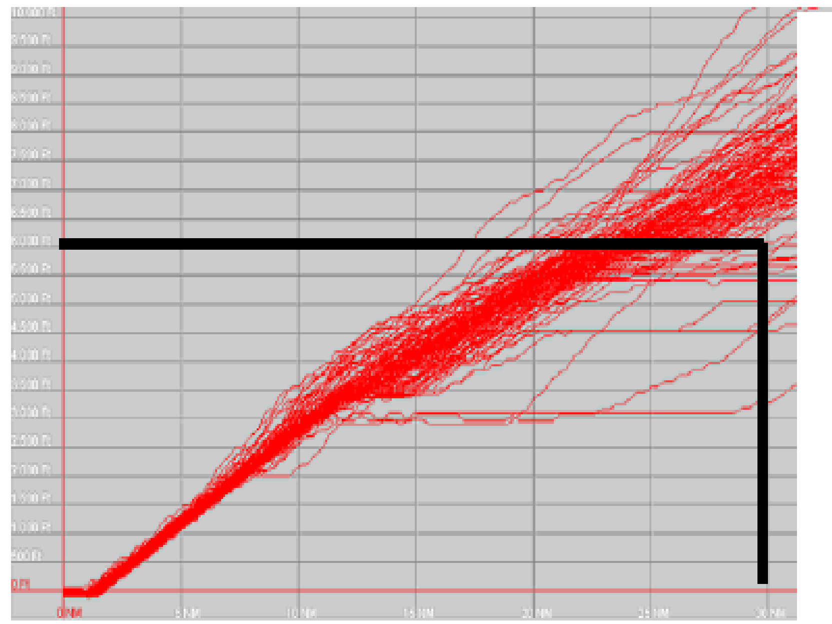
Continuous descent operation



Actual CDO Operation



Flight tracks before CDO



Flight tracks after CDO

What the Pilot/FMS needs to Know

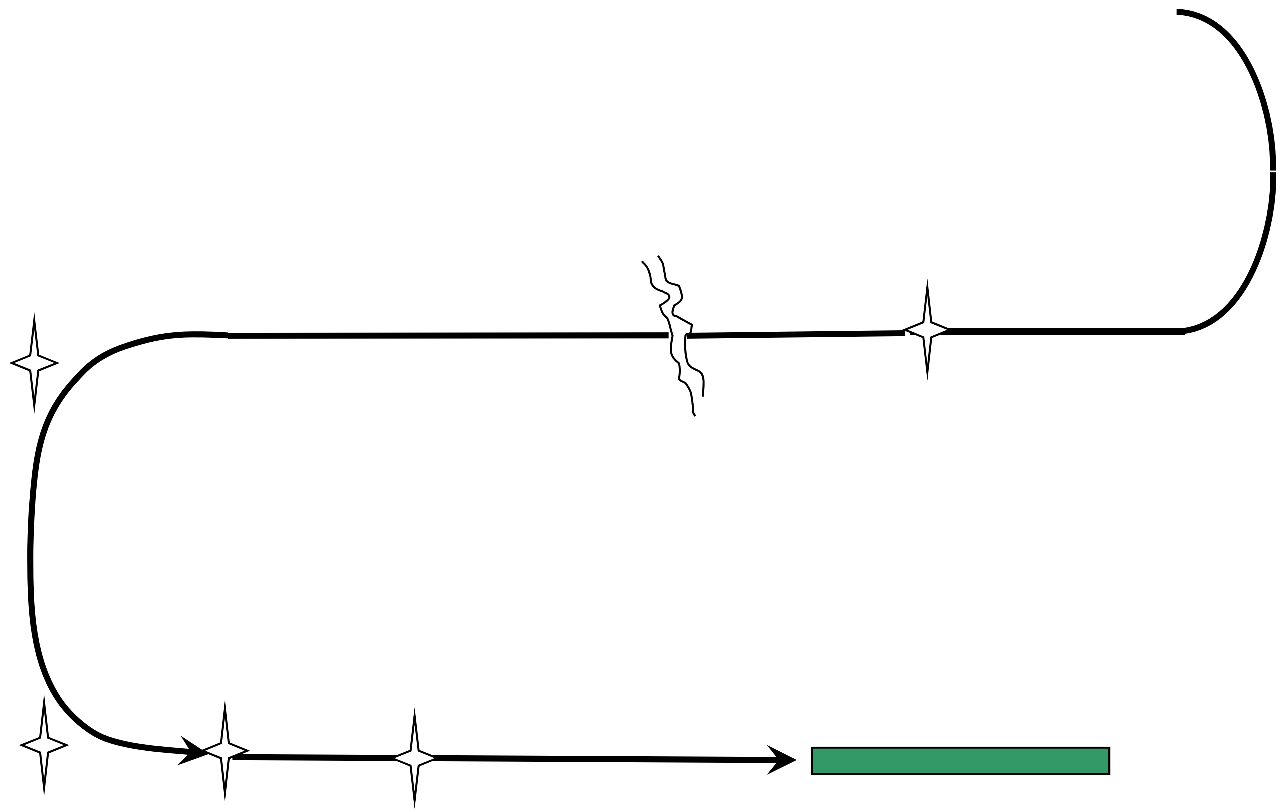
- Accurate planning for an optimum descent path is facilitated by the pilot and/or the FMS knowing the flight distance to the runway, and the level above the runway from which the CDO is to be initiated.
- This will allow an accurate calculation of flight descent path.
- Although CDO are optimized by using vertical navigation (VNAV) systems, these types of systems are not a prerequisite.

CDO Closed Path Design

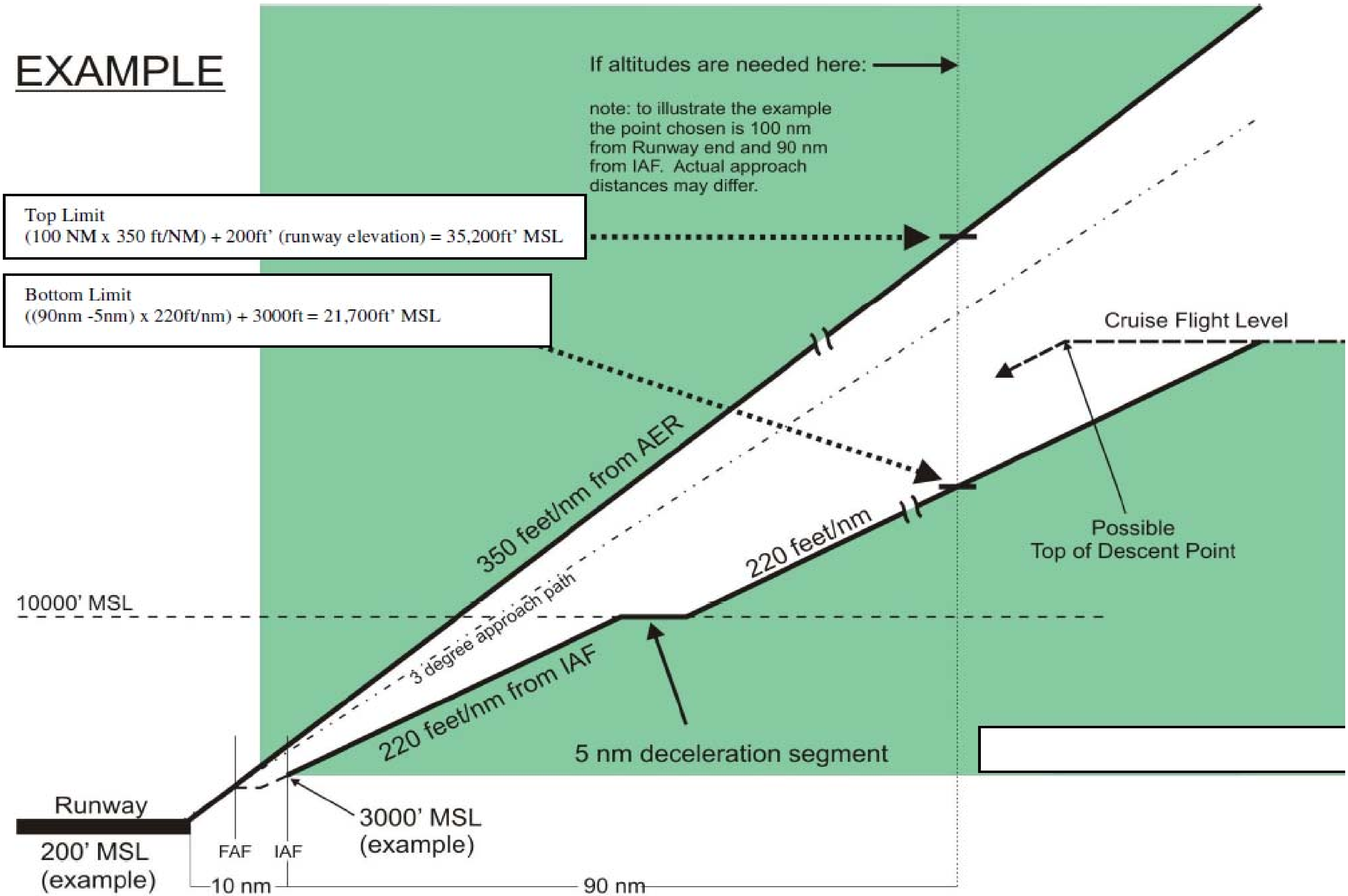
Closed path designs:

- 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



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
220 feet/nm
Possible
Top of Descent Point
10000' MSL
3 degree approach path
220 feet/nm from IAF
5 nm deceleration segment
Runway
200' MSL
(example)
FAF
IAF
3000' MSL
(example)
10 nm
90 nm

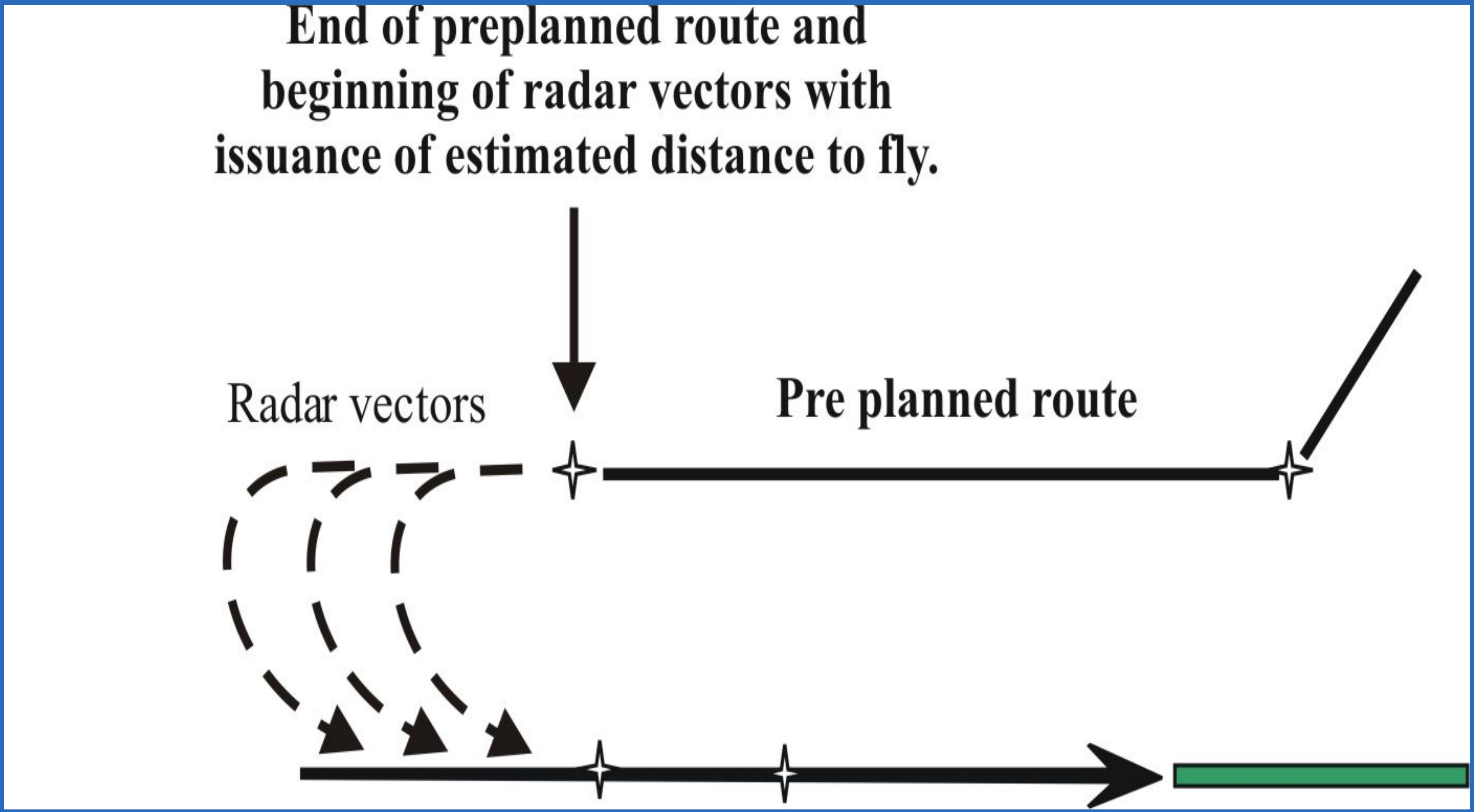
CDO Open Path Design

Open path designs finish before the final approach fix.

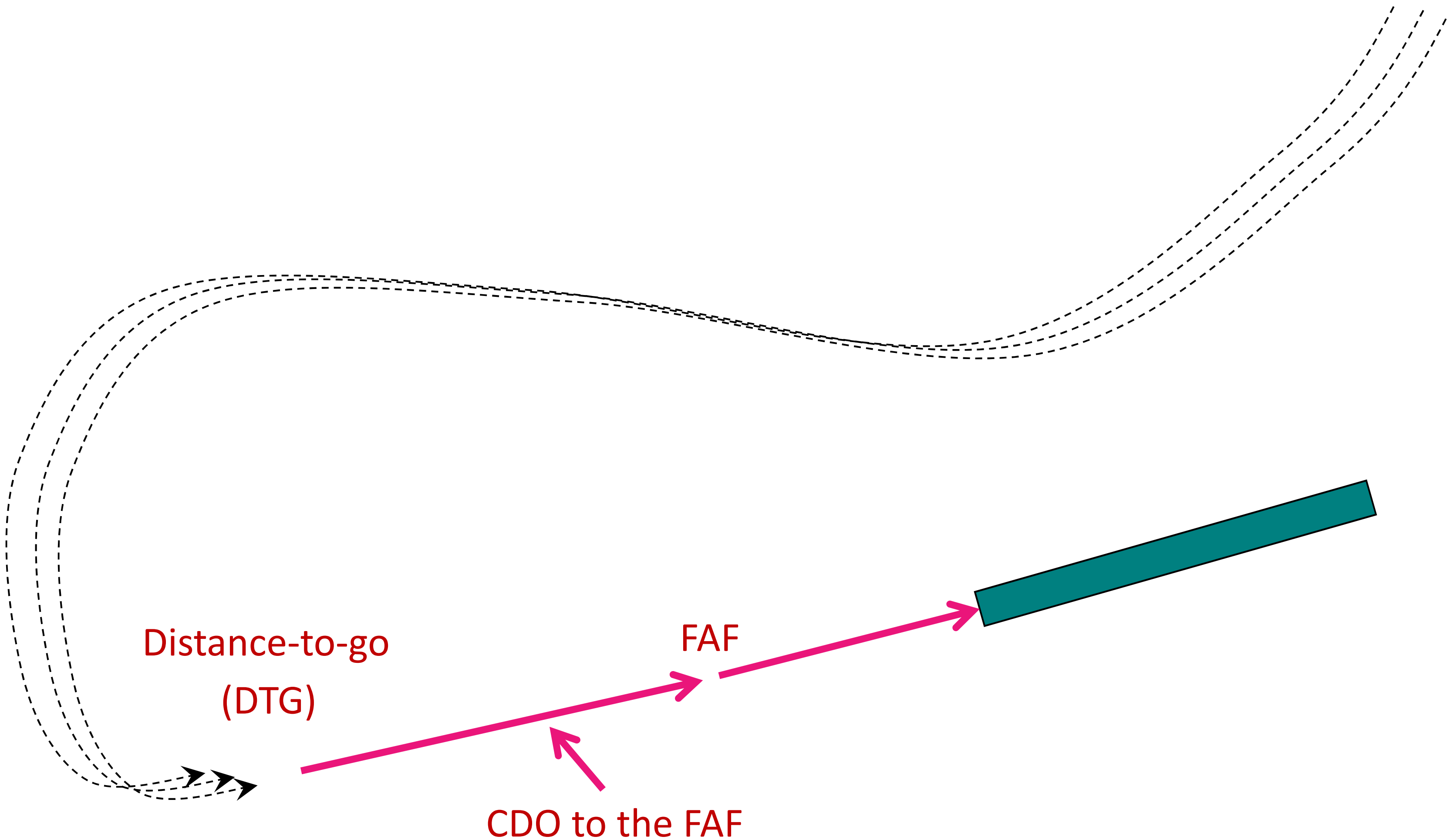
Two main types of open paths exist:

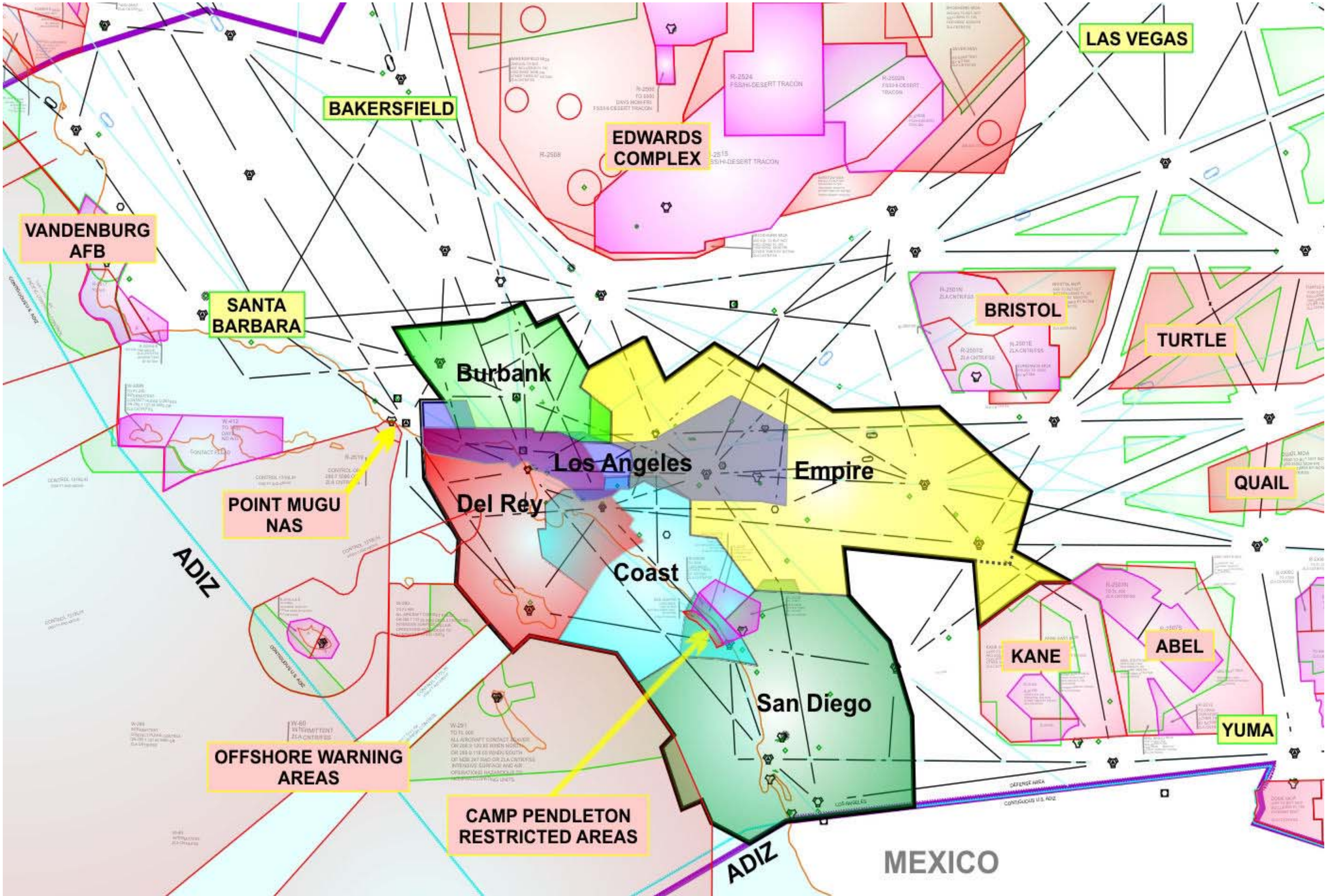
- The first ending in a downwind leg leaving the controller to clear the aircraft to final.
- The second ending with approach sequencing undertaken by radar vectors. Here the CDO can only be planned to an outer fix and the ATCO will need to communicate to the pilot, to the extent possible, an estimate of distance-to-go (DTG) to the runway end. 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

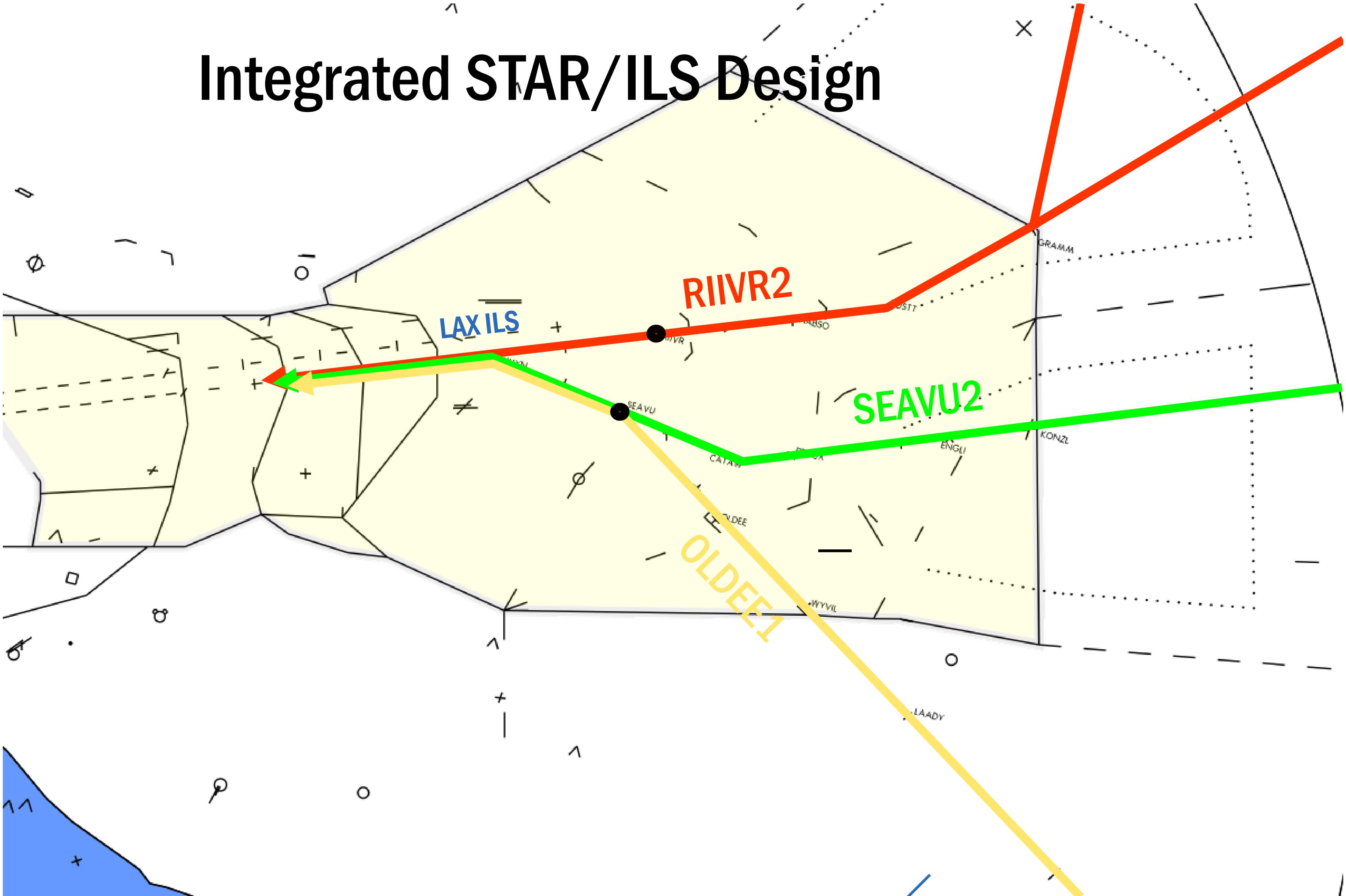




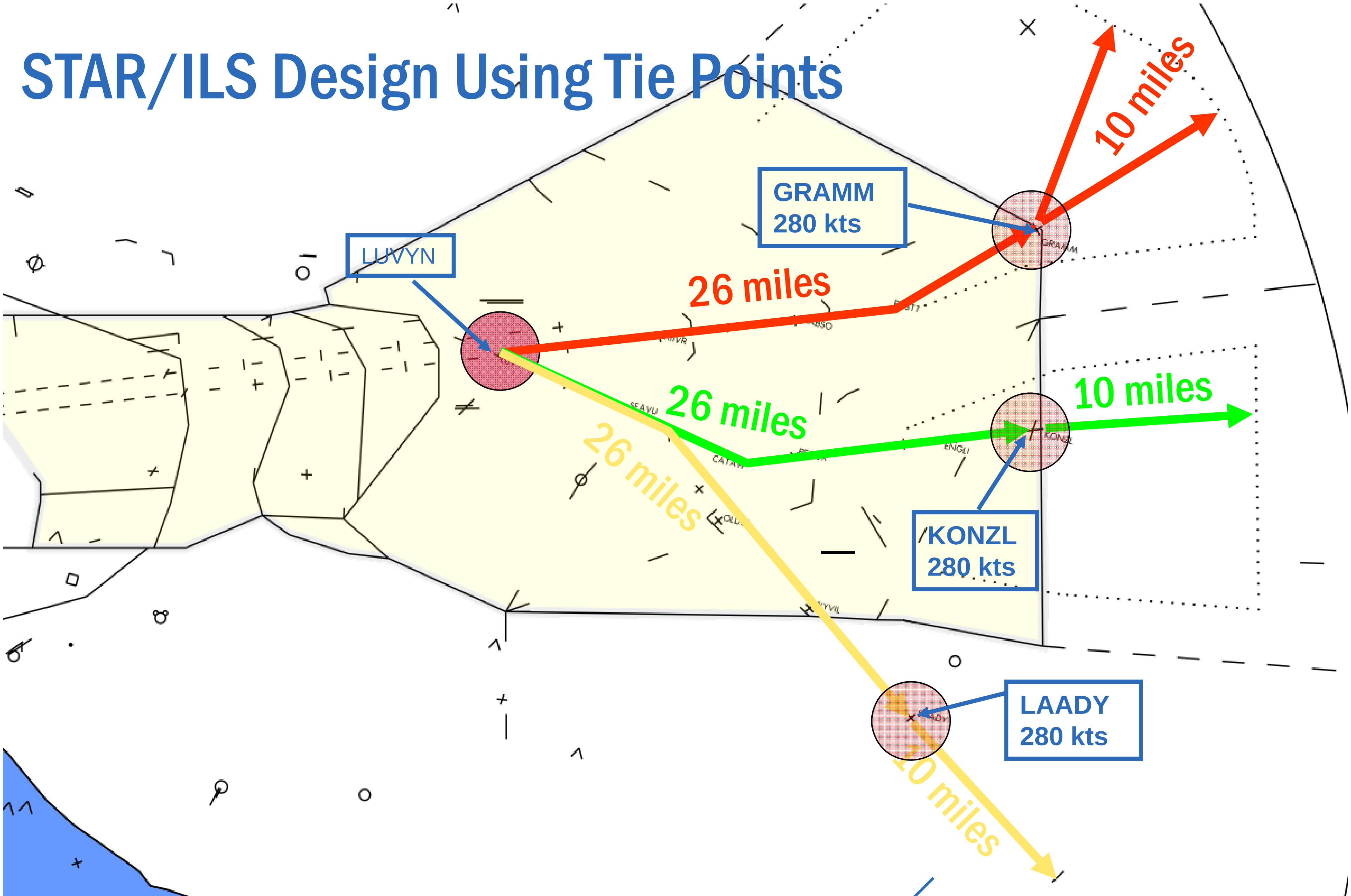
LAS VEGAS
BAKERSFIELD
EDWARDS COMPLEX
VANDENBURG AFB
SANTA BARBARA
BRISTOL
TURTLE
Burbank
Los Angeles
Empire
QUAIL
POINT MUGU NAS
Del Rey
ADIZ
Coast
KANE
ABEL
San Diego
YUMA
OFFSHORE WARNING AREAS
CAMP PENDLETON RESTRICTED AREAS
ADIZ
MEXICO

080
140/110/090/070
110
J 130-150/M
160
070
090/050
100/080/060
120
150
130
060-050
080/060
070/050
050
035
040
025
140
060/090
090
100
080
110-130
090-150
150-170
170-210
080-090
160-170
080-130
170
070-100
130-180
SZP
CMA
OXR
NTD
VTU
TROYE
GINNA
CASTA
PIRU
SOLED
BOGET
WHP
VNY
EMT
ONT
CNO
PDZ
LGB
HHR
L26
L67
L35
SBD
BNG
HMT
SKYLARK
CA 89
F70
L18
NFG
OCN
OKB
R2503 A-B-C
MT SAN ANTONIO
MENDENHALL PEAK
ROSE BOWL
HOLLYWOOD BOWL
V386
V186
V264
V208
V27-208-458
V208-458
BENET
WEEZL
GOATZ
DMPS
BLOCKHOUSE
SKYES
HEMET
MUELR
HUMAN
UDHAY
VISTA
ROBNN
HOMLY
BONDO
DEASY
ESCON
RECCO
GENTA

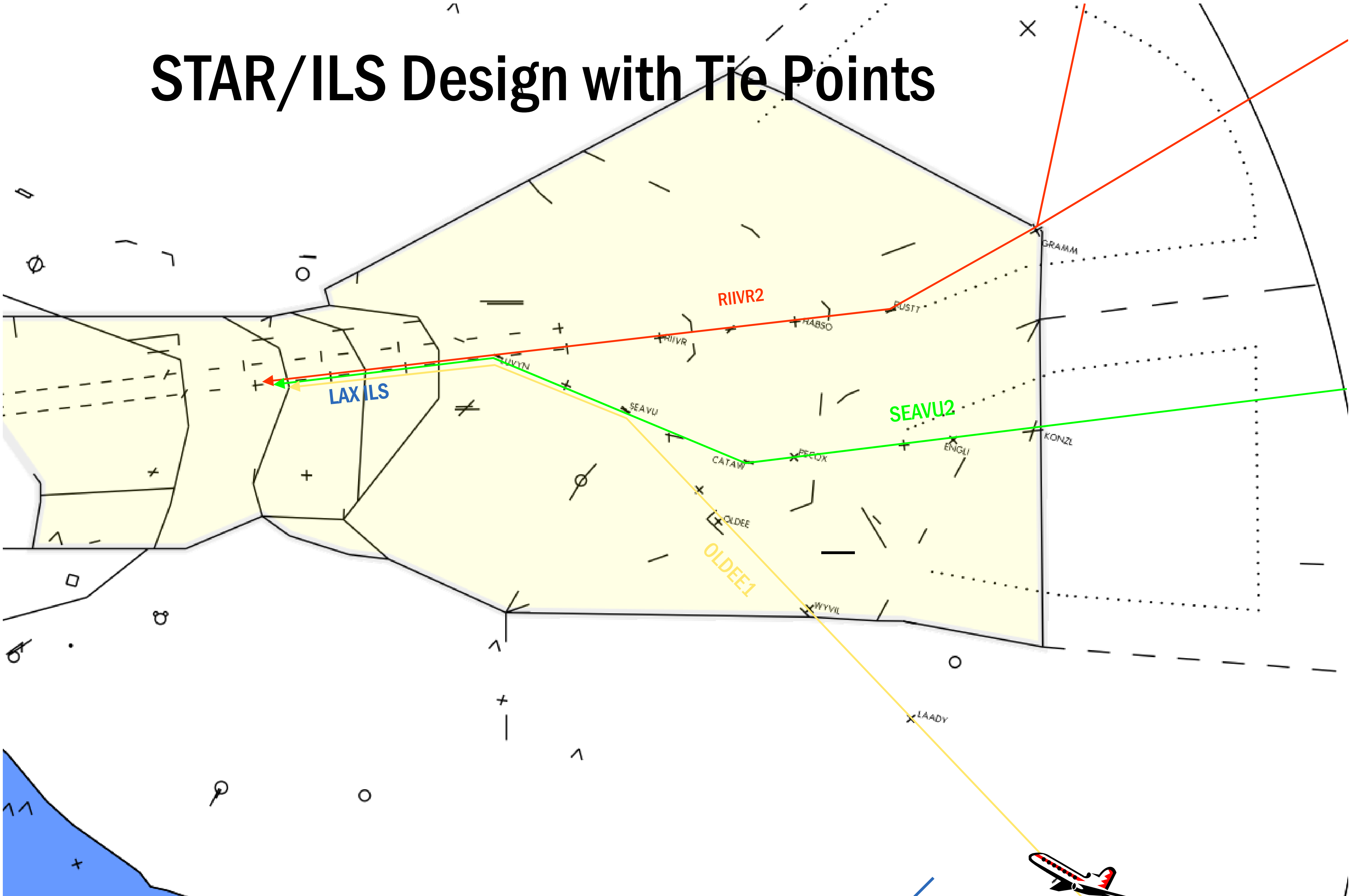
Integrated STAR/ILS Design



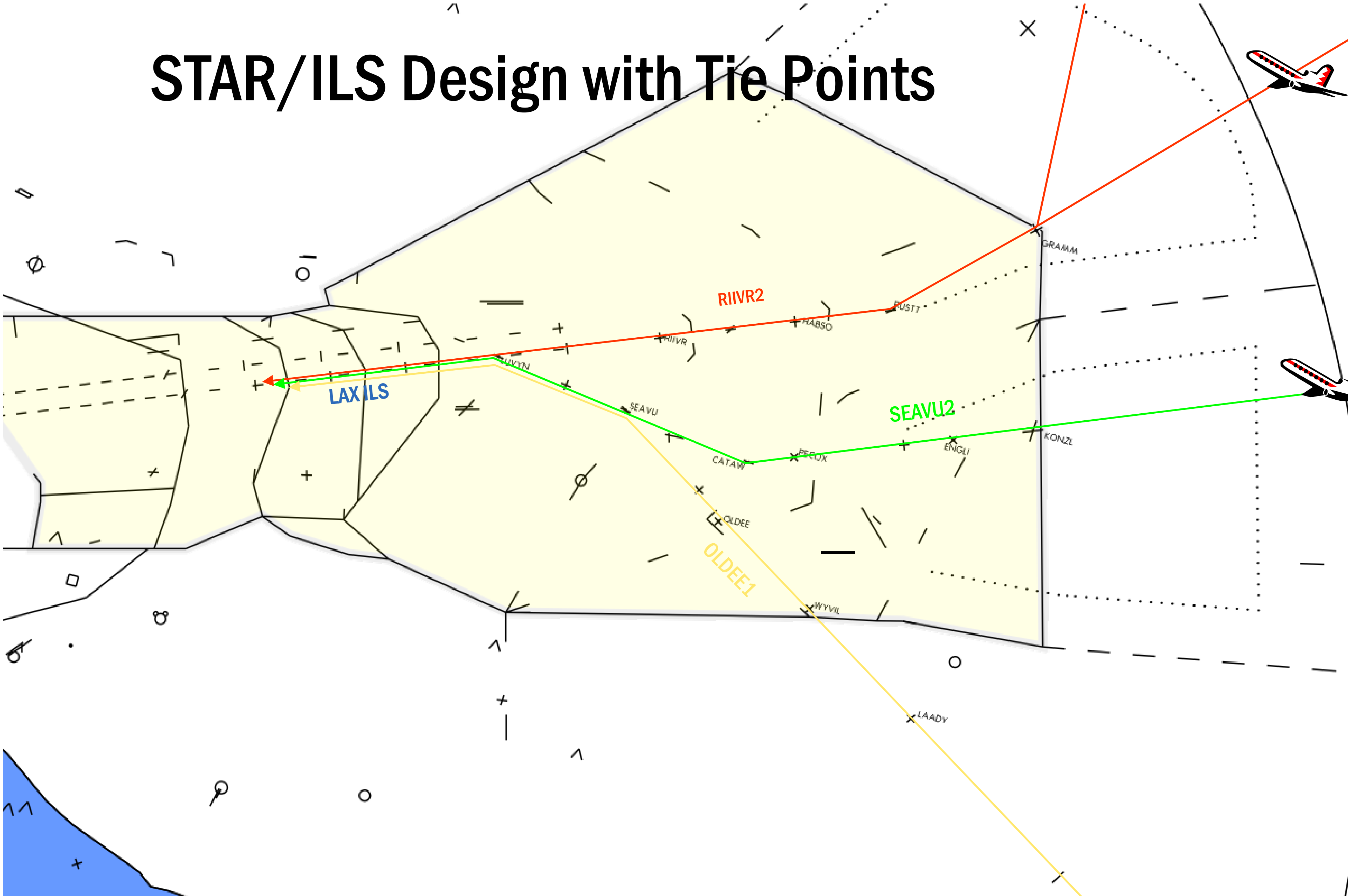
STAR/ILS Design Using Tie Points



STAR/ILS Design with Tie Points



STAR/ILS Design with Tie Points



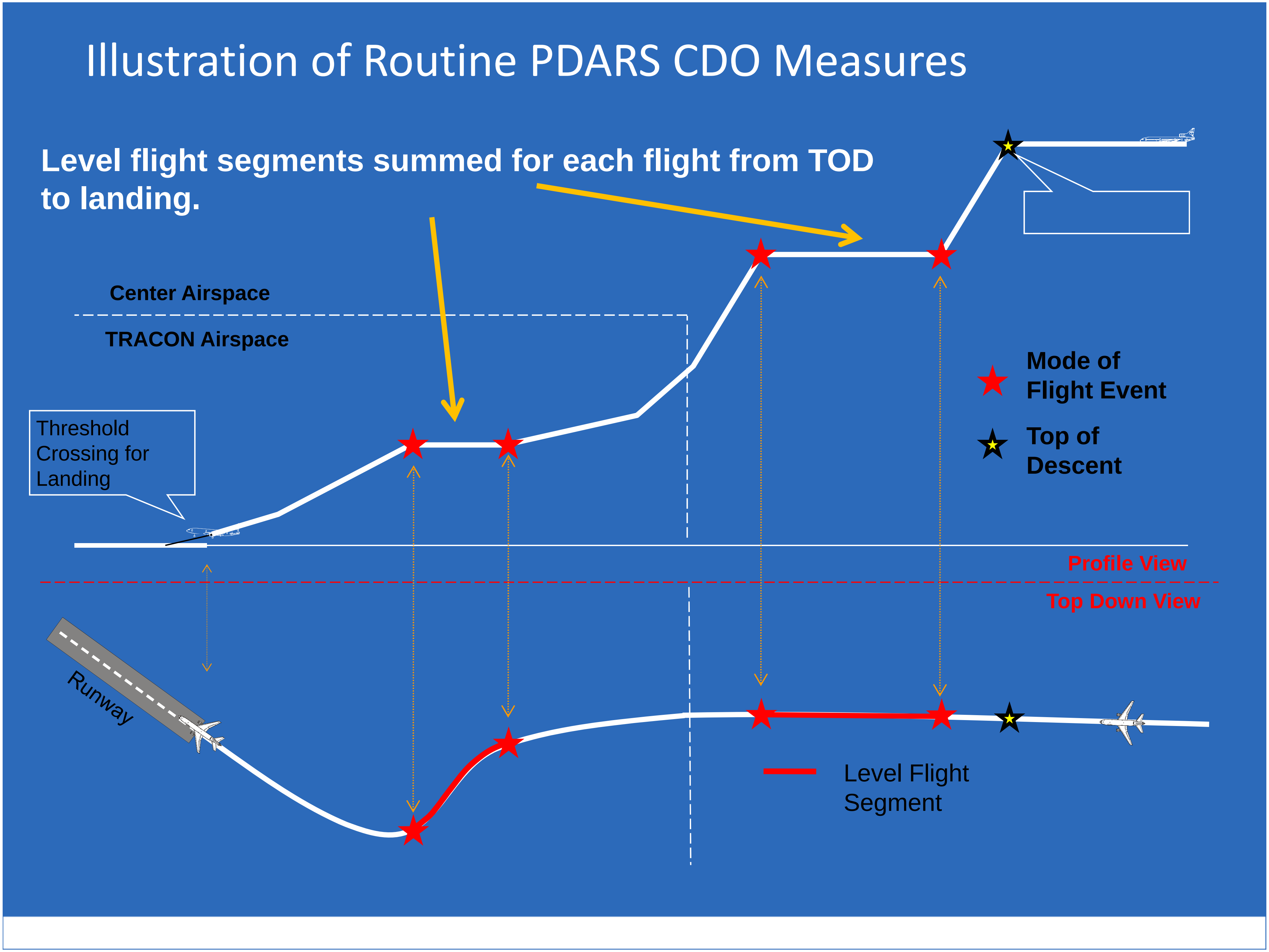
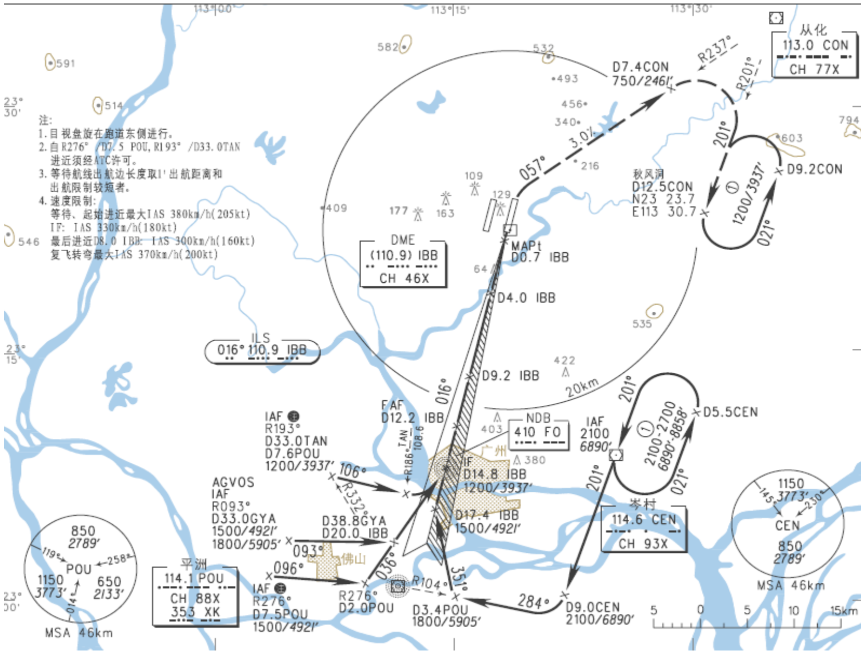
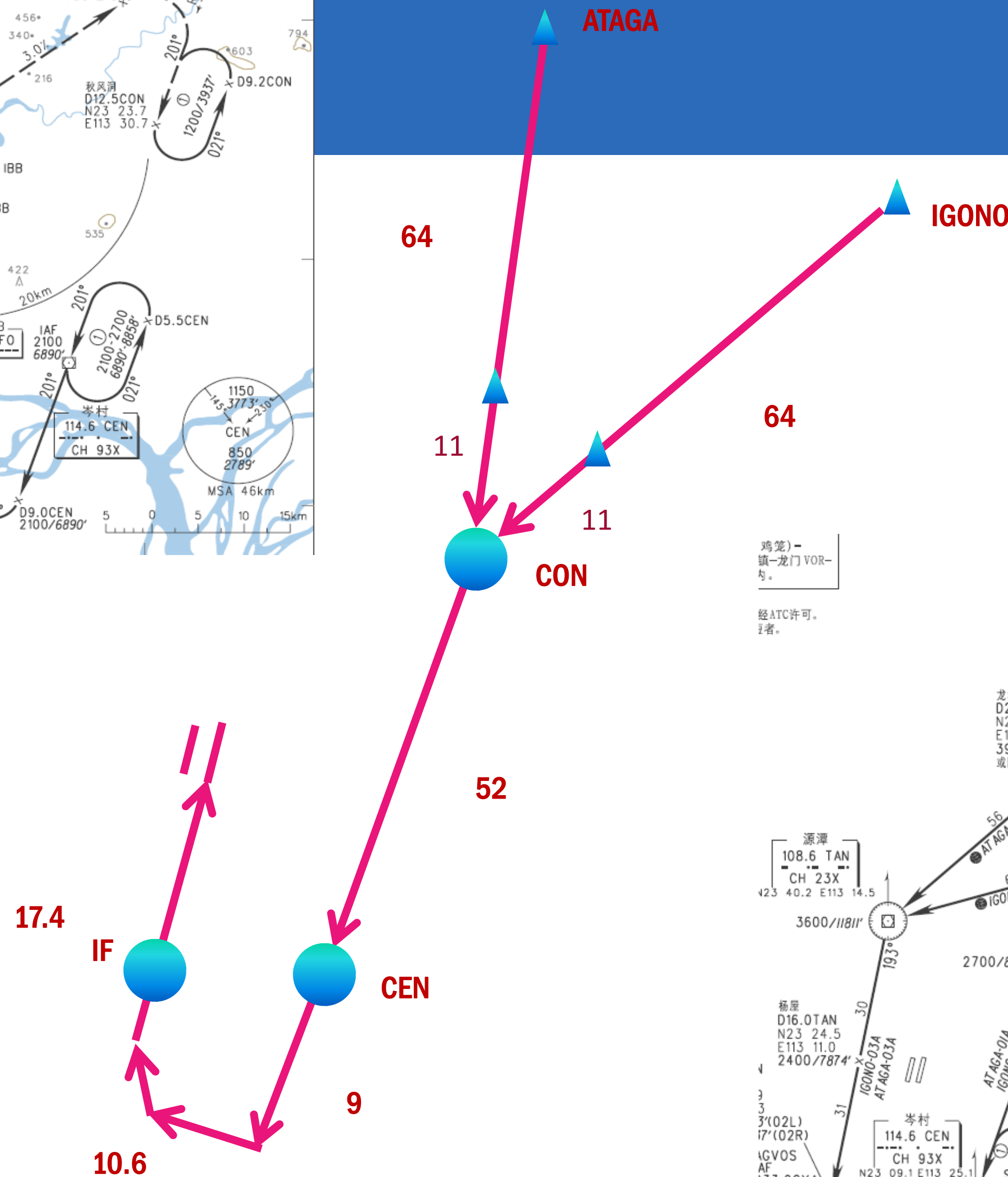
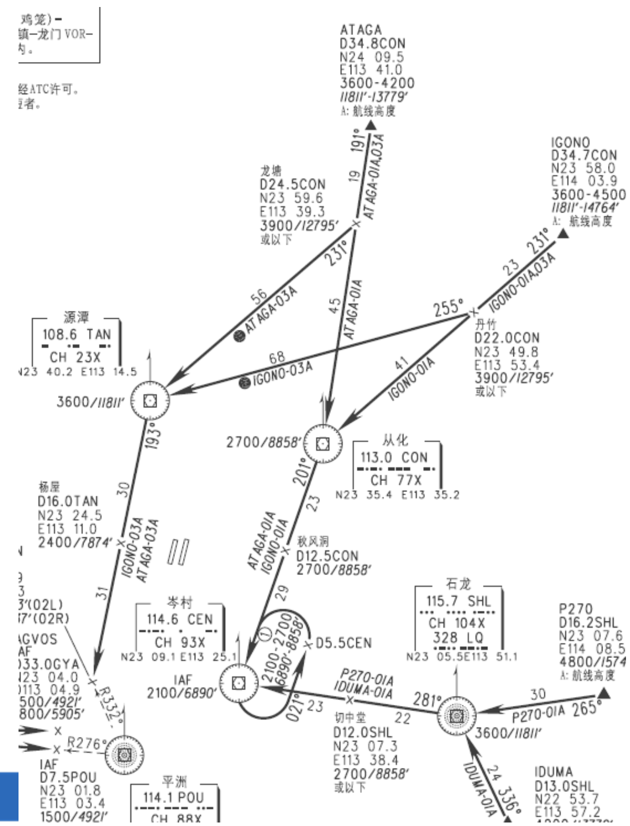


Illustration of Routine PDARS CDO Measures
Level flight segments summed for each flight from TOD to landing.
Center Airspace
TRACON Airspace
Threshold Crossing for Landing
Mode of Flight Event
Top of Descent
Profile View
Top Down View
Runway
Level Flight Segment

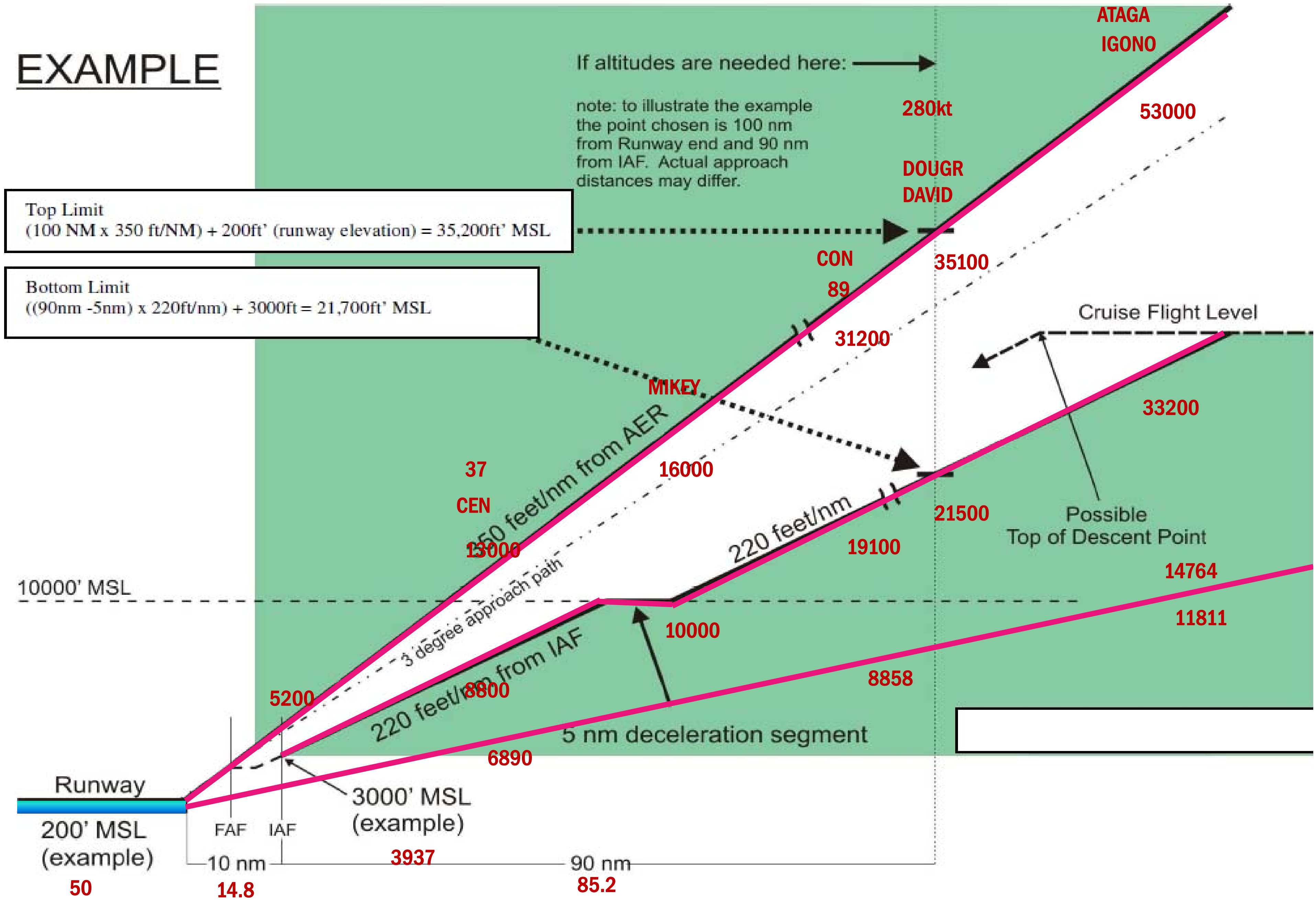






Guangzhou, China
ILS/DME 02R

EXAMPLE



ATAGA
IGONO
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.
280kt
53000
DOUGR
DAVID
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
CON
89
35100
31200
Cruise Flight Level
MIKEY
33200
350 feet/nm from AER
37
CEN
16000
13000
21500
220 feet/nm
19100
Possible
Top of Descent Point
14764
10000' MSL
3 degree approach path
10000
11811
220 feet/nm from IAF
5200
8800
8858
5 nm deceleration segment
6890
Runway
3000' MSL
(example)
200' MSL
(example)
FAF
IAF
3937
10 nm
90 nm
50
14.8
85.2

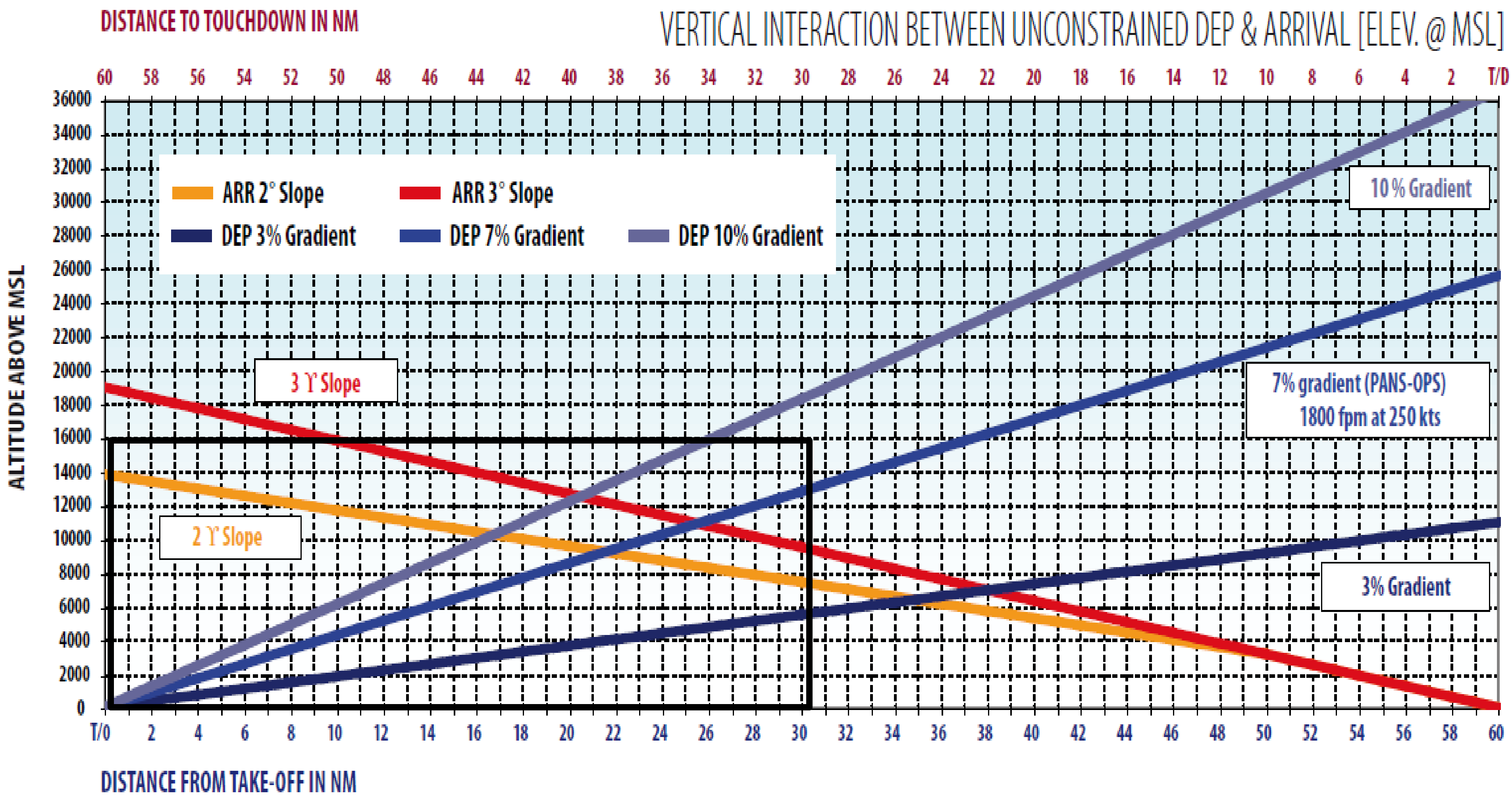
Facilitating continuous descent operations

- Air traffic controllers are required to provide a safe and efficient management of arriving aircraft.
- The term “efficiency” can result in different targets to different stakeholders and may vary depending on:
  - **Traffic density levels**
  - **Aircraft mix**
  - **Noise sensitive areas**
  - **Weather**
  - **Special use airspace**

Balancing the demands

- Arriving and departing traffic are usually interdependent and the airspace design supporting CDO should ensure that both arriving and departing flights can achieve fuel efficient profiles.
- Balancing the demands of capacity, efficiency, access and the environment within the overall requirement for safe operations, is the most demanding task when developing an airspace design.

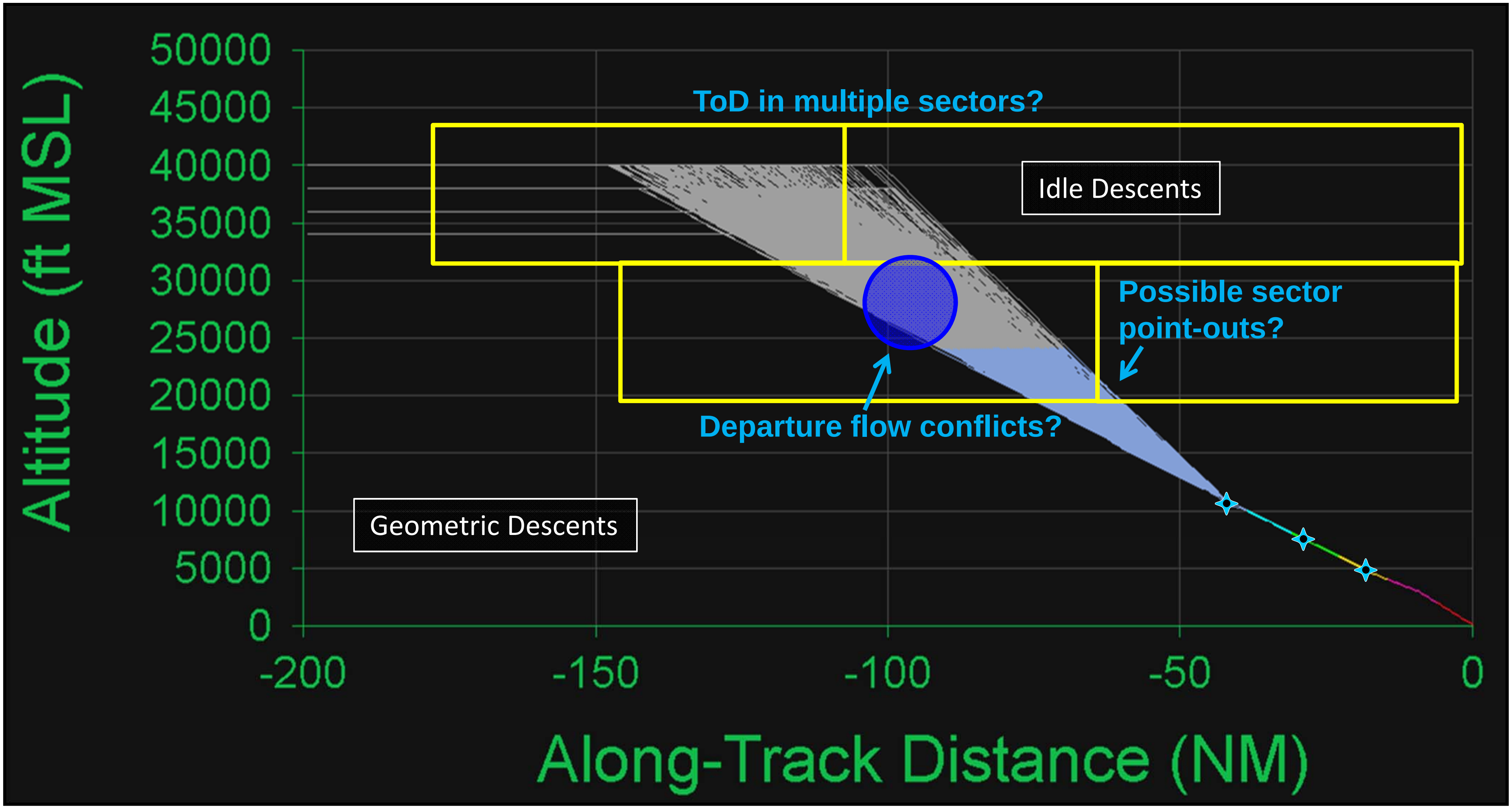
VERTICAL INTERACTION BETWEEN UNCONSTRAINED DEP & ARRIVAL [ELEV. @ MSL]



ATC Impacts on a CDO

- Crossing traffic impacts sequencing/issuing descent clearance
- Departure traffic frequently uses the same fixes as arrivals
- Intra-facility sector point-outs for coordination of high and low airspace
- Inter-facility coordination requires voice coordination

Impacts on ATC



Feedback

Feedback from flight simulations is one way to ensure that the proposed design does not adversely affect aircraft and/or that it can facilitate CDO being available to the majority of the expected aircraft fleet.

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

Training is an on-going process

- Simulations of the CDO procedures to be tested should be designed and then run by the controllers to ensure that the procedures performs as expected.

- This training provides an environment which allows any questions or concerns to be raised and addressed well in advance of the actual procedures being flown by the users.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