PBN Airspace Design Workshop

CDO and CCO

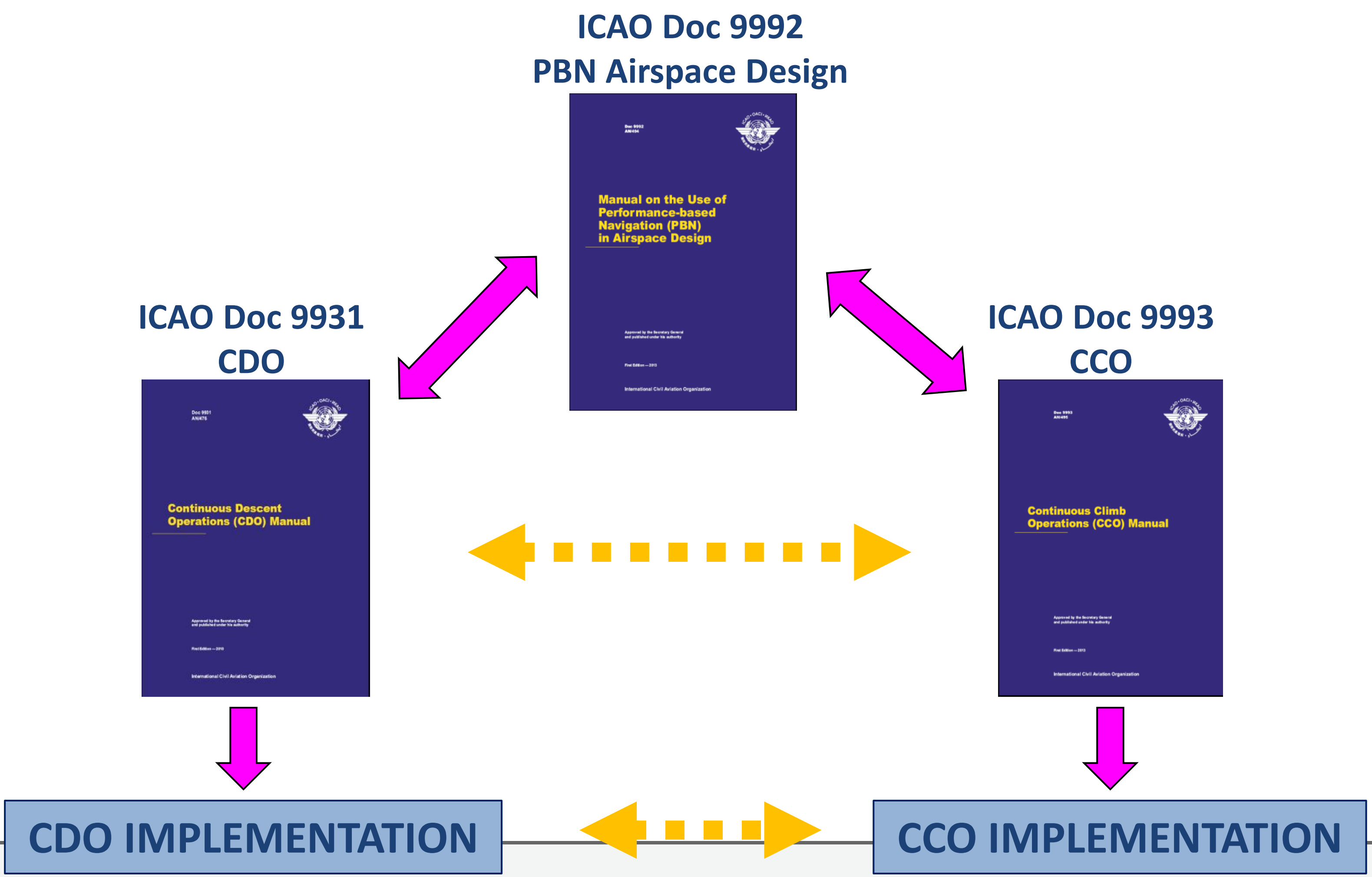
Asia and Pacific Regional Sub-Office
Beijing, China

Learning Objectives

- By the end of this presentation, you will understand:
  - CDO and CCO Design methods and limitations
  - CDO and CCO Design Considerations
  - CDO and CCO Implementation Process
  - Possible CDO sequencing methods
  - CDO design possibilities

GENERAL OVERVIEW

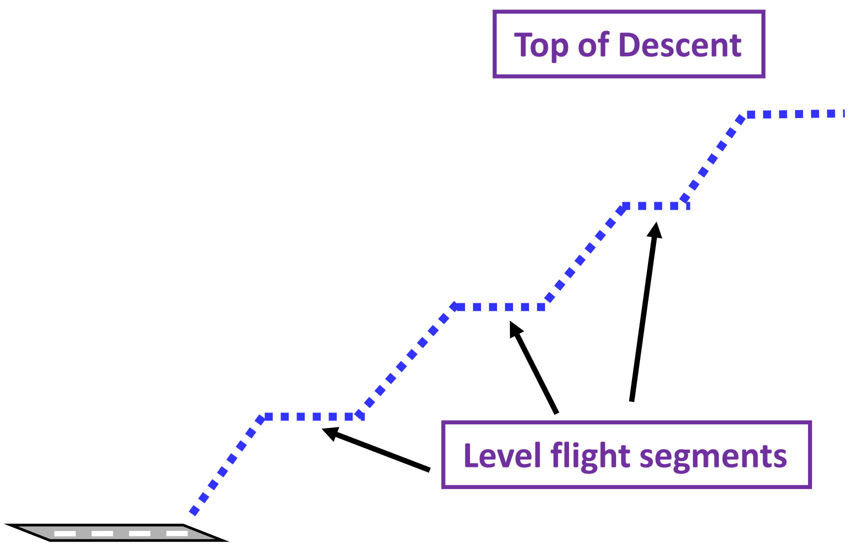
❖ CDO, CCO, and Airspace

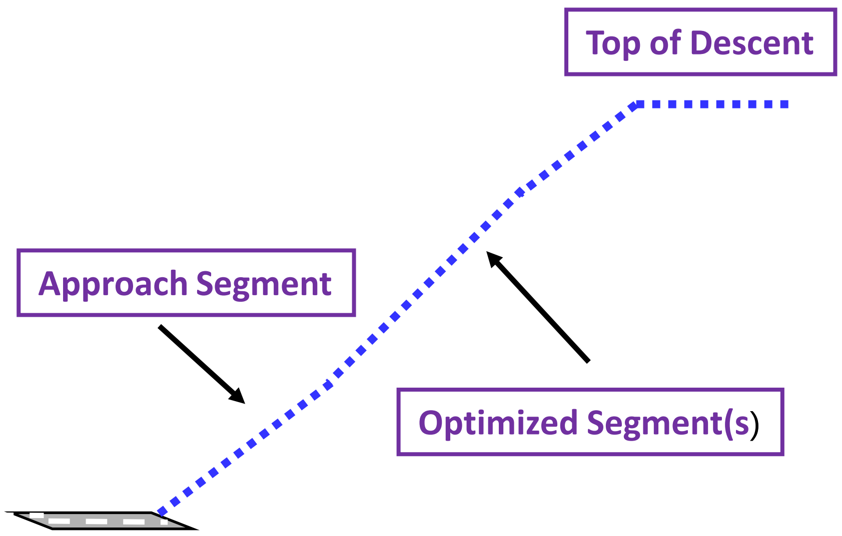


GENERAL OVERVIEW

- CDO is an aircraft operating technique
  - Aided by appropriate airspace design, procedure design, and appropriate ATC clearance
  - Enabling the execution of a flight profile optimized to the operating capability of the aircraft
  - With low engine trust setting and a low drag configuration
  - Thereby reducing fuel burn and emissions during descent
- CDO should always be considered by
  - airspace designers and procedure designers
  - especially when implementing new Arrivals (STAR) and Approaches
- Usable by 85% of the aircraft, 85% of the time

GENERAL OVERVIEW

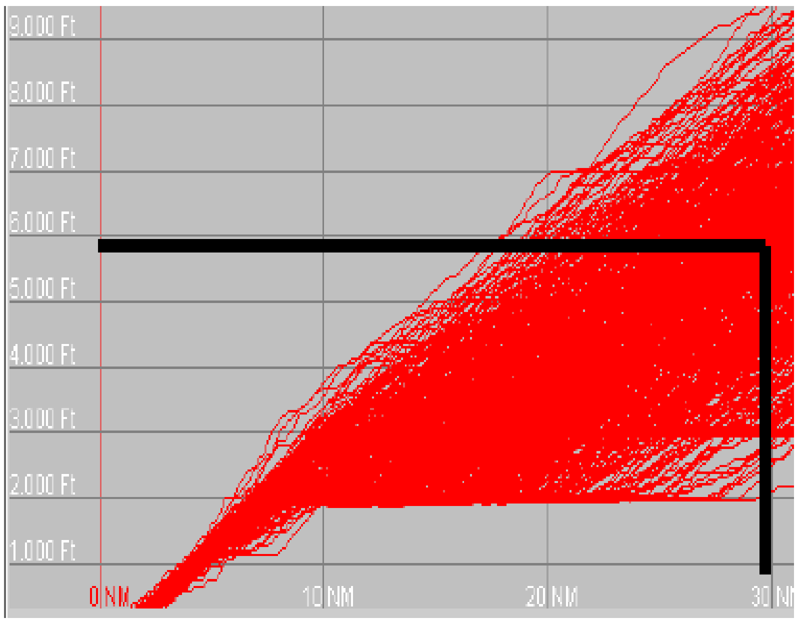




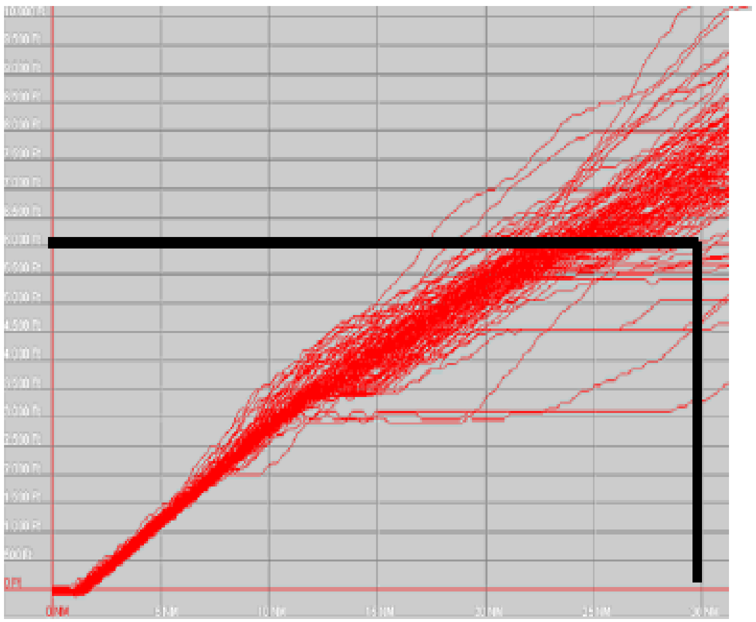
OPTIMUM VERTICAL PATH

- The optimum vertical path angle will vary depending on:
  - Type of aircraft and its actual weight
  - Weather (wind, temperature, atmospheric pressure, icing conditions)
  - Other dynamic considerations
- The maximum benefit is achieved by keeping the aircraft as high as possible until it reaches the optimum descent point.

OPTIMUM VERTICAL PATH



Flight tracks before CDO



Flight tracks after CDO

FACILITATING CDO

- Should start from the TOD to FAF/FAP, but …
- Sequencing could be achieved during cruise or early phase of descent.
- Must consider aircraft performance limits and known wind data, when assigning altitude and speed restrictions.
- Distance to go (DTG) should be provided while being radar vectored.
- Supporting tools (e.g. AMAN) may increase airspace capacity.

➡ These methods should be considered and included in the design with the goal of allowing the highest percentage of use during the broadest period of air traffic operations

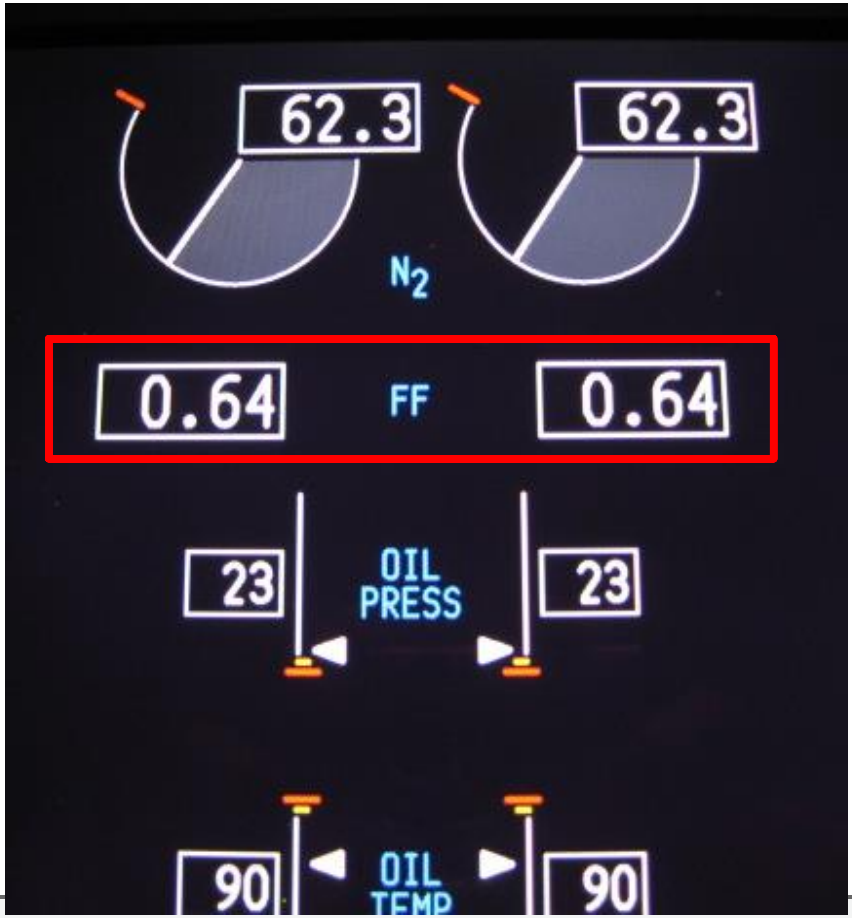
BENEFITS OF CDO

- CDO increases
  - Flight predictability (predefined routes)
  - Airspace efficiency & Capacity (segregated Dep. & Arr. routes)
  - Safety (consistent and stabilized flight path, CFIT)
- CDO reduces
  - Fuel burn (cost savings) (125-1400 lbs/flight)
  - Emissions and noise level (up to 40% less) (environmental benefits)
  - Pilot & controller workload
  - Radio transmission and read back/hear back errors
  - CFIT
- However, if either CDO is not properly designed or ATC lose the flexibility, there could be a risk of reduced capacity and efficiency.

BENEFITS OF CDO

❖ Importance of an Idle Descent

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



BENEFITS OF CDO

CDO DESIGN (1/5)

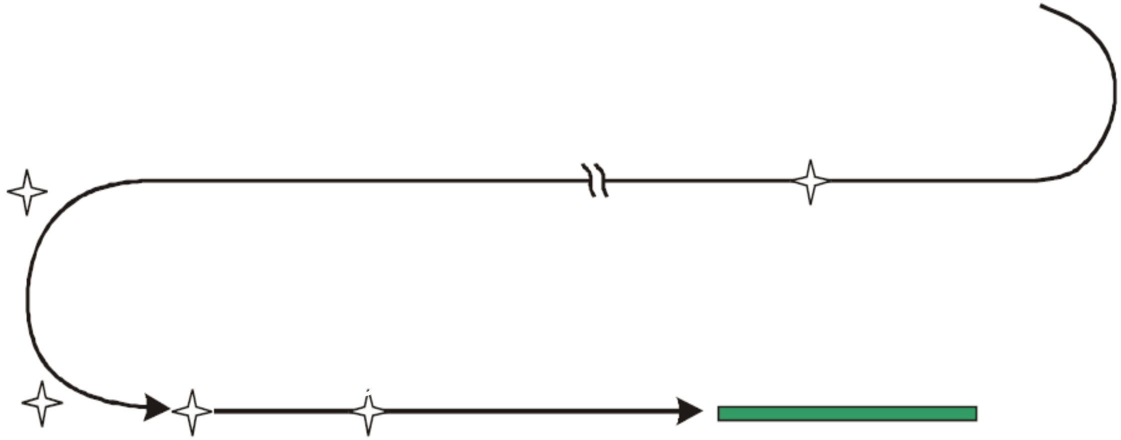
- A CDO design
  - is integrated with the airspace concept
  - must balance the needs of departing aircraft with the CDO arrival aircraft.
  - needs to consider populated areas, adherence to noise abatement routes, any dedicated take-off techniques, implementation time, etc.
- Fully optimized CDO may not always be possible
- Laterally and/or vertically fixed CDO routes could be applied to dense traffic environment.
- Vector based CDO could offer worthwhile efficiency and improvements

CDO DESIGN (2/5)

- 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
- Wind and weather information helps to improve the accuracy of the flight descent path.
- However, exact distance or flying time may not always be precisely known.
- Thus planning and communication between the pilot and the ATC are required for a CDO.

CDO DESIGN (3/5)

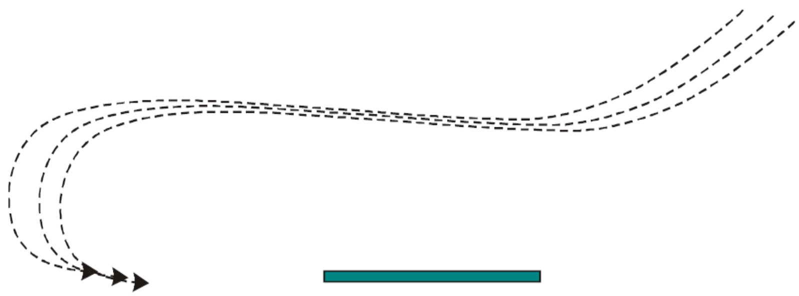
- Two methods of CDO design : "closed path" and "open path"
- Closed path design
  - Lateral flight track is predefined up to/including FAF/FAP, e.g. STAR.
  - Exact distance to runway is precisely known.
  - FMS can accurately implement automated optimized descents.
  - The procedure may be published with crossing levels, level windows and speed constraints.



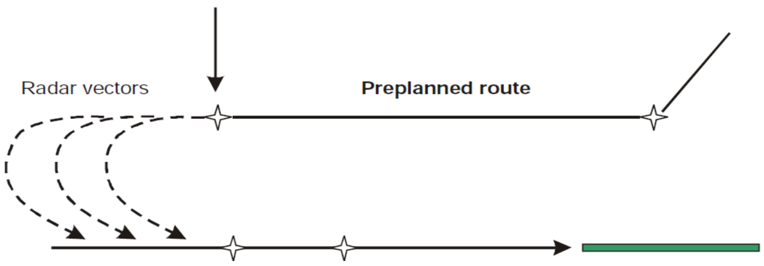
CDO DESIGN (4/5)

- Open path design

1) Vectored CDO
   - ATC gives "Distance-To-GO" estimate
   - Descent is at the pilot discretion.



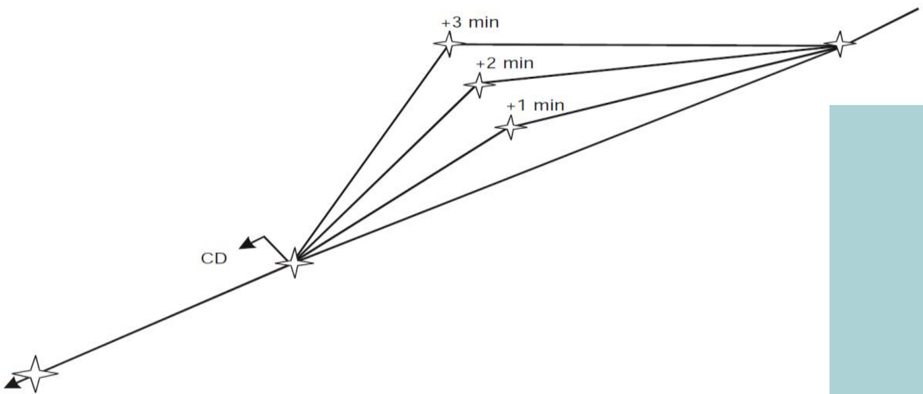
2) Open CDO to downwind
   - Ends in a downwind leg leaving the controller to clear the aircraft to final
   - ATC gives "Distance-To-GO" estimate
   - Combination of a fixed route and radar vector to FAF/FAP



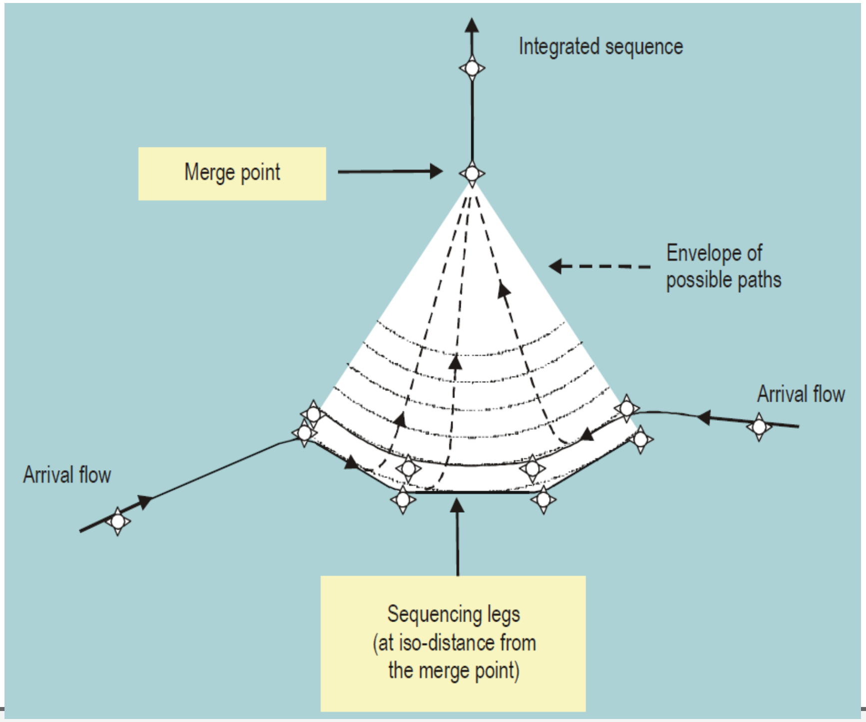
CDO DESIGN (5/5)

❖ Open path design

3) Path stretching method



4) Point Merge method



CDO DESIGN METHODS (1/9)

- CDO design procedures
  - Choose the minimum lateral path
  - Optimize the lateral path considering
    - Airspace (restrictions, noise abatement, etc.)
    - Departing aircraft of the destination airport
    - Other traffic toward/out of adjacent airports
    - Aircraft navigation capability
    - Airport agreements, traffic flow rates, airport sectorization
    - Terrain, etc.
  - Apply required speeds and/or altitude profiles
    - But limit speed/altitude restrictions to the minimum necessary
    - Altitude restrictions may “at”, “at or above/below”, or a window
    - Speed restrictions should not be less than 280kts above 10,000ft
  - Review and modify as necessary

CDO DESIGN METHODS (2/9)

- **Closed path CDO design**
  - Altitude restrictions of STAR should allow most aircraft to descent unimpeded.
  - An upper limit is set for
    - Separation from other air traffic flows, or
    - ATC coordination purposes
  - The lower limit is set for
    - Terrain clearance
    - Airport arrangements
    - Separation from other air traffic flows, and
    - ATC coordination purposes.

CDO DESIGN METHODS (3/9)

❖ Closed path CDO design

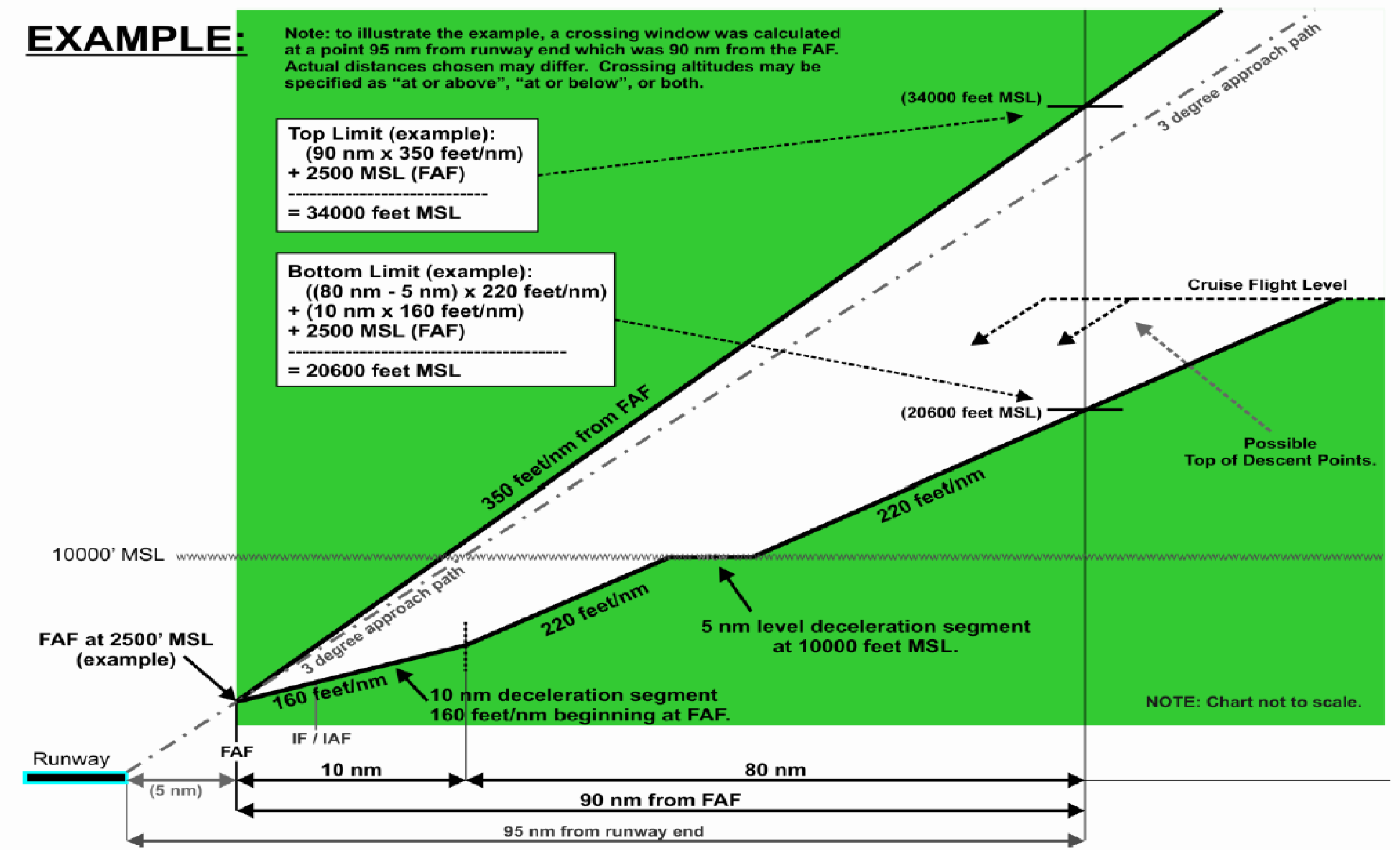


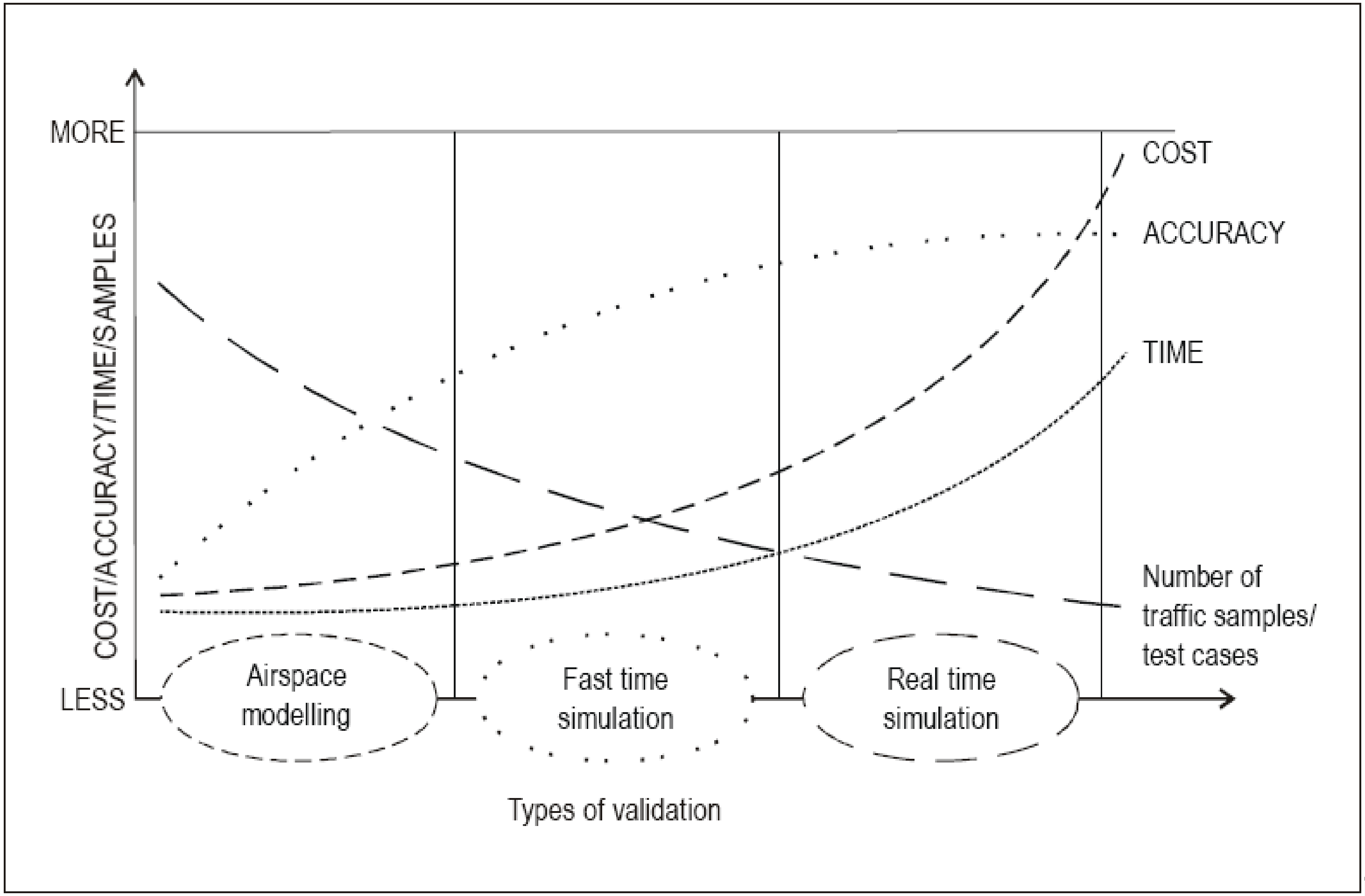
Figure 1-6. Instrument approach in an optimized CDO procedure

CDO DESIGN METHODS (4/9)

- **Closed path CDO design**
  - Basic design may need to be modified
    - To avoid high terrain or other air traffic flows;
    - To comply with airport or environmental agreements; and/or
    - To comply with ATC coordination procedures.
  - If modified, additional calculations should be made to ensure that
    - the largest number of aircraft can fly the procedure with the least number of restrictions.
  - Feed back from flight simulation is one way to ensure that
    - the proposed design does not adversely affect aircraft; and/or
    - it can facilitate the availability of CDO to the majority of the expected aircraft fleet.

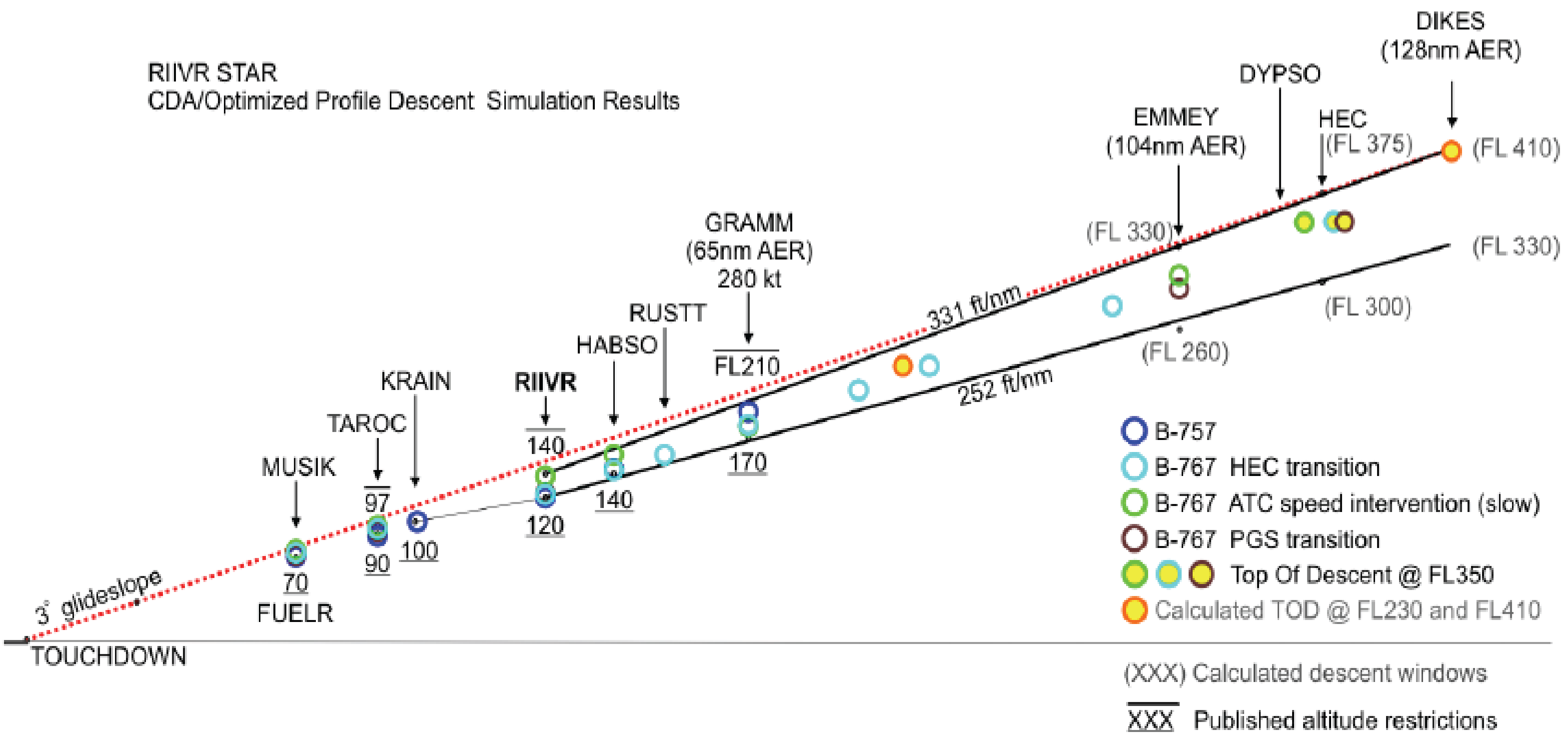
CDO DESIGN METHODS (5/9)

❖ **Comparison of simulation models**



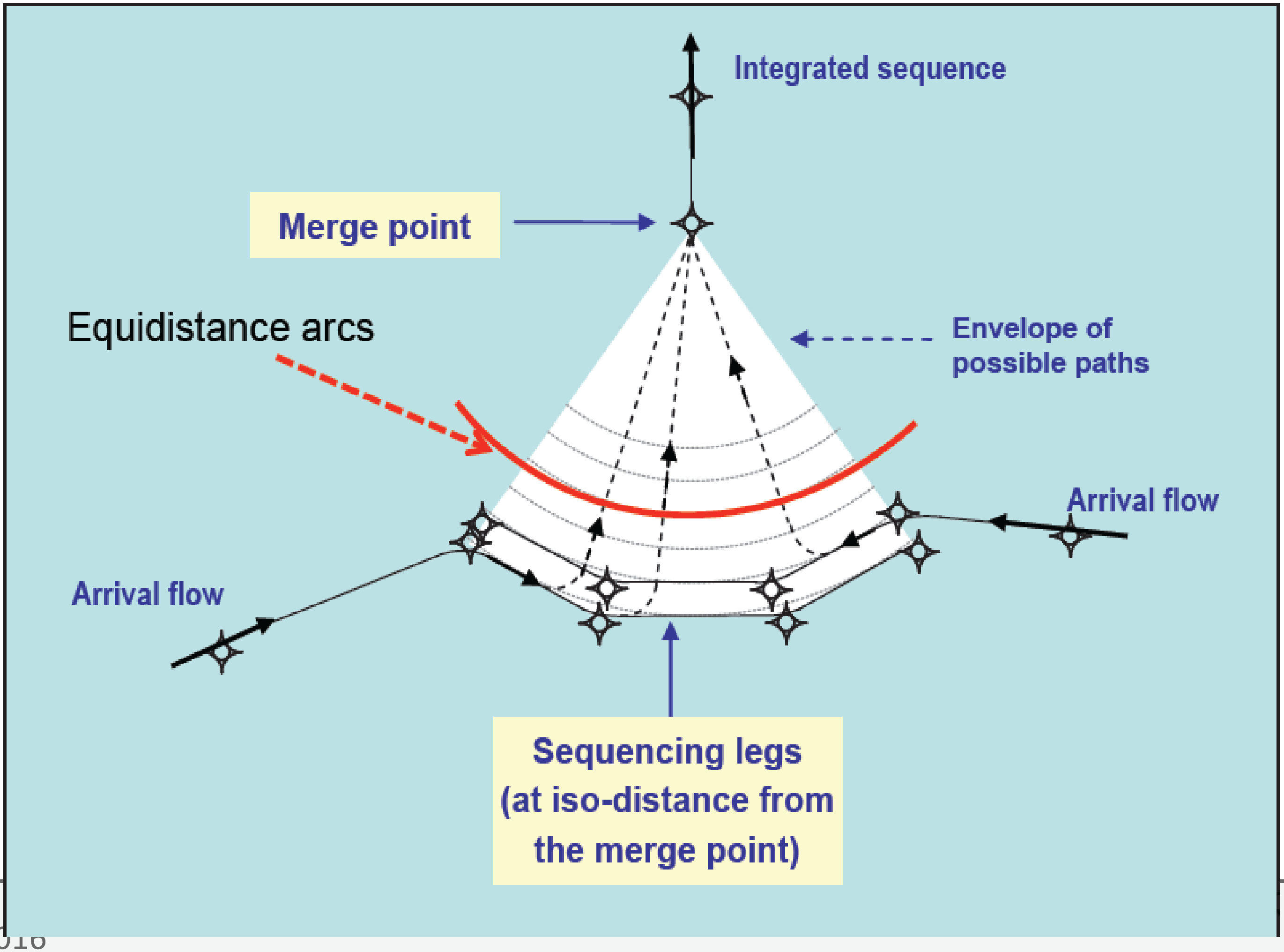
CDO DESIGN METHODS (6/9)

- **Closed path CDO design**
  - **Simulation results (RIIVR STAR, KLAX)**



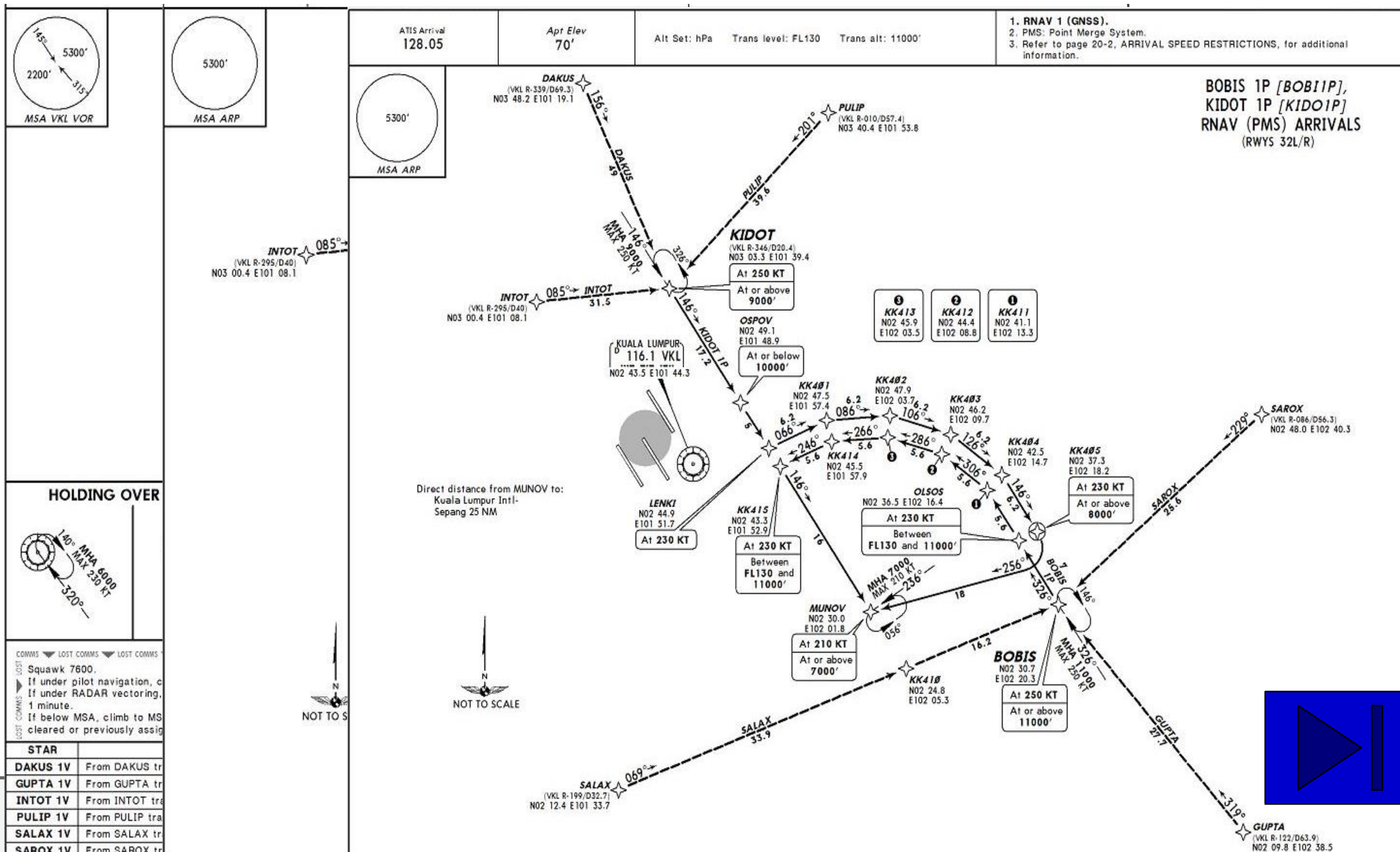
CDO DESIGN METHODS (7/9)

❖ Open path CDO design – Point Merge



CDO DESIGN METHODS (8/9)

❖ **Point Merge Procedures** – Kuala Lumpur, Malaysia (RWY 32L/R)



CDO DESIGN METHODS (9/9)

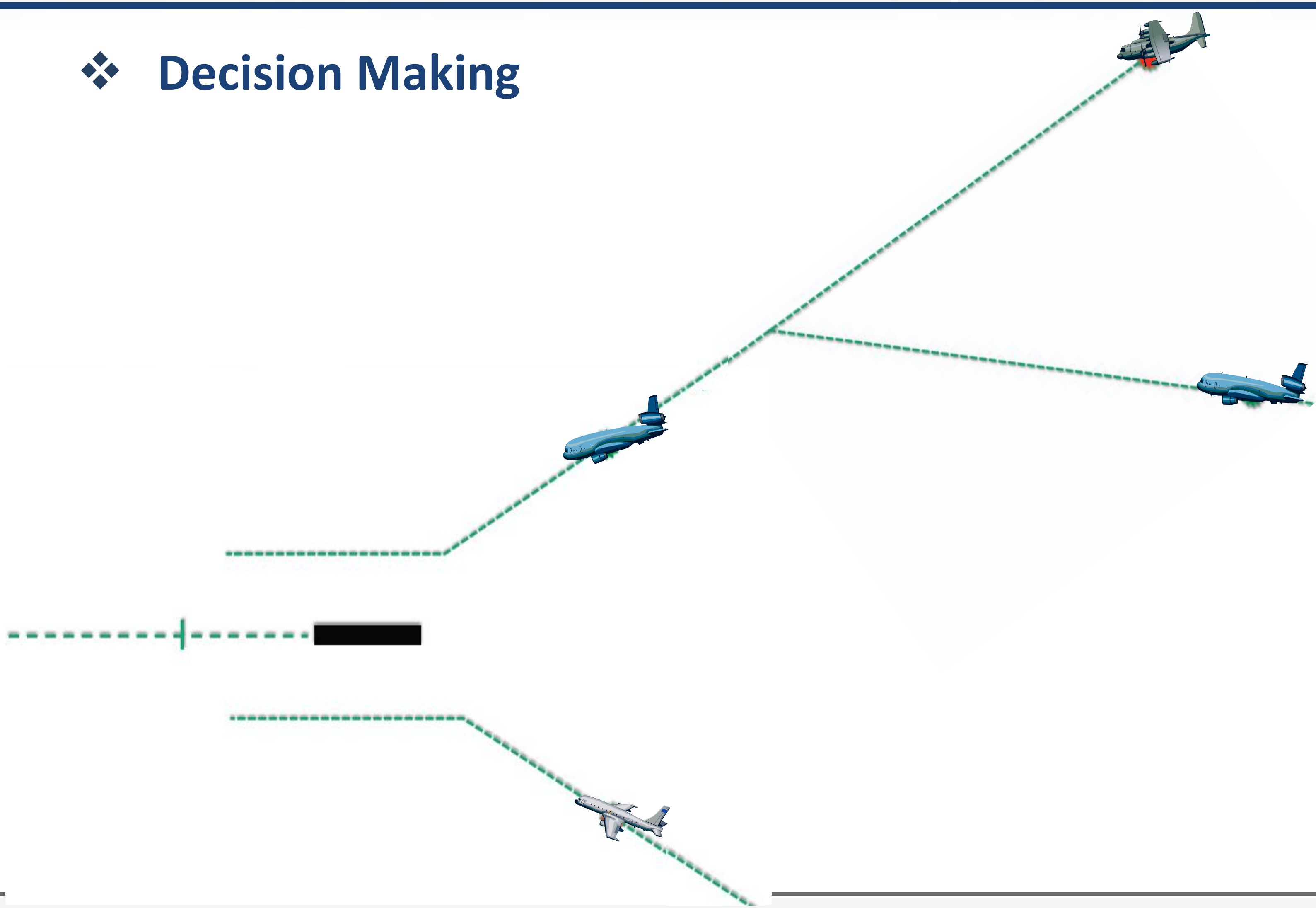
- **CDO Design Considerations**
  - Closed Path design improves predictability and efficiency.
    - STARs join/terminate at IF/IAF, path continues to touchdown.
  - Open path may increase flexibility.
  - Use speed control in preference to vectors.
  - 280kts provides opportunity for meaningful speed ATC adjustments.
  - Minimize number of required windows.
  - Avoid specifying hard altitudes, make windows as large as feasible.
    - “at or above 7000” is preferable to “at 7000”.
    - “above 7000, below 11000” is preferable to “above 7000, below 7500”.
  - Structured Decision Points on radar scope gives ATC ability to judge control actions early.

CDO APPLICATION (1/9)

- **Sequencing method for CDO**
  - **Automated Sequencing methods**
    - RTA, traffic management advisory display, relative position indicators
    - Provide for efficient planning adjustment
  - **Speed control**
    - Most effective when a small correction is made in early stage
    - Predictable and consistent performance, maintain separation
    - Large speed adjustments may be counter-productive
  - **Vectoring**
    - Most flexible way to sequence arriving traffic and maintain capacity
    - Least advanced predictability to pilots in terms of flight path distances
    - Can be applied both method of CDO design

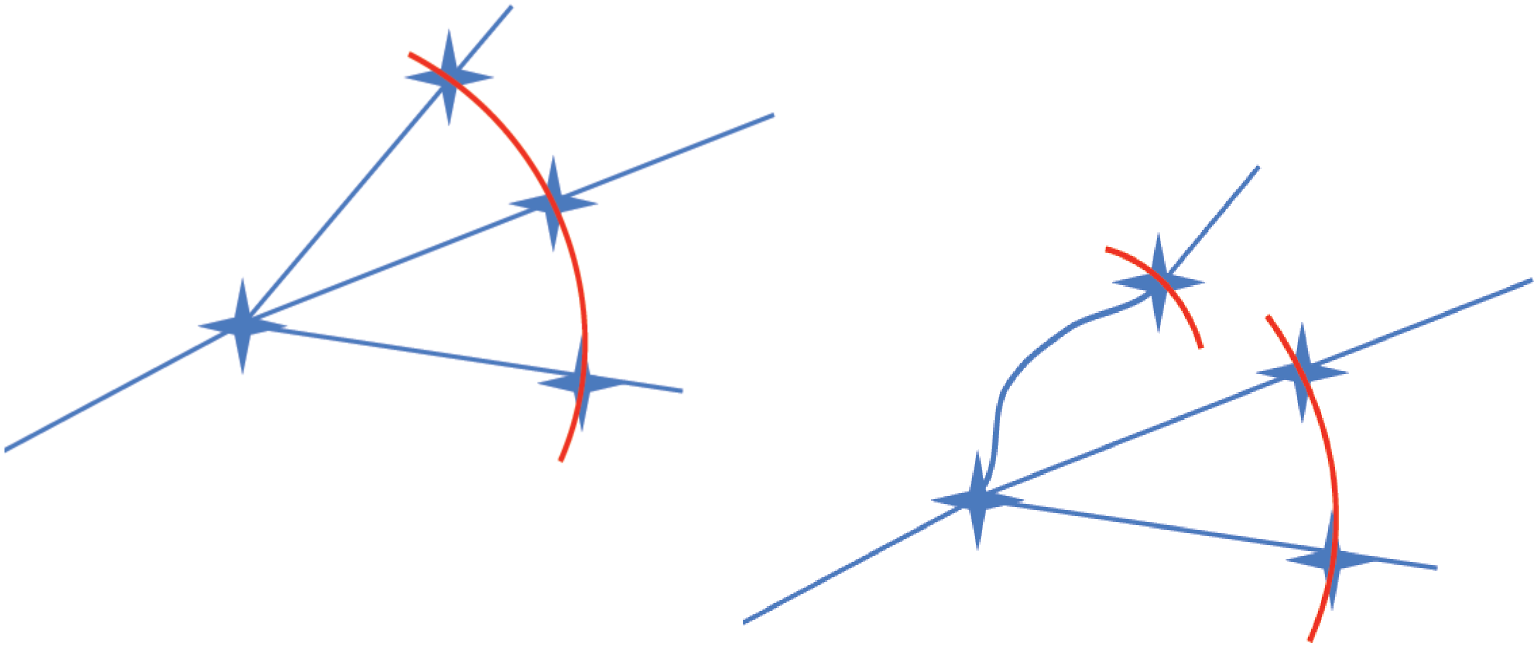
CDO APPLICATION (2/9)

❖ **Decision Making**



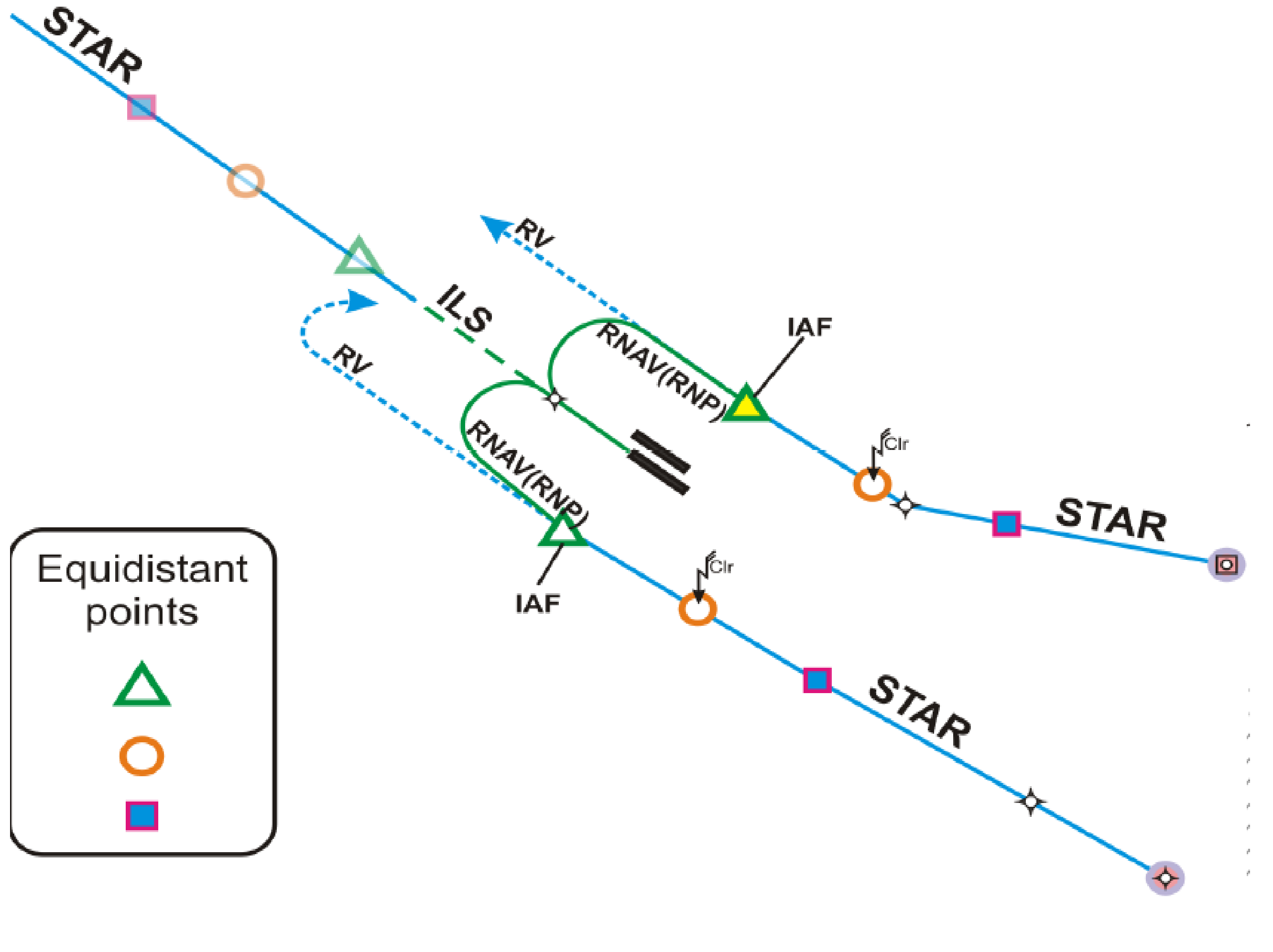
CDO APPLICATION (3/9)

- Sequencing using structured decision points
  - Use equidistant points to judge distance
  - PBN consistency allows equidistance for non linear paths



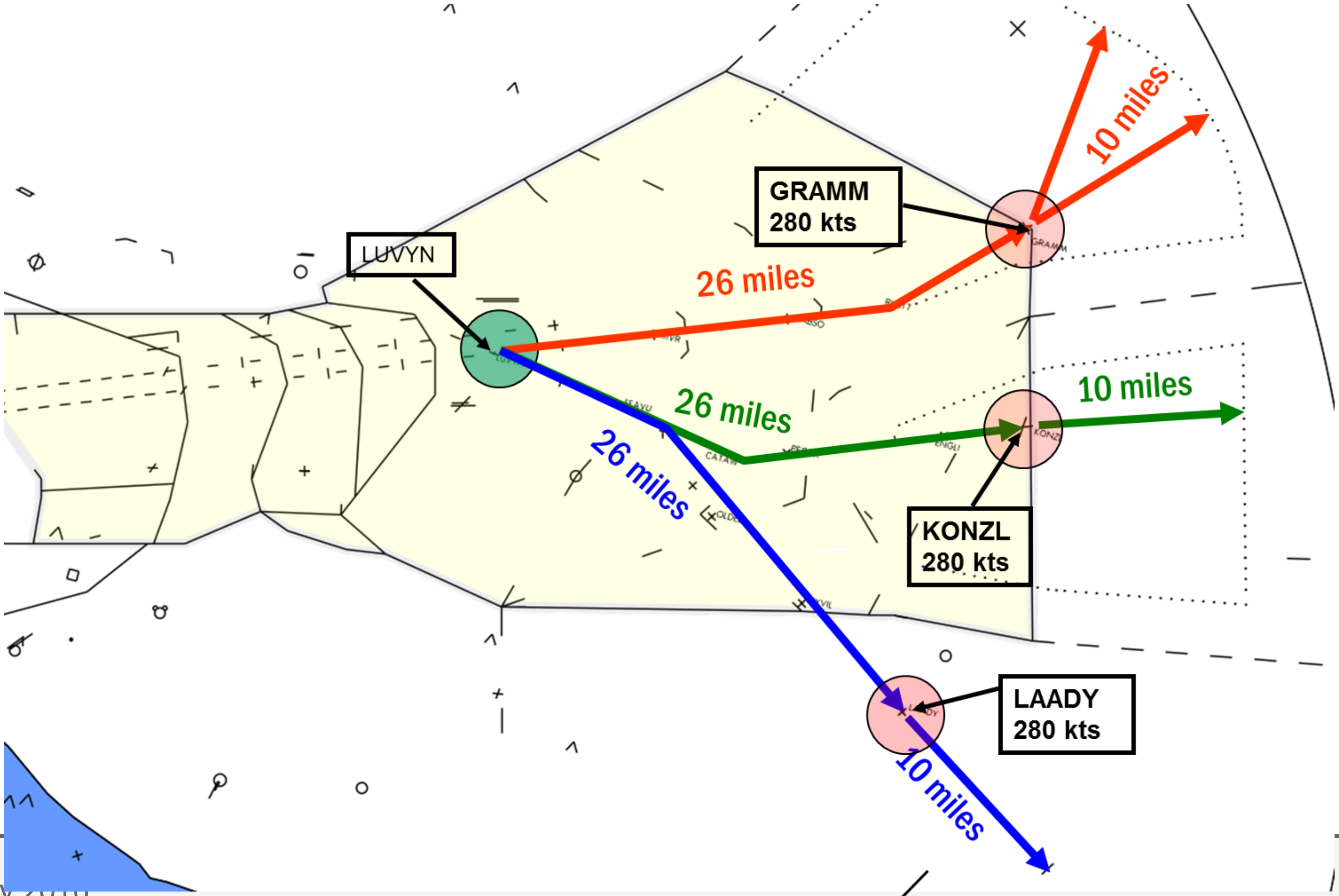
CDO APPLICATION (4/9)

- Sequencing using structured decision points



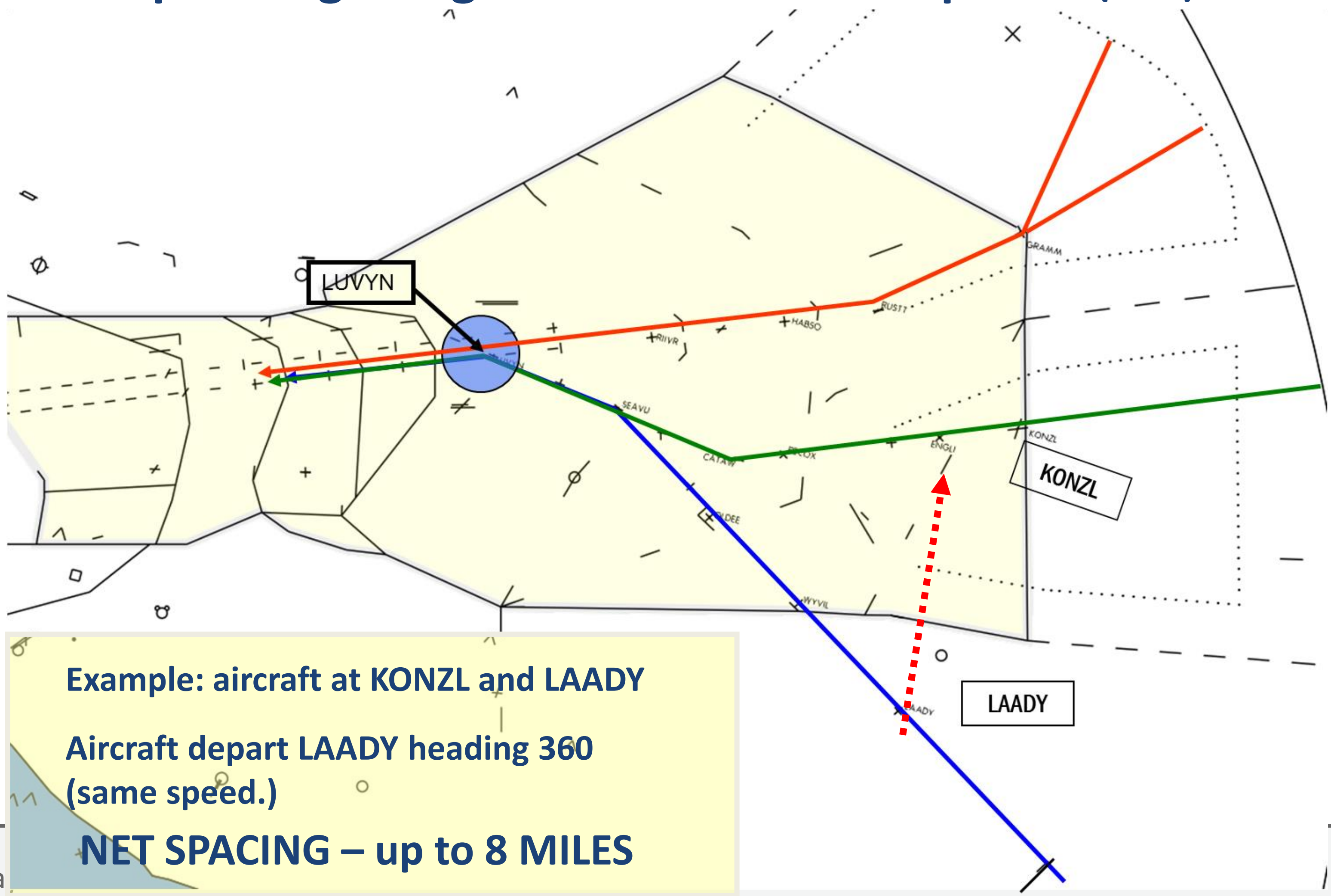
CDO APPLICATION (5/9)

- Sequencing using structured decision points (LAX)



CDO APPLICATION (5/9)

- Sequencing using structured decision points (LAX)



Example: aircraft at KONZL and LAADY

Aircraft depart LAADY heading 360 (same speed.)

NET SPACING – up to 8 MILES

CDO APPLICATION (6/9)

- **ATC Phraseologies** (CDO Manual Appendix 2)
  - "Descend at pilots discretion" or "Descend when ready" clearance
    - Provides options and flexibility to the operation
    - Should be given as close as possible to a distance from touchdown from where a optimized continuous descend will result

    Ex) 25NM to fly, descend at pilots discretion.
    Cross BUDDY at level 120, then descend when ready.
  - "Descend via ~ " clearance
    - Instruct to the pilot to descend while complying with the published lateral path, altitudes and speeds.
    - Shall be used when lateral and vertical flight paths are known
    - May be given well in advance of the actual descent point

    Ex) Cross ABC intersection at FL240, then descend via COAST 2 Arrival.
    Descend via the RIIVR 2 Arrival, after RIIVR cleared ILS RWY 24L.

CDO APPLICATION (7/9)

- **ATC Phraseologies (PANS-ATM Amendment Proposal, Nov 2016)**
  - **"Descend via STAR to (level)" clearance**
    - **descend to the cleared level and comply with published level restrictions;**
    - **follow the lateral profile of the STAR; and**
    - **comply with published speed restrictions or ATC-issued speed control instructions as applicable.**
  - **"Descend via STAR to (level), cancel level restriction(s)" clearance**
    - **descend to the cleared level, published level restrictions are cancelled;**
    - **follow the lateral profile of the STAR; and**
    - **comply with published speed restrictions or ATC-issued speed control instructions as applicable.**

CDO APPLICATION (8/9)

- ATC Phraseologies (PANS-ATM Amendment Proposal, Nov 2016)
  - "Descend via STAR to (level), cancel level restriction(s) at (point(s))" clearance
    - descend to the cleared level, published level restriction(s) at the specified point(s) are cancelled;
    - follow the lateral profile of the STAR; and
    - comply with published speed restrictions or ATC-issued speed control instructions as applicable.
  - "Descend via STAR to (level), cancel speed restriction(s)" clearance
    - descend to the cleared level and comply with published level restrictions;
    - follow the lateral profile of the STAR; and
    - published speed restrictions and ATC-issued speed control instructions are cancelled.

CDO APPLICATION (9/9)

- **ATC Phraseologies** (PANS-ATM Amendment Proposal, Nov 2016)
  - "Descend via STAR to (level), cancel speed restriction(s) at (point(s))" clearance
    - descend to the cleared level and comply with published level restrictions;
    - follow the lateral profile of the STAR; and
    - published speed restrictions are cancelled at the specified point(s).
  - "Descend unrestricted to (level), or Descend to (level), cancel level and speed restriction(s)" clearance
    - descend to the cleared level, published level restrictions are cancelled;
    - follow the lateral profile of the STAR; and
    - published speed restrictions and ATC-issued speed control instructions are cancelled.

CDO IMPLEMENTATION

- **CDO implementation principles**
  - Safety of operations shall not be compromised in any way;
  - Collaboration between ANSP, aircraft operator and airport is essential;
  - A hybrid approach of a CDO procedure may be a viable solution;
  - CDO should be considered as the total current operations;
  - The effectiveness of a CDO procedures relies on unambiguous and timely clearances;
  - An optimum CDO procedures require unimpeded descent of aircraft with a fixed lateral path and a preplanned vertical path;
  - Energy management is critical to a successful CDO;
  - Improved fuel efficiency and emission reduction become available at higher levels, if possible, from TOD;
  - CDO should not adversely affect capacity, other operations, etc.;
  - Changes to flight tracks may require consultation with external entities.

CCO (1/14)

- CCO is an aircraft operating technique made possible by
  - Appropriate airspace and procedure design
  - Appropriate ATC clearances
- Enabling the execution of a flight profile optimized to the performance of the aircraft,
- Allowing the aircraft to attain initial cruise flight level at optimum air speed with climb engine thrust settings set throughout the climb,
- Thereby reducing total fuel burn and emissions during the whole flight.

CCO (2/14)

- Arriving and departing traffic are usually **interdependent**.
- The airspace design supporting CCO 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**.

CCO (3/14)

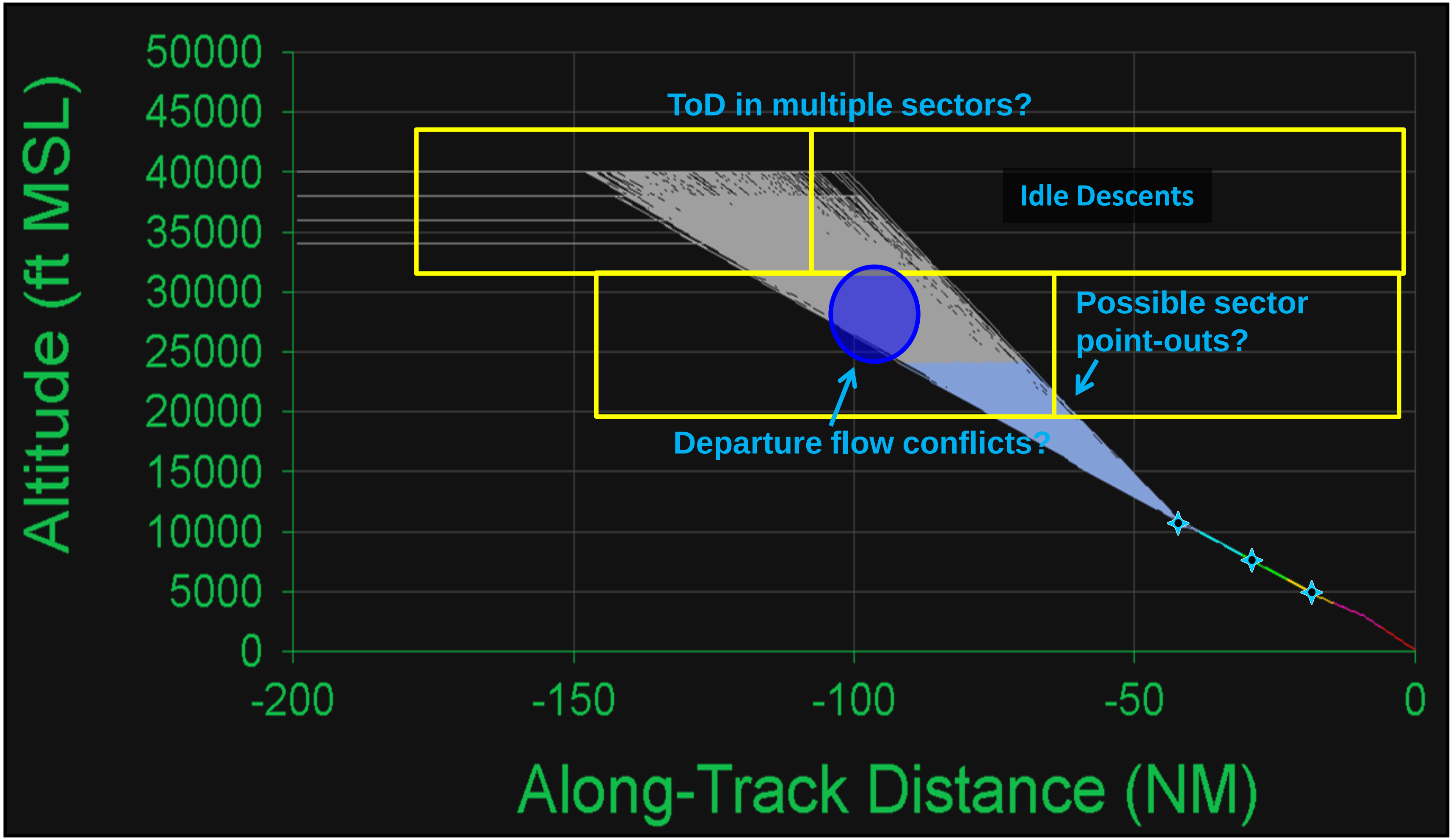
- **How to make balance between CDO and CCO?**

  - **Where a trade-off between CCO and CDO is unavoidable, the local analysis and decision making should take into account that a level segment for an aircraft in descent would normally burn less fuel than for the same duration of level segment for an equivalent aircraft in climb.**

  - **Often there is far more unnecessary level flight in the descent phase than in the climb phase.**

  - **The balance will depend on local characteristics such as the extent of level flight in both phases, the significance of noise in the areas affected etc.**

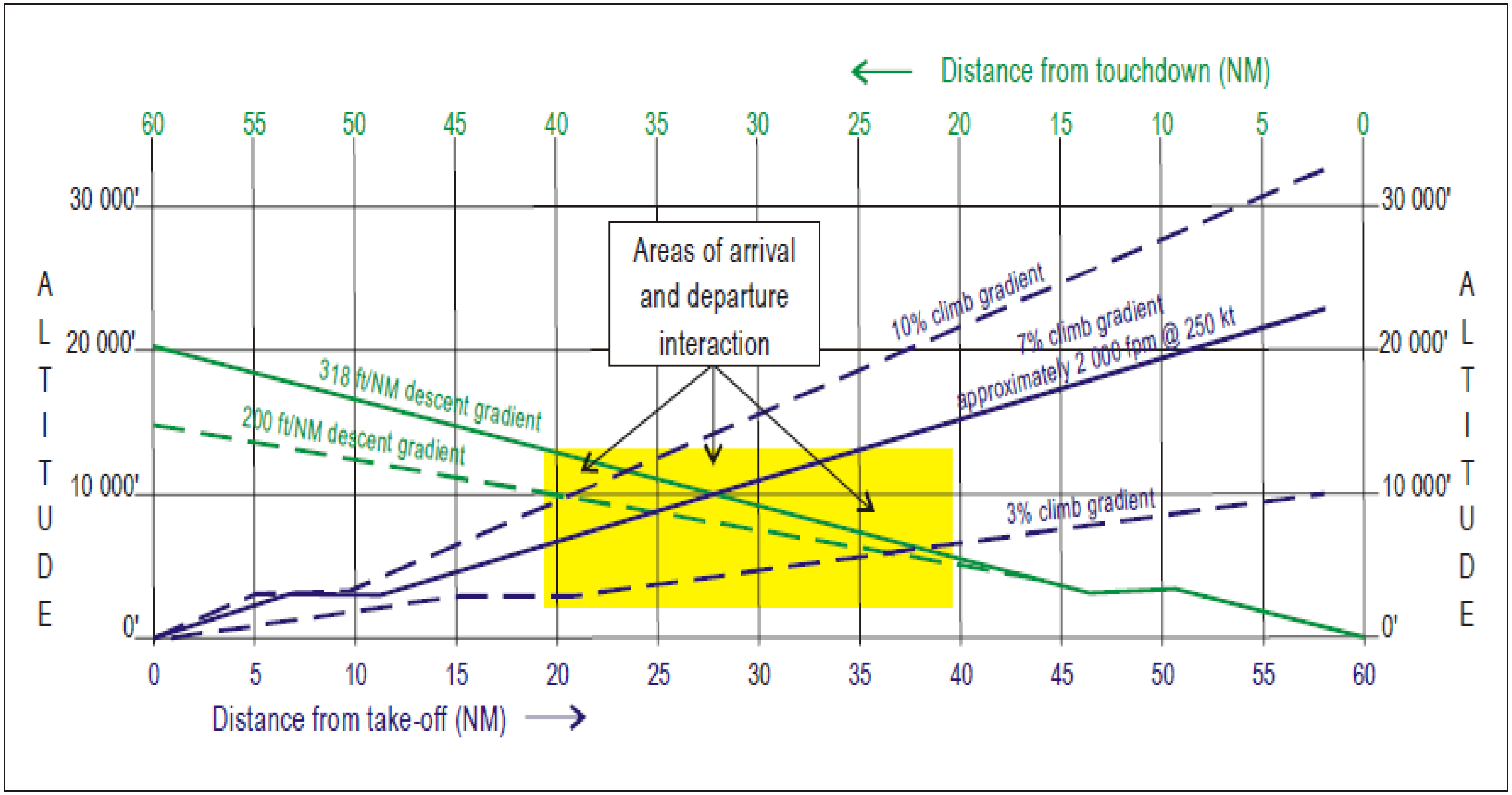
CCO (4/14)



Altitude (ft MSL)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-200
-150
-100
-50
0
Along-Track Distance (NM)
ToD in multiple sectors?
Idle Descents
Possible sector point-outs?
Departure flow conflicts?

CCO (5/14)

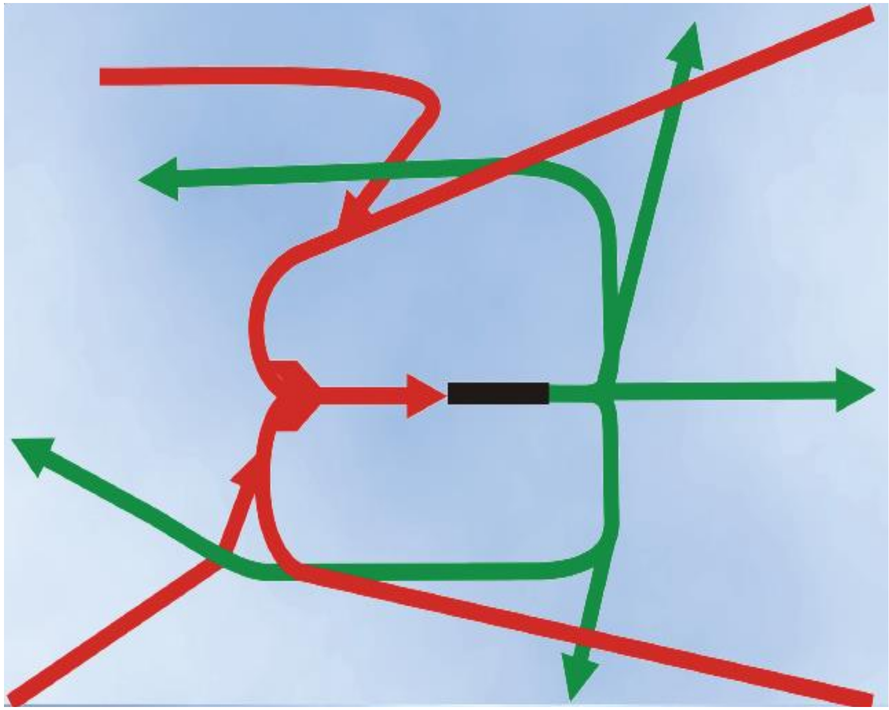
❖ Conflict Zones

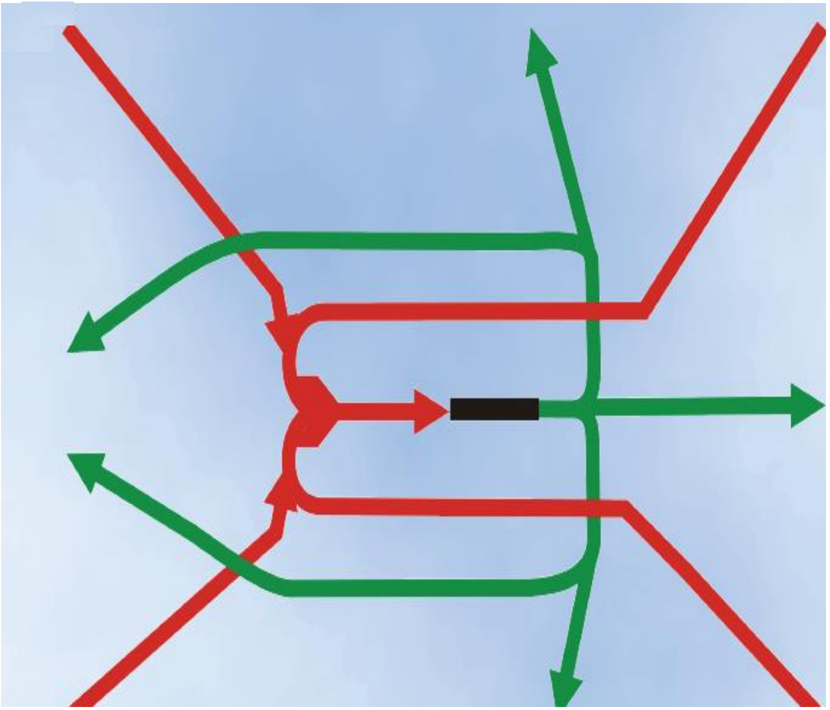


SAMPLE CHART ONLY: Similar graphs should be developed for each implementation depending on fleet

CCO (6/14)

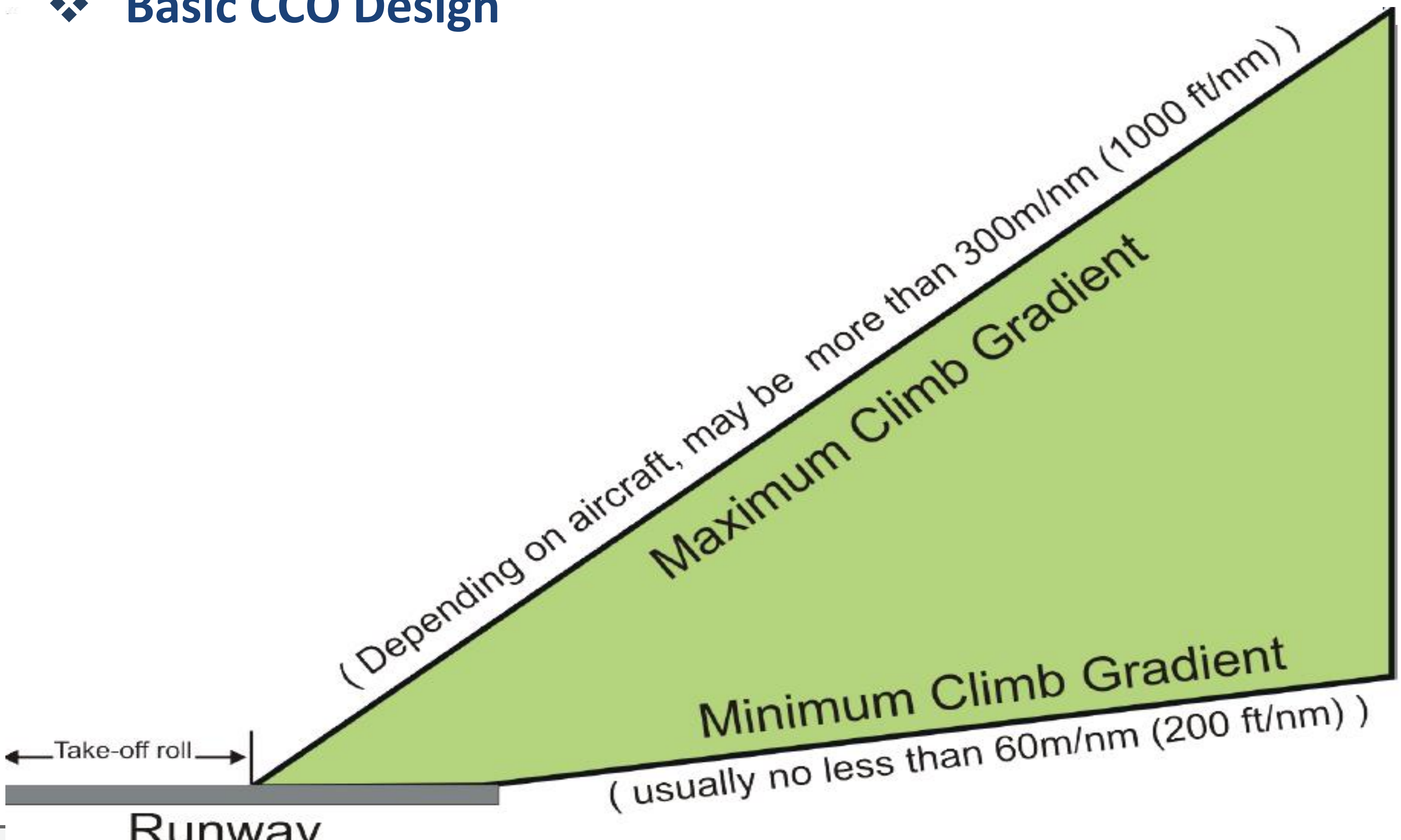
- Profile interaction





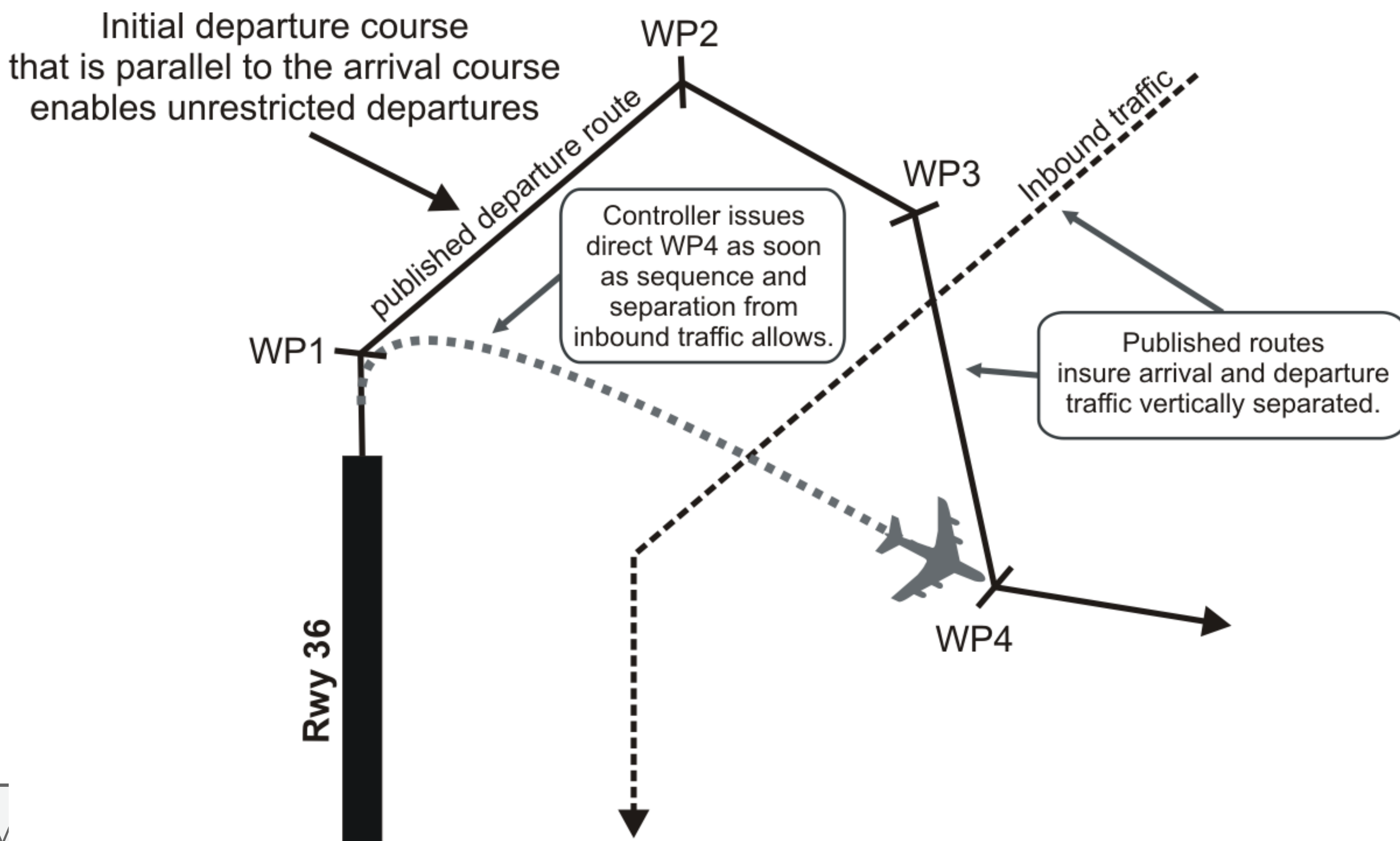
CCO (7/14)

- Basic CCO Design



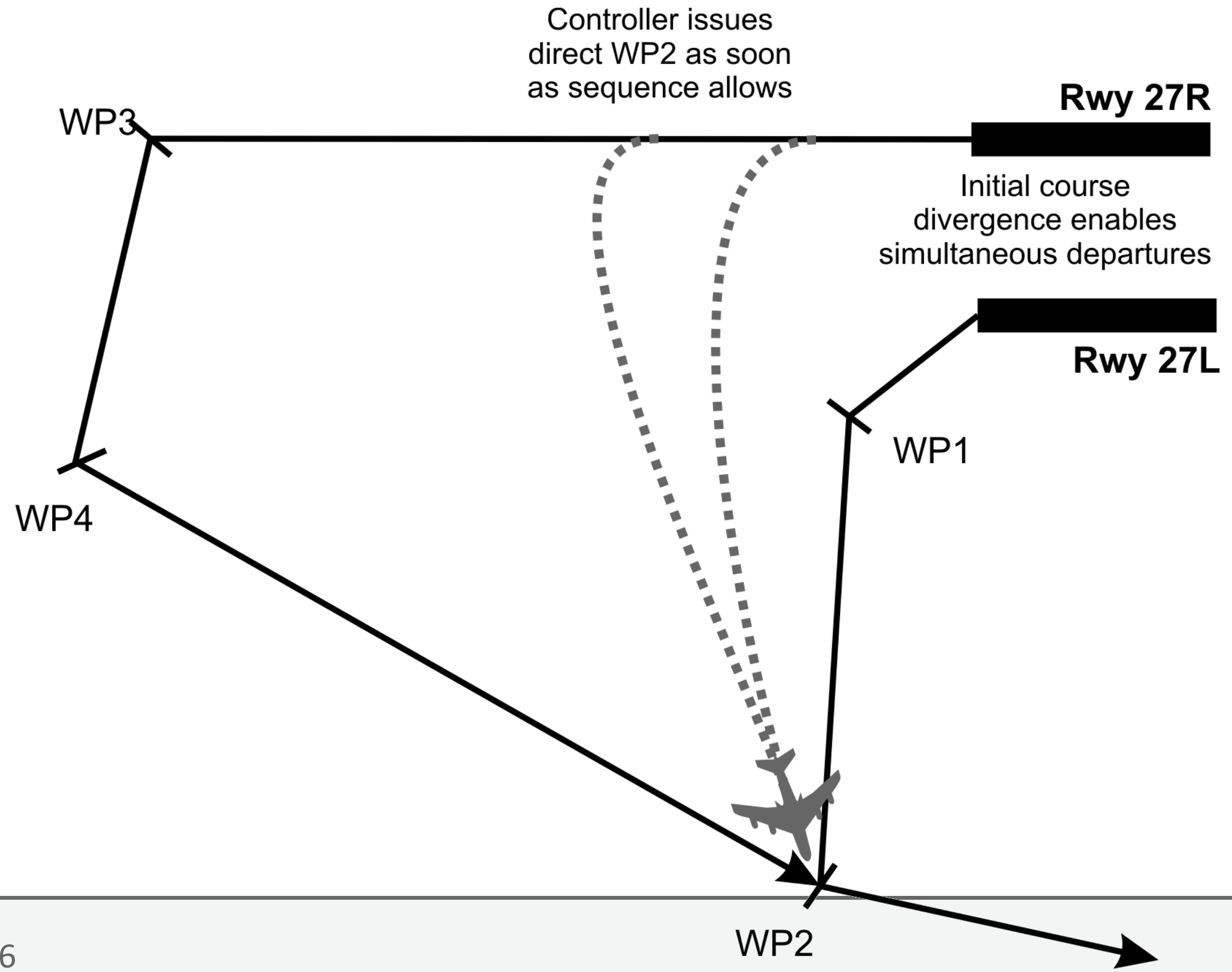
CCO (8/14)

❖ CCO vs. Inbound Traffic



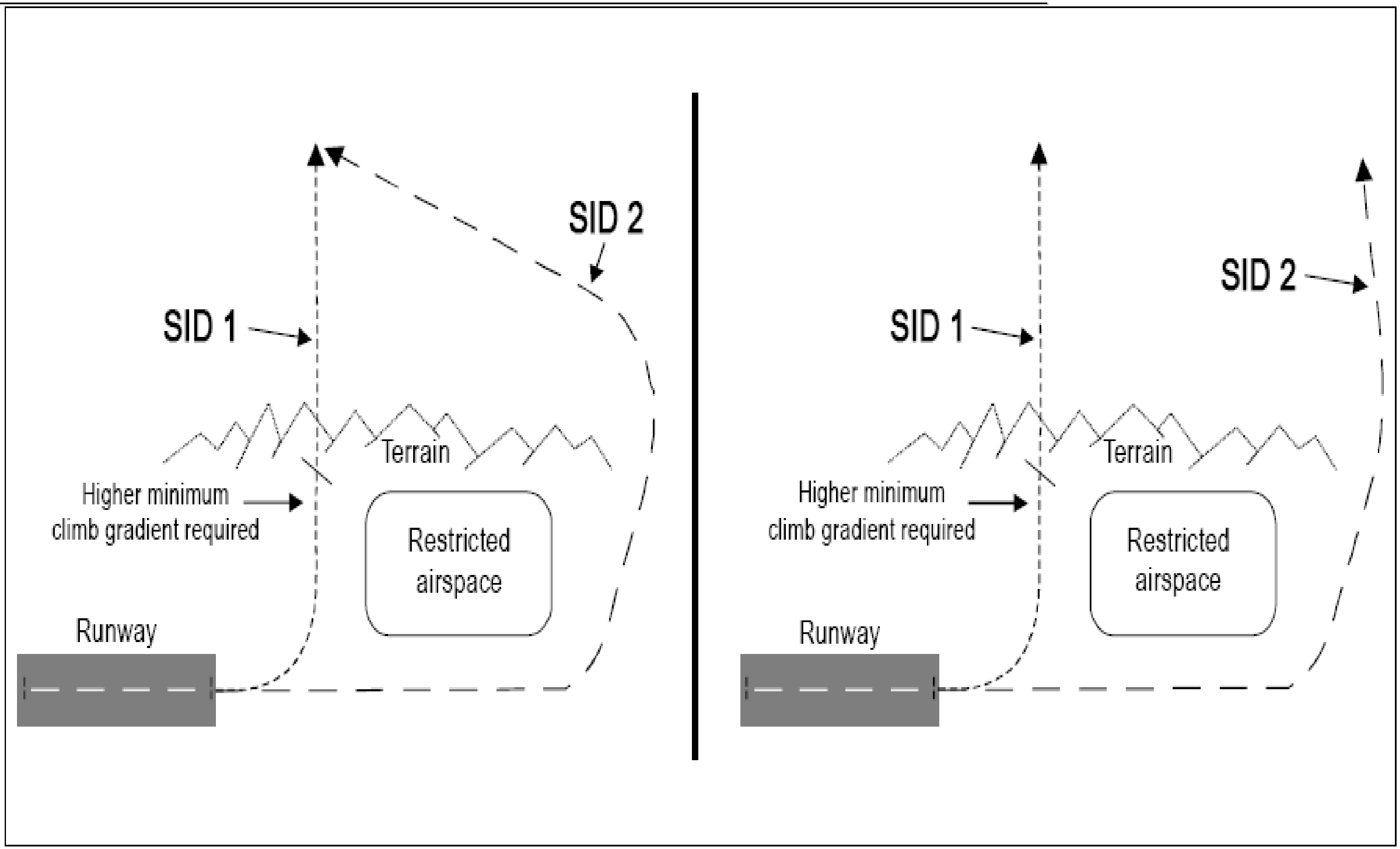
CCO (9/14)

❖ Multi-runway CCO Departures



CCO (10/14)

❖ Multiple Performance CCO



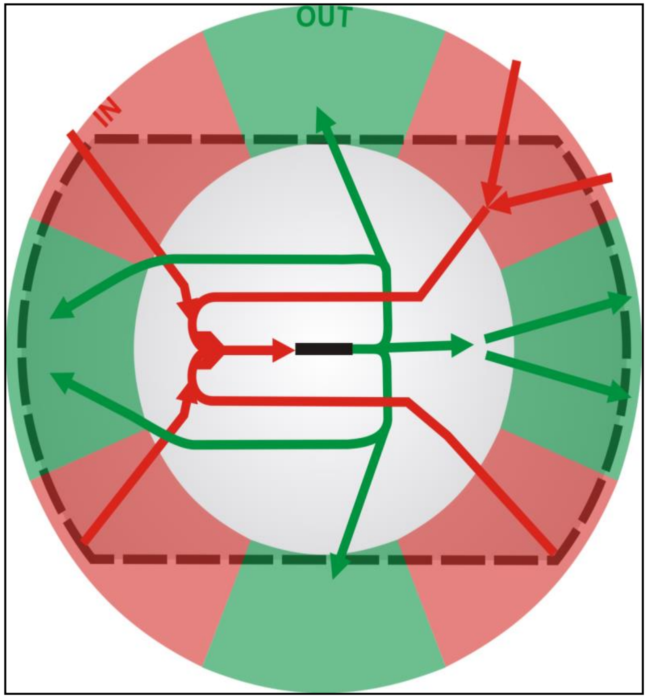
CCO (11/14)

❖ Good Design Practice

- Flows by quadrant (Corner Post), segregate Arrivals laterally and vertically from Departures

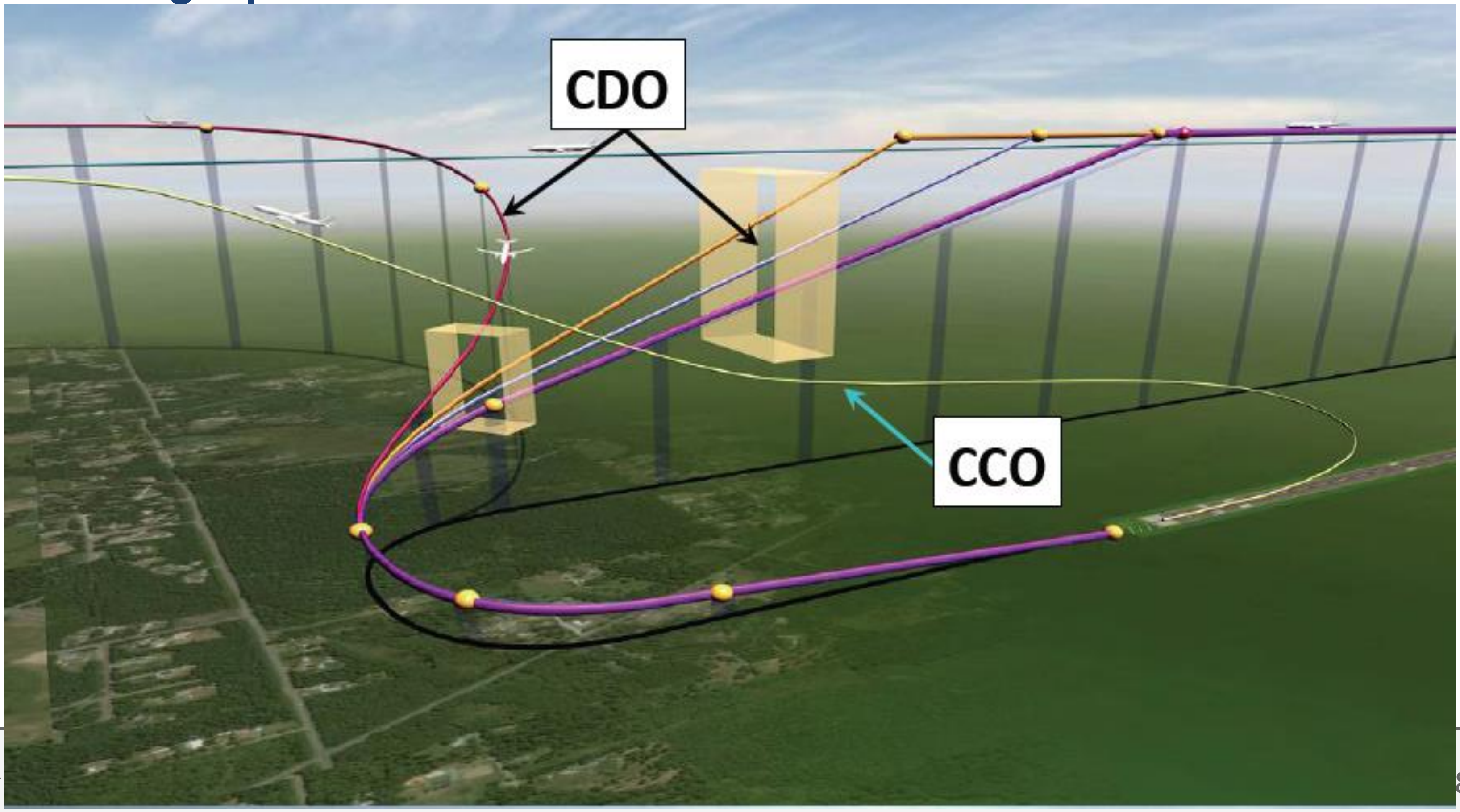
❖ Rules of Thumb

- CDO descent rate
  - 1000ft/3NM plus 1NM/10knots or
  - 1000ft/4NM (4.1%)
- CCO climb rate
  - Slow : 1000ft/5NM (3.3%)
  - Medium : 1000ft/3~4NM (4.1~5.5%)
  - Fast : 1000ft/2NM (8.2%)



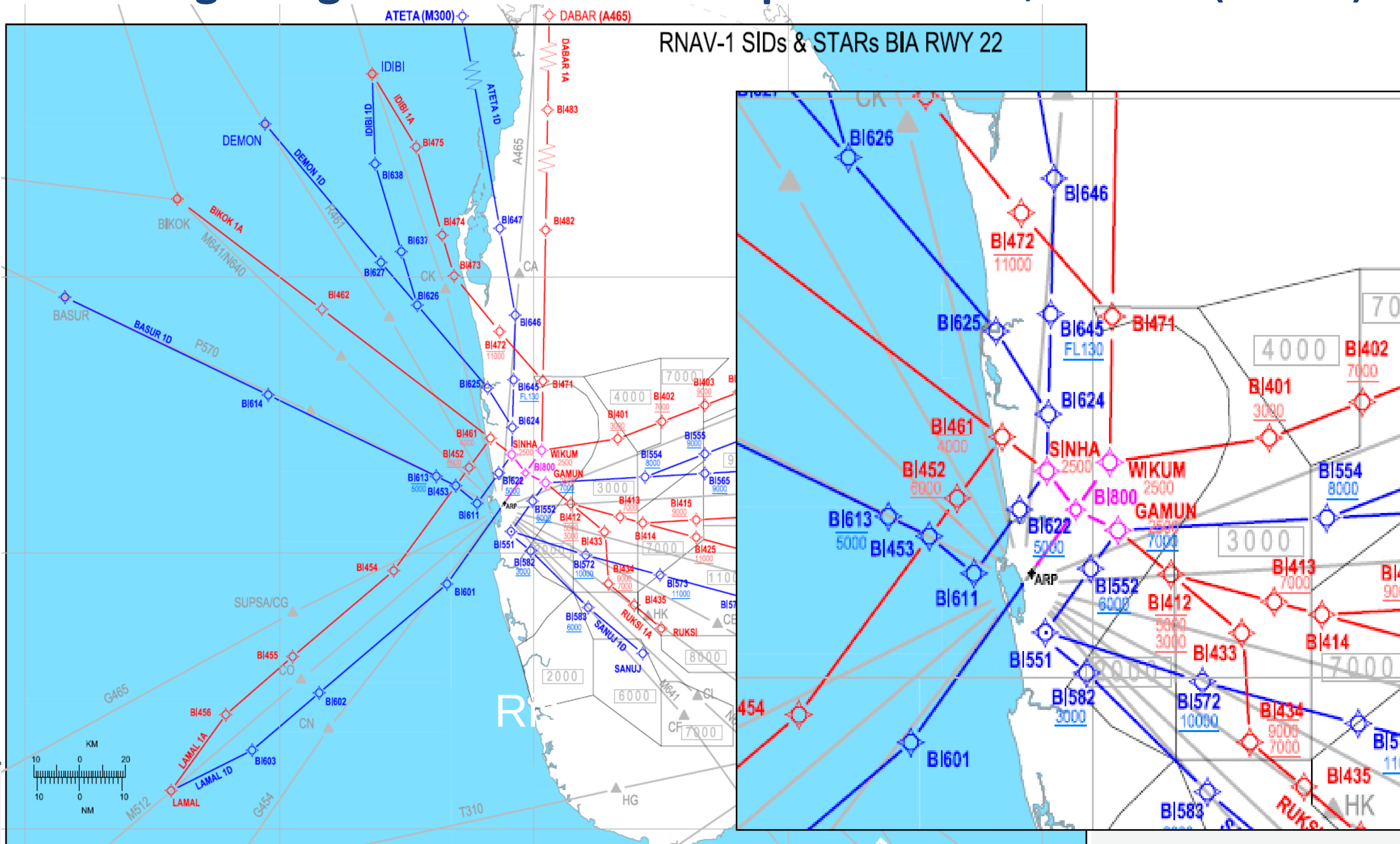
CCO (12/14)

- Integrating CCO and CDO designs
  - Altitude windows safely separate aircraft and allow predictable flight performance



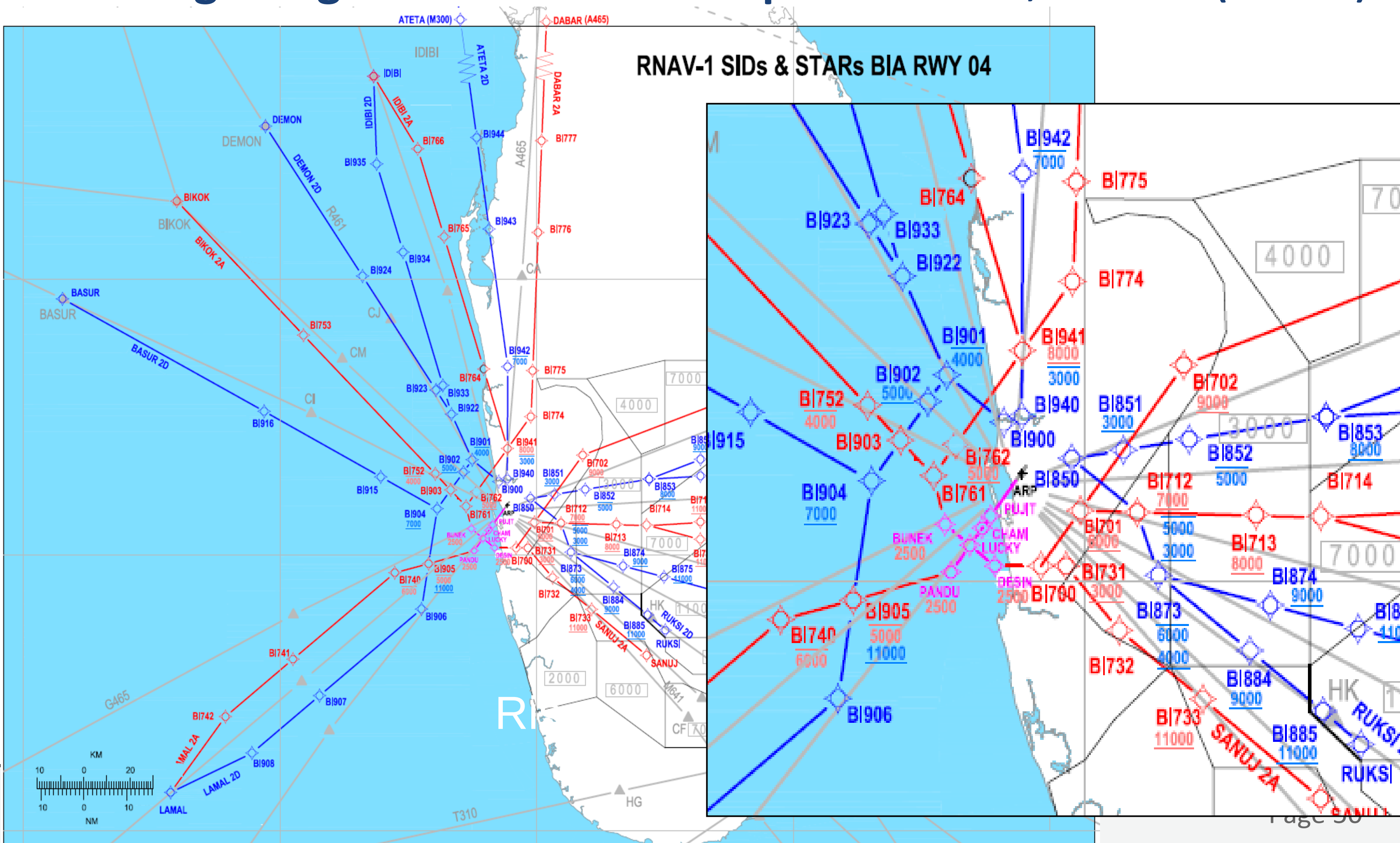
CCO (13/14)

- **Integrating CCO and CDO example** – **Colombo, Sri Lanka (RWY22)**



CCO (14/14)

❖ **Integrating CCO and CDO example** – **Colombo, Sri Lanka (RWY04)**



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Thank You