ICAO MID

الهيئة العامة للطيران المدني
GENERAL CIVIL AVIATION AUTHORITY

CCO-CDO Workshop

ICAO MID Workshop on the Continuous Climb Operations (CCO) / Continuous Descent Operations (CDO) Implementation

Abu Dhabi, UAE 13 – 14 June 2022

CCO/CDP Database Coding & Charting

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Continuous Descent Operations (CDO)

- **CDO** is one of several tools available to operators and ANSPs to increase flight safety, trajectory predictability and airspace capacity while reducing noise, fuel burn and direct controller-pilot comm (DCPC).
- **CDO** is *not* a Flight Procedure Design (FPD) criteria; it is an aircraft operating technique aided by airspace & procedure design and appropriate ATC clearances enabling the execution of an optimized flight profile.
- Ideally, an optimum **CDO** starts from top of descent (TOD), continues through to the FAF/FAP and uses descent profiles that reduce the communication and segments of level flight.
- **CDO** can be flown with or without FMS support for LNAV and VNAV functions, but the maximum benefit is readily determined by the onboard FMS.

CDO Design Options

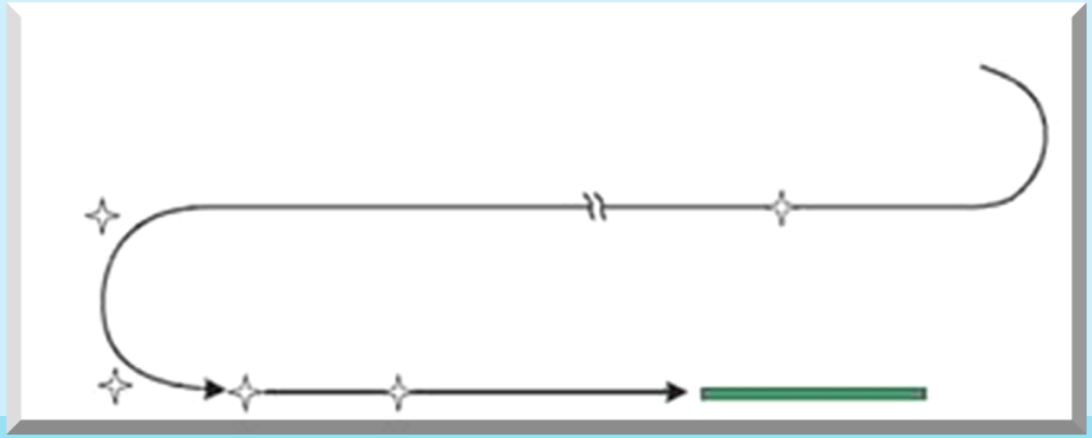
- The optimum descent path is facilitated by the pilot and/or the FMS knowing the flight distance to the runway threshold and the Top Of Descent (ToD).
- The CDO is optimized by using vertical navigation (VNAV) systems, however this system is not a prerequisite.
- Based on “laterally fixed” routes and requiring different methods for the distance to go, there are two (2) CDO design methodology identified as:
  - **Closed path** design.
  - **Open path** design.

CDO: Closed Path Design

- **Closed Path** is a procedural design where the lateral flight is predefined up to FAF/FAP i.e., STAR is terminating at a point that defines a part of an Instrument Approach Procedure (IAP).

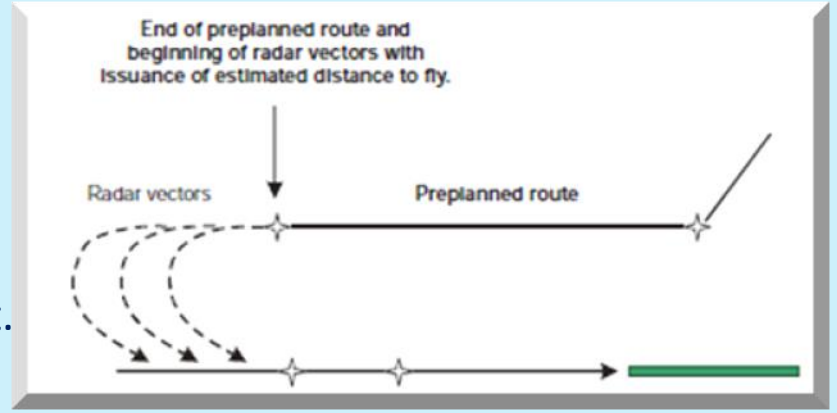
- **Closed Path** permits very precise distance planning allowing FMS to automate optimized descents.

- **Closed Path** comprises a fixed route (STAR + Initial/Intermediate Approach) and a specific distance to the runway that is known prior to the start of the continuous descent operation.



CDO: Open Path Design

- **Open Path** is a design where the procedure finishes before FAF/FAP.



There are two (2) main options for **Open path** design**:**

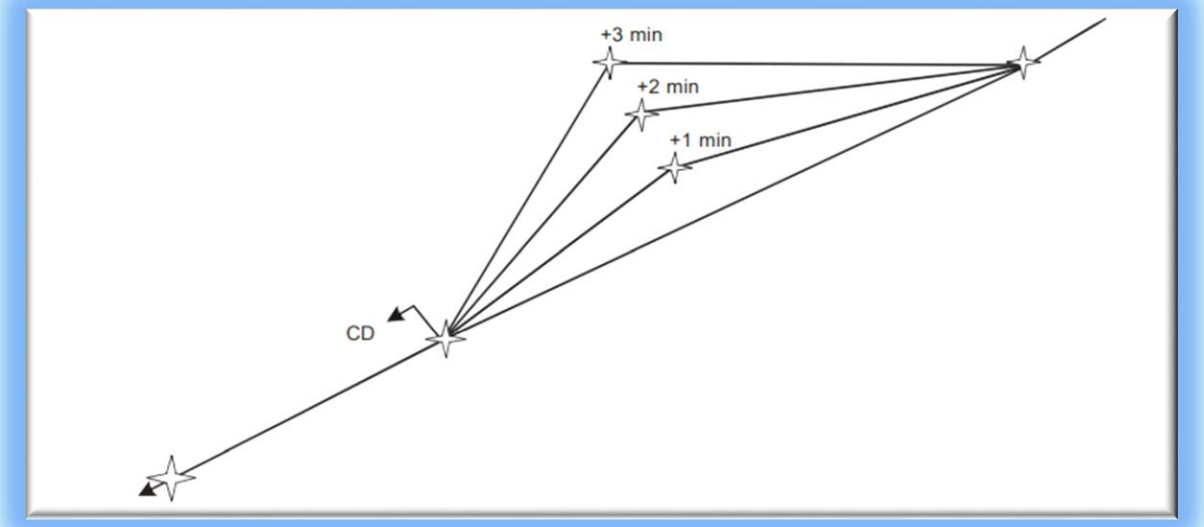
1. Open CDO to downwind i.e., combination of fixed route with vectoring segment.

2. Vectored CDO i.e., the aircraft is entirely vector-ed and the pilot is given an estimate of Distance To Go to runway threshold. Then the descent is at pilot discretion.

CDO: Path Stretching Method

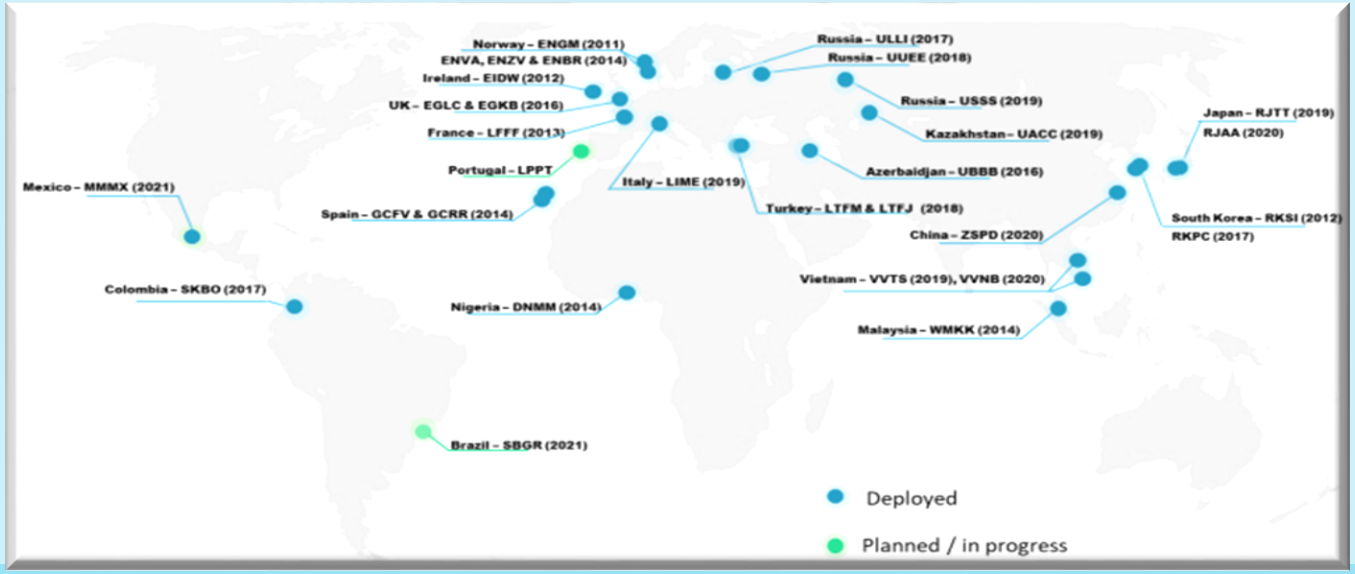
- **Patch Stretching** design is a planned vectoring path required during traffic peeks that has predetermined waypoints stored in the FMS as well as known to the pilot and ATC.

- The procedure can be used to increase separation while allowing the FMS to fly aircraft on the CDO. **Path stretching** may be used in addition to speed control methods.



CDO: Point Merge Method

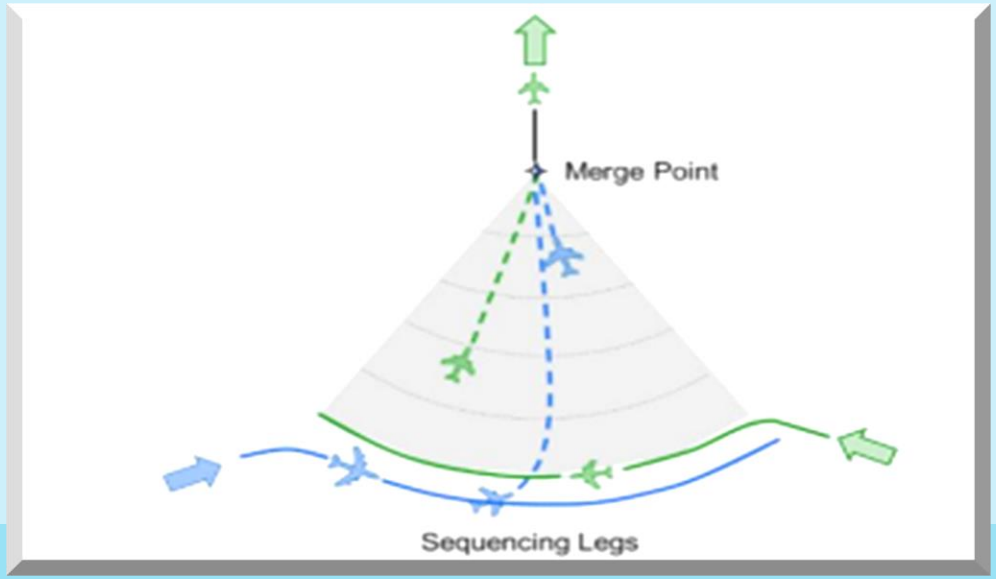
- **Point Merge** is an innovative sequencing technique developed by Eurocontrol Experimental Centre to allow controllers to sequence and merge arrivals without vectoring, while enabling continuous descent operations even under high traffic.
- After 1st implementations in Oslo (2011) and Dublin (2012), the new method spread not only within the ECAC area, but also far beyond its borders (around 30 airports).



* as of May 2021, ECTL "Quick Guide on Point Merge"

CDO: Point Merge Method Explained

- **Point Merge** design uses a single point to merge arrivals which differs from current techniques where traffic merges to the extended runway centerline.
- From the Merge Point (MP) , aircraft join the final approach via a fixed path. Before merging, a portion of the procedure (sequencing legs) is devoted to path stretching/delay absorption.
- The legs are designed in the form of segments forming "quasi arcs" with equidistance from MP.



CDO: Point Merge loaded in FMS

- **Point Merge,** as similarly to any arrival procedure that incorporates a path extension (e.g., trombones), the route to be loaded in the FMS (used by default) is the extended one which includes the full length of sequencing legs.
- This induces a change of reference for fuel planning if taken as a basis for the trip fuel i.e., it would introduce an un-justified penalty.
- Early **Point Merge** implementations have considered different ways to address this issue (1) using a short route and/or (2) relying on statistics on the expected arrival delays depending on the time of the day.
- Doc. 9976 “FPFM Manual”: The practice of using a short STAR into FMS database for fuel forecast purposes and accounting for linear holding along sequencing legs as part of contingency or extra fuel.

CDO/CCO Database Coding Considerations

As CDO is not "procedure design" criteria, there are no specific ARINC 424 rules for CDO procedures

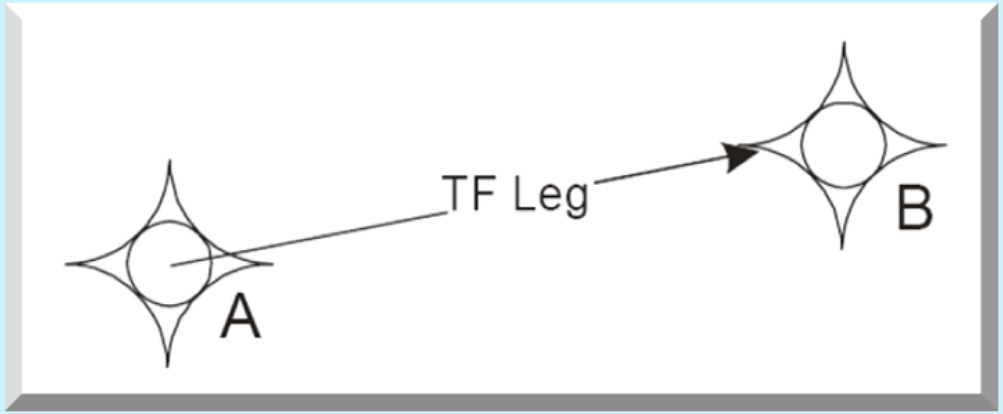
In FMS world, any terminal procedure must be inter-connected by common waypoints

- **Path/Terminator** Concept (total of 23 legs) permits coding of all Terminal Procedures and includes a two-character codes and data associated.
- **Path** – logically describes how the aircraft gets thru air to the **Termination** (track, course, heading).
- **Termination** – is the event or condition (fix, altitude, distance, manual) that causes the system to switch to the next leg;
- Twelve (12 legs) P/T acceptable for PBN procedure design.
- There is *no* FMS coding (ARINC 424) used for enroute routes.

RNAV Path & Terminator for CDO/CCO (short-description)

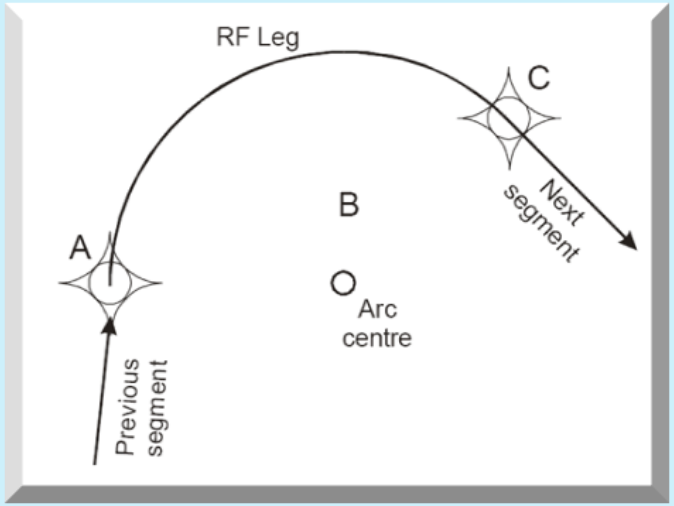
Track to Fix (TF)

- Preferred leg for PBN terminal procedures.
- Easiest to implement, database requirements are minimal.
- The aircraft trajectory is repeatable and predictable (ATC friendly).
- TF leg contains “leg distance” value, it facilitates an accurate FPL.

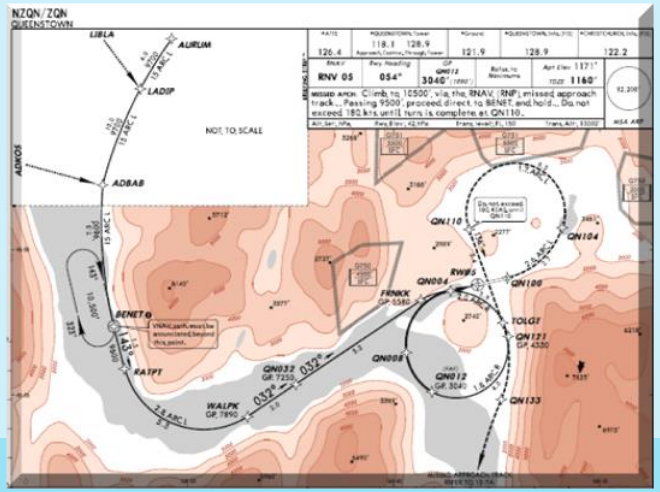


RNAV Path & Terminator for CDO/CCO (short-description)

RF (Constant Radius Arc)

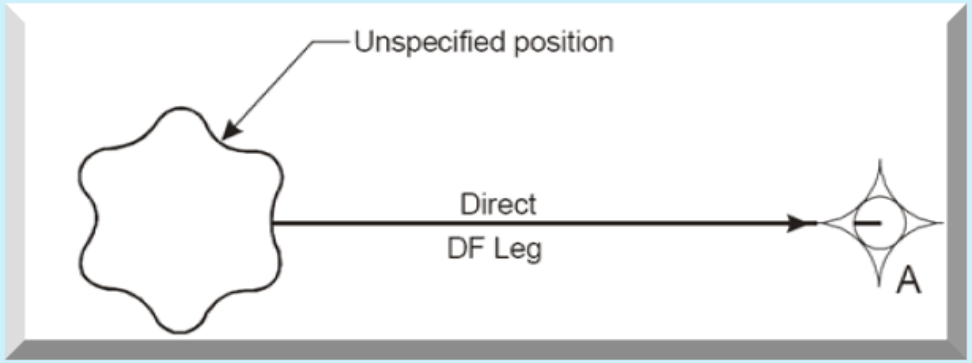


- When procedure type designed with RF leg capability as a design criteria;
- Does not require a ground navaid as the arc origin, but a center fix.
- Single RF turn limited to turns between 2° and 358°.
- The aircraft trajectory is repeatable and predictable (ATC friendly).



RNAV Path & Terminator for CDO/CCO (short-description)

DF (Direct to Fix)

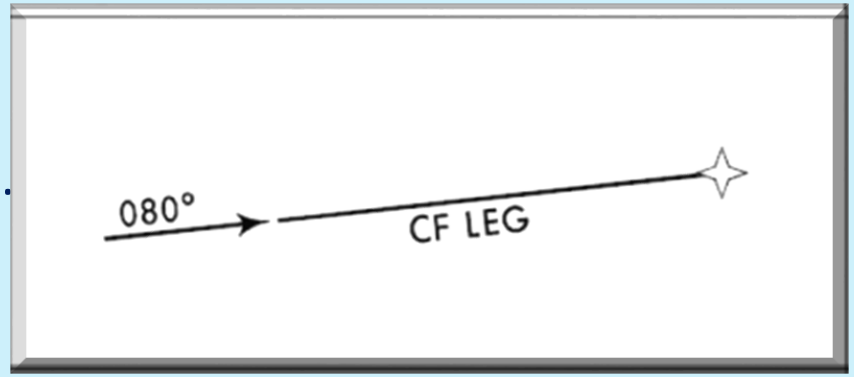


- Its construction is essentially similar to the TF leg.
- The aircraft trajectory is not repeatable and predictable (Not ATC friendly).
- Correct “leg distance” cannot be accurately calculated.

RNAV Path & Terminator for CDO/CCO (short-description)

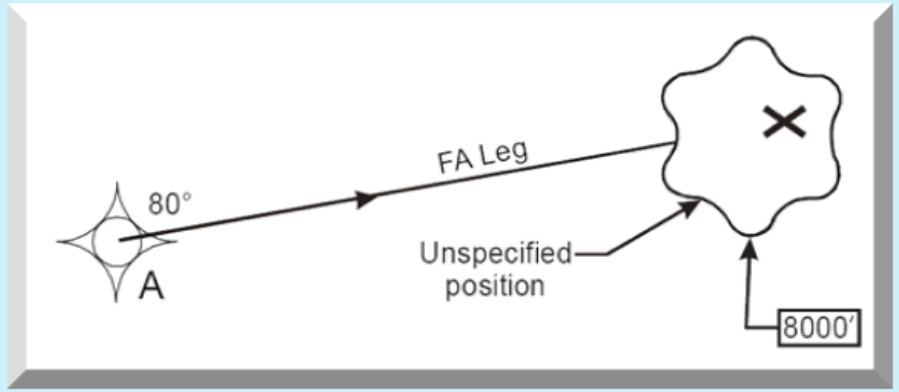
CF (Course to Fix)

- Specifies an inbound course to location identified by its latitude and longitude.
- When starting from an undefined position, ‘recovers’ the defined course;
- The aircraft trajectory is not repeatable and predictable (Not ATC friendly).
- Correct “leg distance” cannot be accurately calculated.

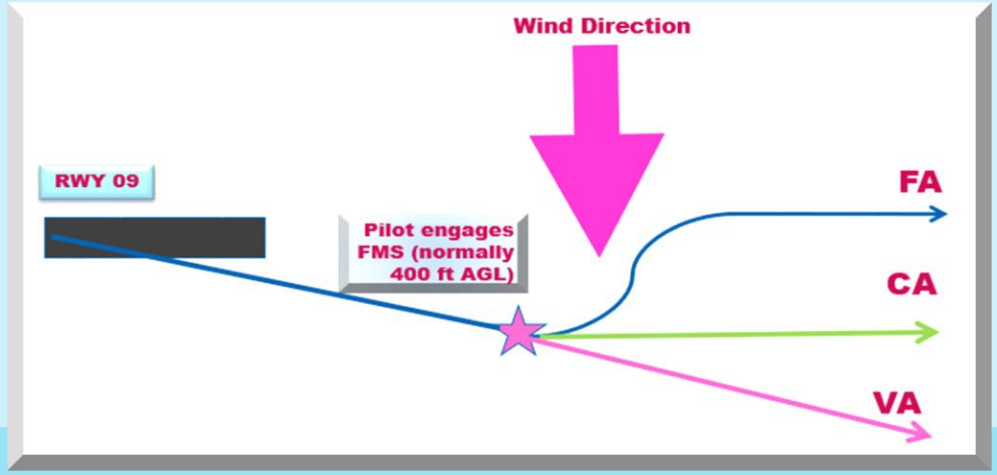


RNAV Path & Terminator for CDO/CCO (short-description)

FA/CA/VA (Fix/Course/Heading to Altitude)



- Altitude Termination is always 'AT or ABOVE' (command to climb).
- Altitude Termination is still at an undefined position as dependent of aircraft performance.
- The aircraft trajectory is not repeatable and predictable.



RNAV Path & Terminator for CDO/CCO (short-description)

Manual Termination (XM) Legs

They are included in RNAV primarily as ending leg of STAR's & Missed Approach and in the definition of SID's initial climb-out with ATC intervention i.e., CDO and CCO procedures.

Course/Heading From A Fix to a Manual Termination (FM/VM)

Figure 8: From a Fix to a Manual termination or FM Leg. Defines a specified track over ground from a database fix until Manual termination of the leg.

- Permits pilot to respond to course vectors while leaving the FMS displayed on the instrument and coupled to the flight control system;
- A VM/FM leg may be coded wherever radar vectoring is provided at the end of a procedure.

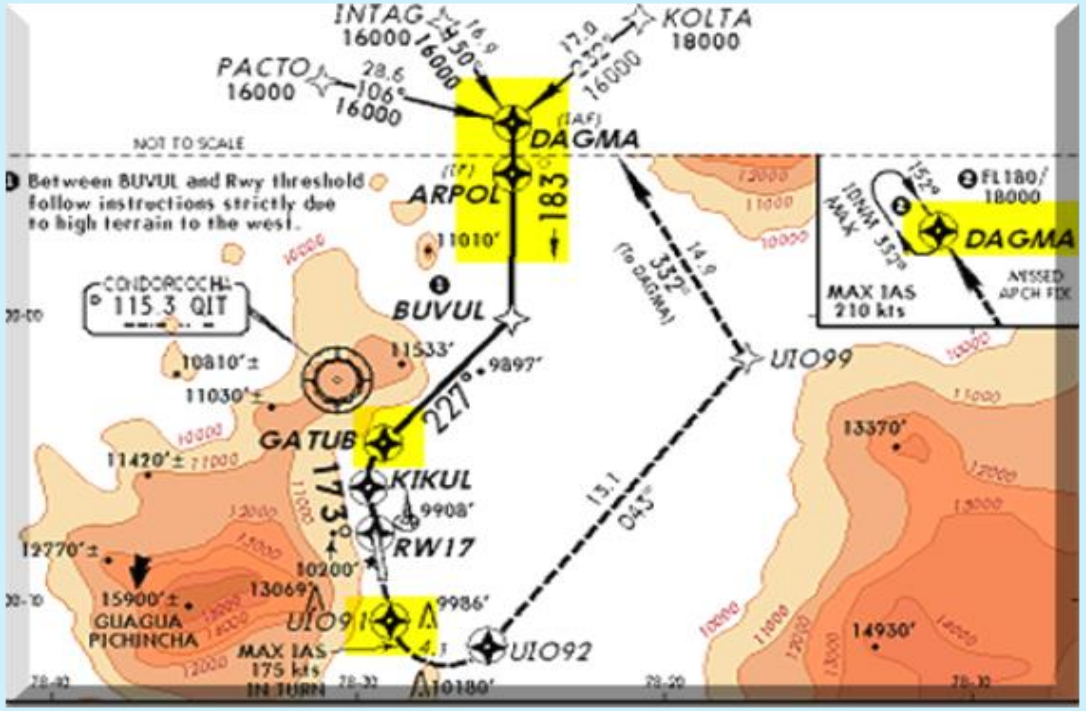
Fly-by (FB) and Fly-Over (FO)

- **Fly-By** = Turn prior to fix (default setting); **Fly-over** = Initiate turn after the fix.

- Standard FMS behavior is to anticipate the turn and FB turn are key characteristic of PBN.

Design/Coding basic rules:

- All approach procedure fixes should be designed as Fly-By.
- Fixes on straight lines are FB and not FO waypoints.
- MAPt shall be defined as Fly-Over waypoint



Speed Restrictions

- **Speed restrictions** are applied at the waypoint; general situation like '*below FL100/IAS 250KT*' or "*maintain 280kts until leaving 10,000ft*" have no procedure coding solution.
- **CCO (SIDs): Speed limit** will apply to all legs up to and including the terminator of the leg on which the limit is encoded from the beginning of the procedure.
- **CDO (STARs): Speed limit** will be applied forward to the end of arrival unless a second speed limit is encoded.
- **CDO (IAPs): Speed limit** in FMS will be applied forward throughout the procedure until superseded by another speed limit.
- **Speed limit** depicted 'somewhere' during a turn shall be associated with a waypoint!

Altitude Constraints

- **Altitude** constraints to be clearly associated to a fix; no appropriate coding solution for minimum segment altitude or MEA's:

- **Altitude** constraints drive the FMS to calculate the vertical profile, if VNAV angle missing.

- **'Expect altitude'** is not code-able unless associated with a waypoint and 'translated' as '*By ATC*'

Vertical Angle

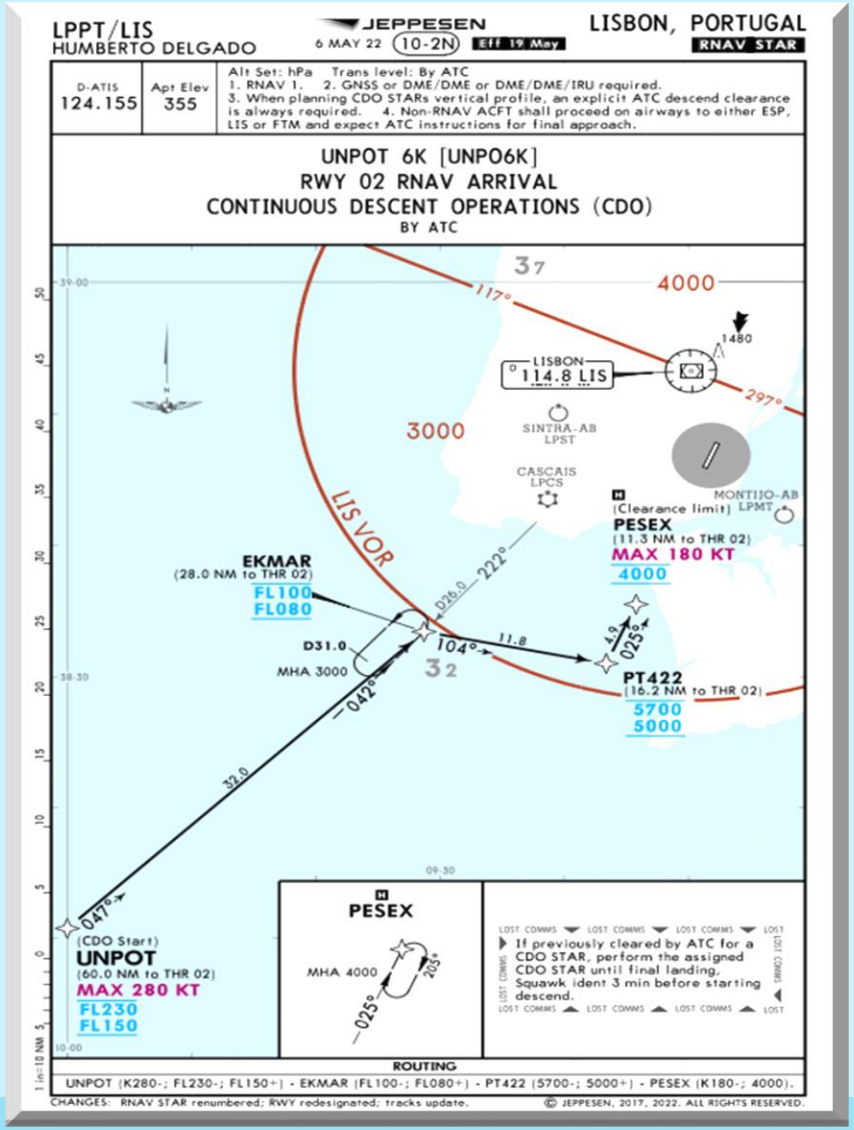
Vertical Angle defines the vertical navigation path prescribed for the procedure. The vertical angle should cause the aircraft to fly at the last coded altitude and then descend on the angle, projected back from the fix and altitude code for that fix at which the angle is coded.

- **Vertical Angle** information is provided only for descending vertical navigation. The angle is preceded by a "–" (minus sign) to indicate the descending flight.
- **Vertical angle** is always included within all straight-in non-precision (conventional and RNAV) approaches coding (if not provided, it's calculated) and STARs.
- Industry and database providers include VNAV function into FMS/RNAV system in support of Continuous Approach operations.
- An FMS usually 'builds' a profile backwards from a point 50ft above the runway threshold to the initial constraints
- **'Expect altitude'** is not code-able unless associated with a waypoint and 'translated' as '*By ATC*'

CDO: Closed Path Coding

- Expertise in FMS performance and flight procedure coding conventions (PANS-OPS, Vol. II) should be included on the design team as arrival procedures will be stored in a navigation database.

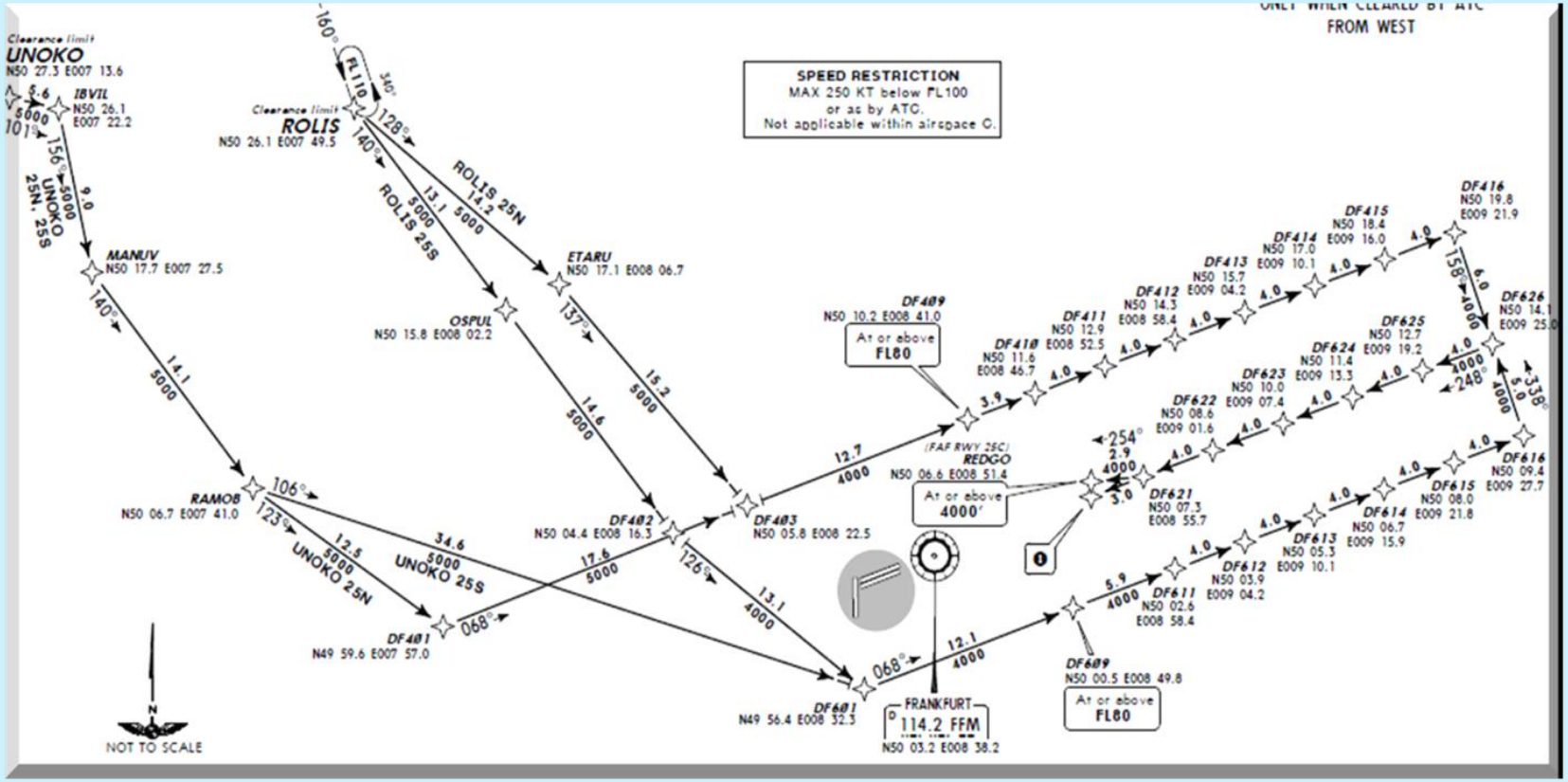
- Specifically, there may be a need for prior consultation with navigation database specialists (Data-house).



CDO: Closed Path Coding

Database Coding:

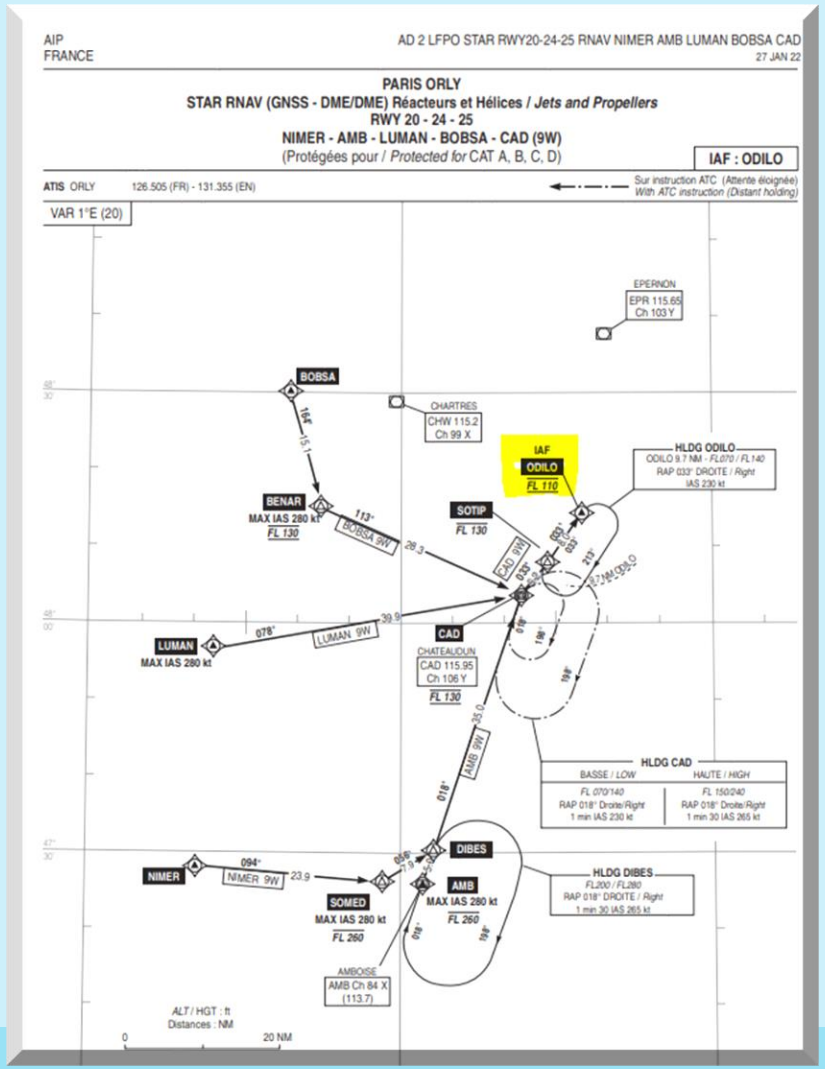
- Use TF legs.
- Fly-By waypoints.
- RF leg is encouraged (fleet capable).
- Link STAR to IAP: Fly-By waypoint.
- If CDO is made of STAR + Initial + Intermediate to FAF is one procedure with one & same Database Identifier.
- IAPs are designed for a 3-degree descent path (320ft/NM), with a shallower segment in the Intermediate.

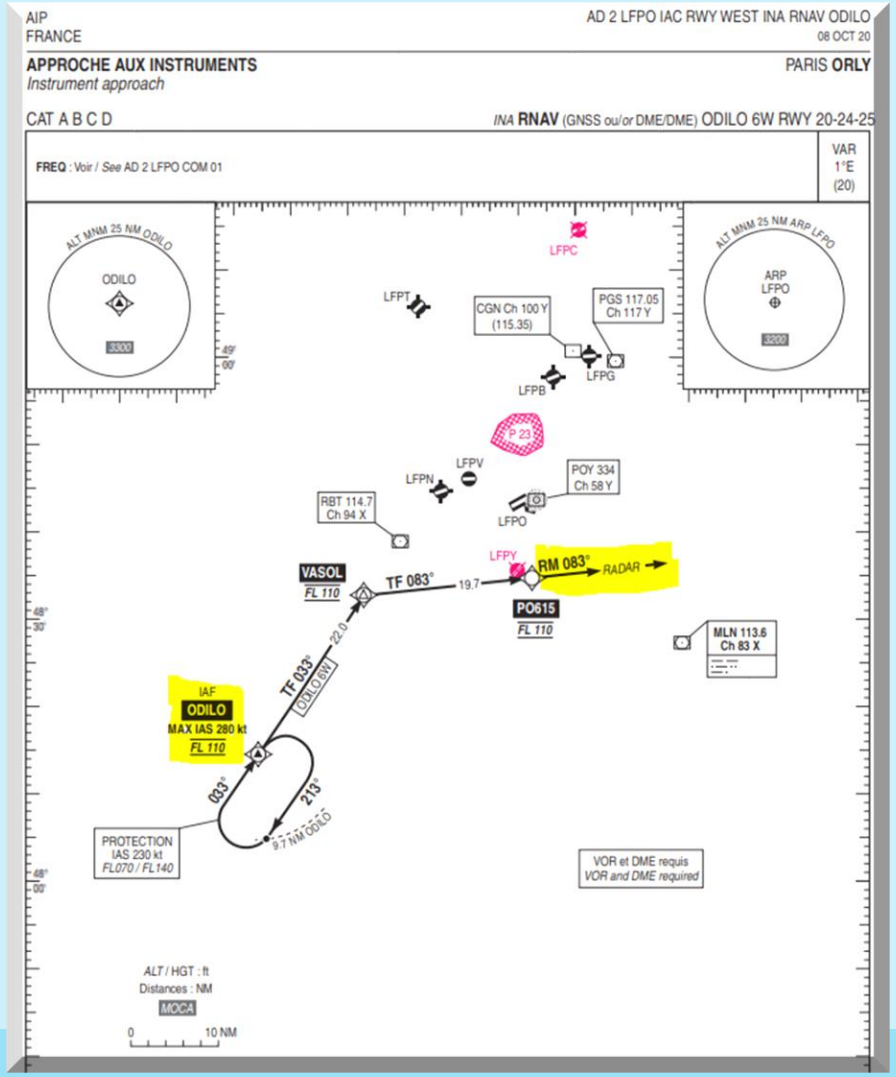


CDO: Open Path Coding

Considerations:

- Sample chart shows CDO made of STAR and Approach Initial terminating with vector-based leg i.e., manual termination.
- Coding translate into FM (defined course 083°, hence more ATC control)



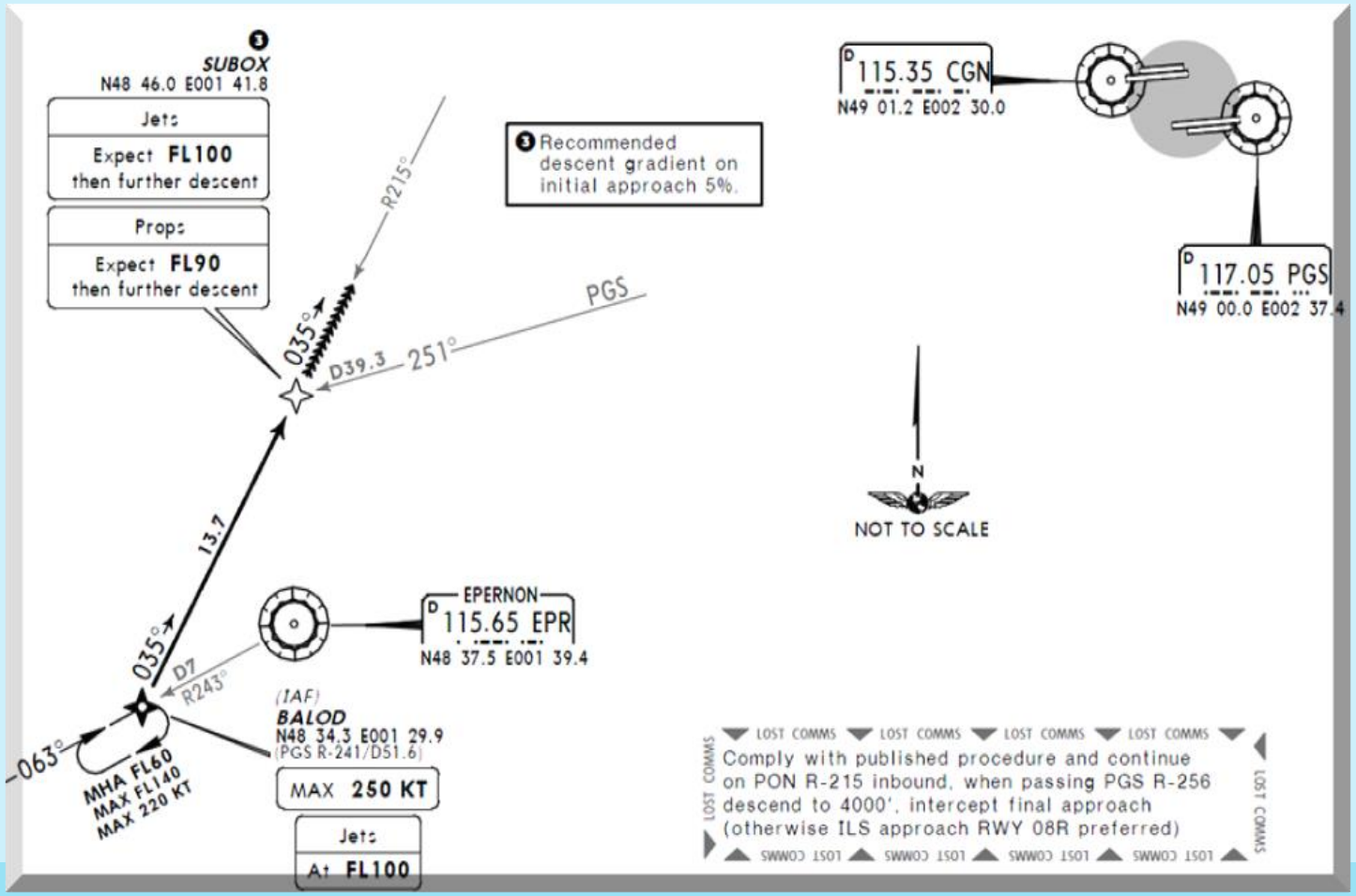


CDO: Open Path Coding

Considerations:

- VM leg (heading)
- More flexibility for ATC due to Heading (wind compensation)
- VNAV Descent gradient

Sample Open-Vectored CDO

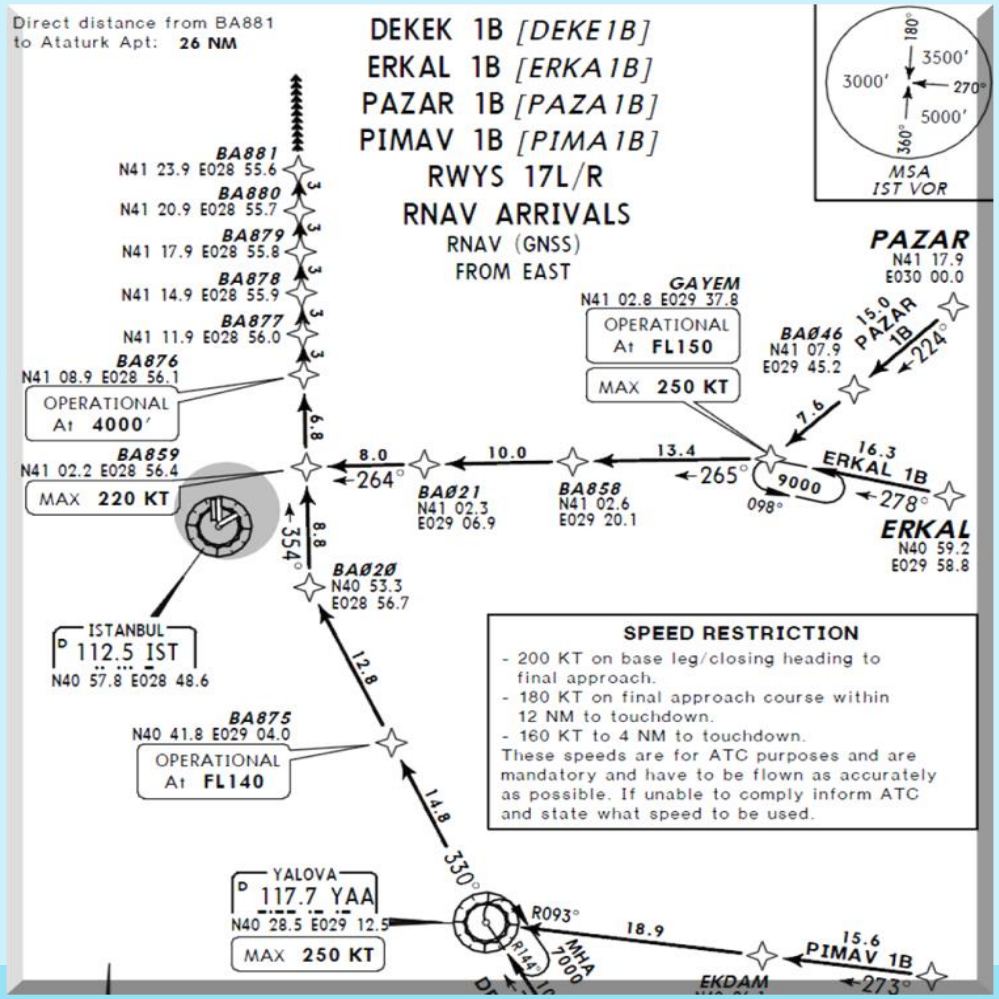


CDO: Open Path Coding

Considerations:

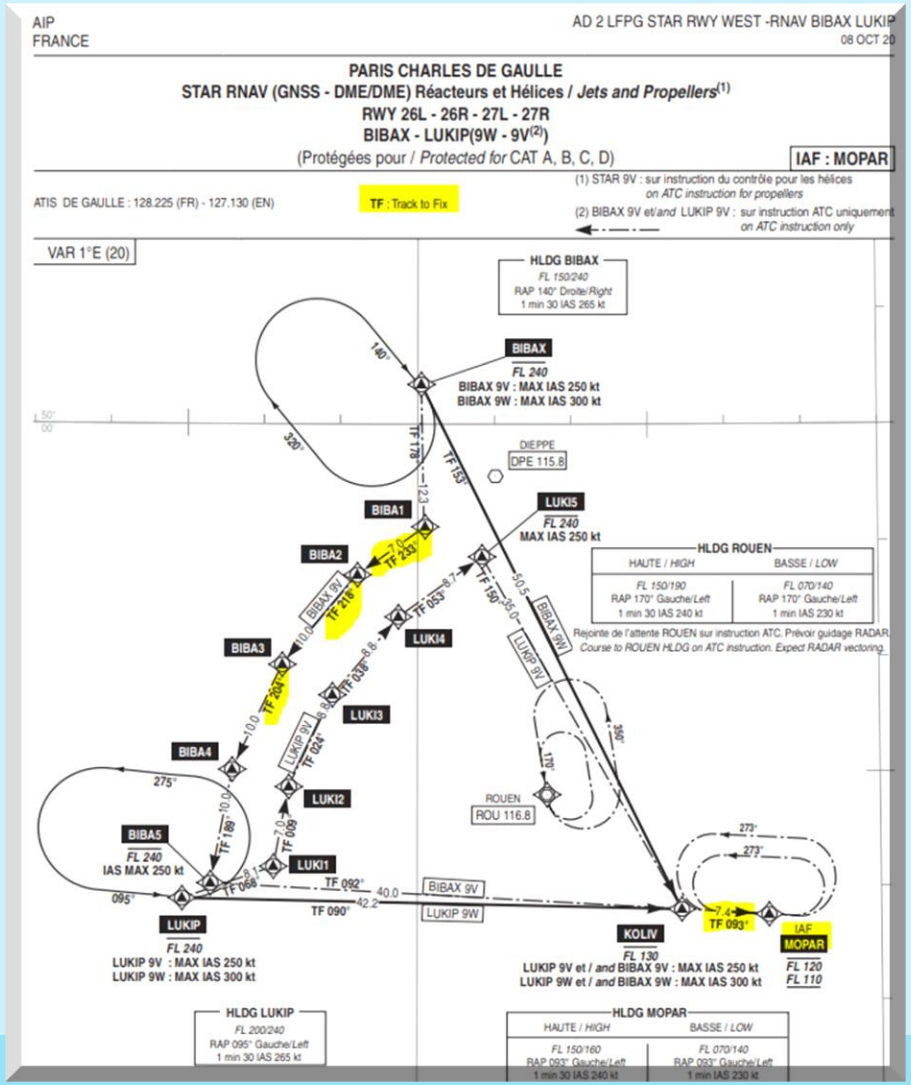
- ‘Trombone’ concept i.e., more Downwind Termination Waypoints (DTW) at Istanbul Apt.
- Coding is a common transition to last waypoint BA881, VM leg contains Apt Ident as Waypoint ID field for reference.
- Arrival (STAR + Approach)

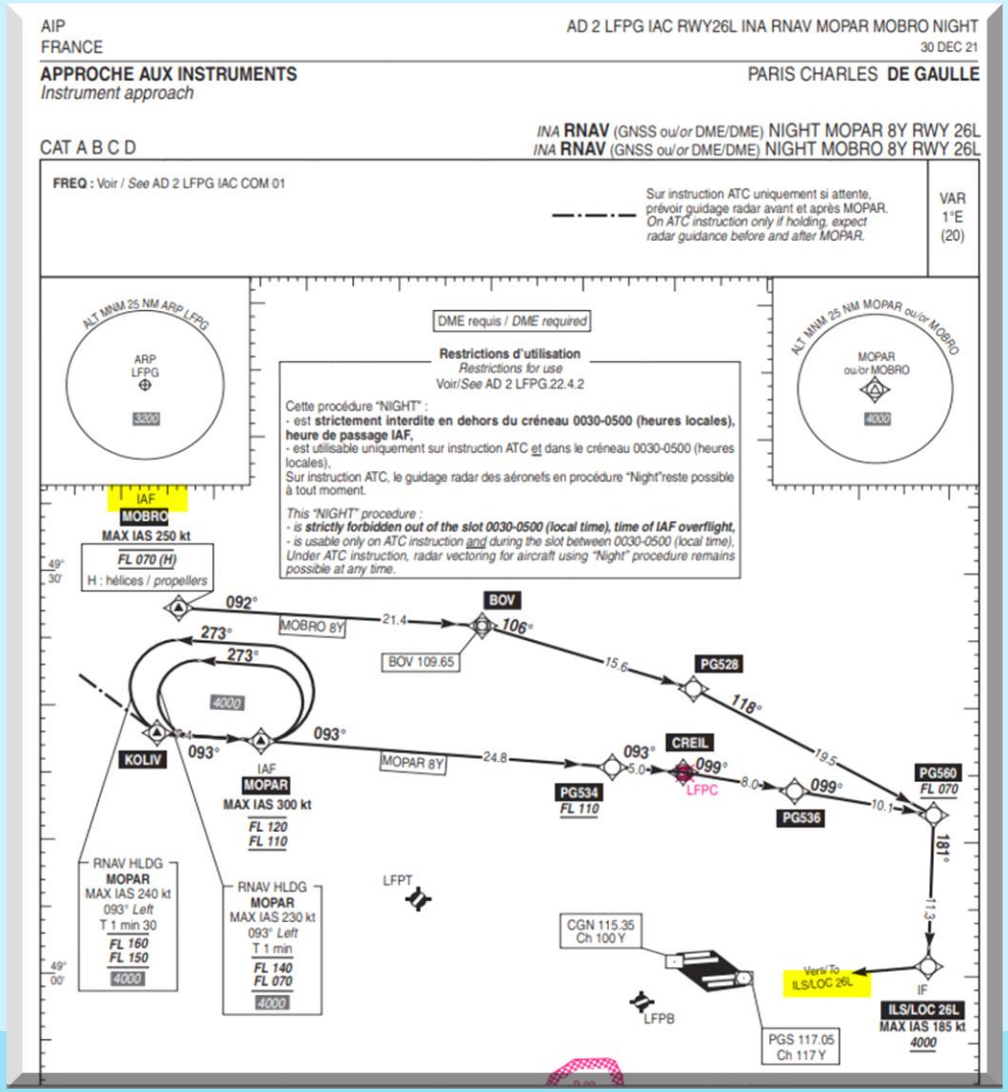
Sample Open-to-Downwind CDO



CDO: Point Merge Coding

CDO made of two (2) complementing STARs e.g., BIBAX9V + MOPRO8Y





CDO Charting (short-considerations)

- **Charting/Publication** element of CDOs is a challenge:
- There are two types of PBN charts may be involved in CDOs:
  a. STAR and,
  b. Approach Chart (IAP)
- May depict procedure alt/levels, any option – ref Table I-3-5-1.
- May depict speed constraints, any option – refer ARINC 424 table field 5.261.

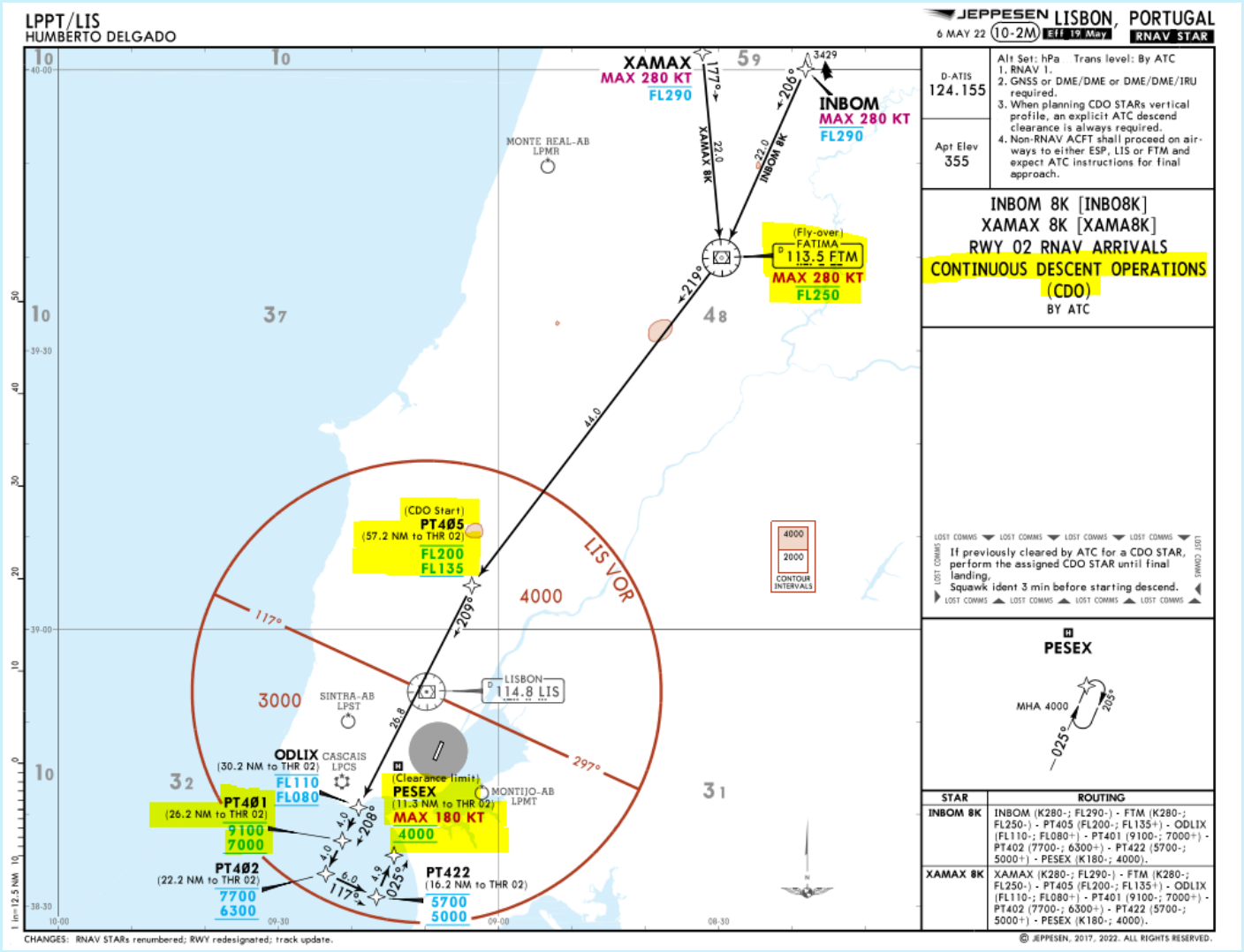
Table I-3-5-1. **Charted procedure altitudes/flight levels**
(Applicable as of 4 November 2021)

Altitude/Flight level "Window"	17 000 FL220 10 000 10 000
"At or above" altitude/flight level	7 000 FL060
"At or below" altitude/flight level	5 000 FL050
"At" altitude/flight level	3 000 FL030
"Recommended" altitude/flight level	5 000 FL050
"Expected" altitude/flight level	Expect 5 000 Expect FL050

Field Content Value	Description
@ (blank)	Mandatory Speed, Cross Fix AT speed specified in Speed Limit
+ (plus)	Minimum Speed, Cross Fix AT or ABOVE speed specified in Speed Limit
- (minus)	Maximum Speed, Cross Fix AT or BELOW speed specified in Speed Limit

CDO Charting (short-considerations)

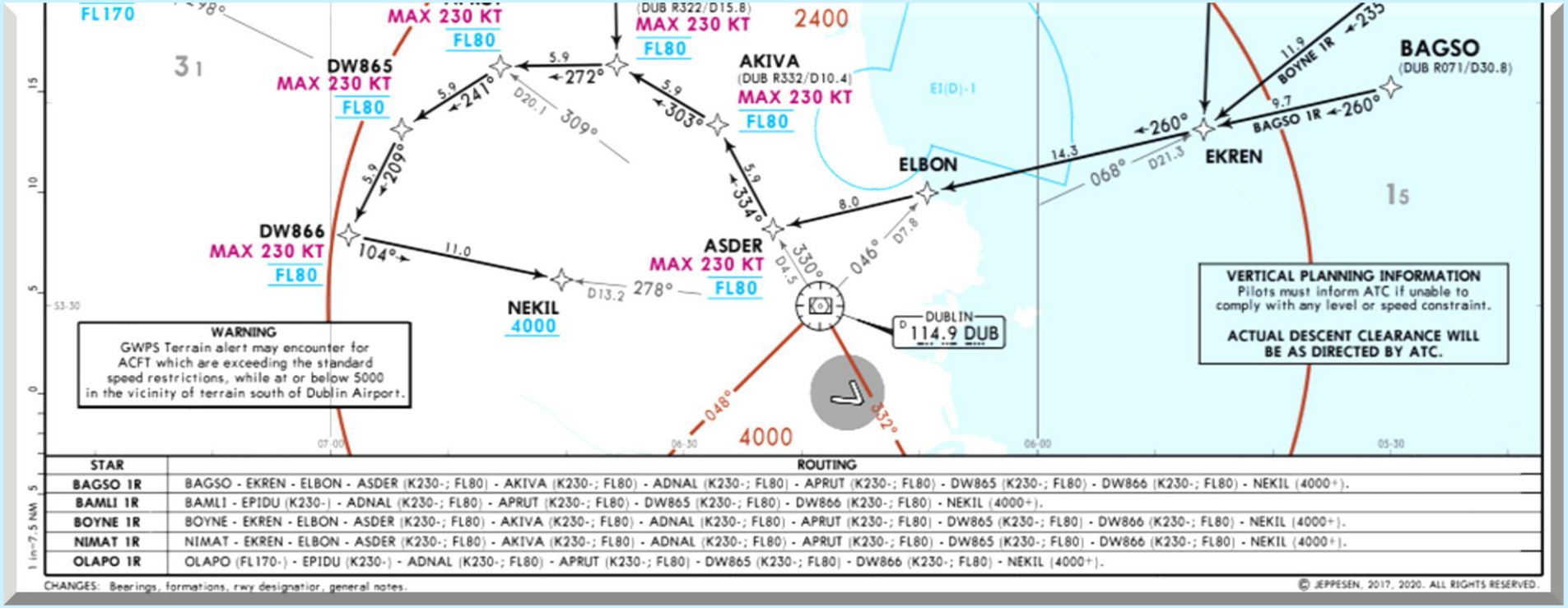
- **Charting/Publication** procedure elements (altitudes, speeds)
- CDO technique applicable (start to clearance limit) should be depicted.
- CDO may be indicated (appropriate text or by procedure designation)



- Application of **CDO** is a cross coverage of enroute and terminal operations i.e., STAR that may continue with Approach transition (3-phases).
- Therefore, **Charting/Publication** is the key element to help in "orientation" for data-house/coding and end-user (pilots, ATCOs)

Issues:

- **IAPs:** Vertical profile.
- **STARs:** Abbreviated text or tabular description
- All Procedure IDs uploaded into FMS (correct selection should be "guided" by charts, especially by main airports)



STAR	ROUTING
BAGSO 1R	BAGSO - EKREN - ELBON - ASDER (K230-; FL80) - AKIVA (K230-; FL80) - ADNAL (K230-; FL80) - APRUT (K230-; FL80) - DW865 (K230-; FL80) - DW866 (K230-; FL80) - NEKIL (4000+).
BAMLI 1R	BAMLI - EPIDU (K230-) - ADNAL (K230-; FL80) - APRUT (K230-; FL80) - DW865 (K230-; FL80) - DW866 (K230-; FL80) - NEKIL (4000+).
BOYNE 1R	BOYNE - EKREN - ELBON - ASDER (K230-; FL80) - AKIVA (K230-; FL80) - ADNAL (K230-; FL80) - APRUT (K230-; FL80) - DW865 (K230-; FL80) - DW866 (K230-; FL80) - NEKIL (4000+).
NIMAT 1R	NIMAT - EKREN - ELBON - ASDER (K230-; FL80) - AKIVA (K230-; FL80) - ADNAL (K230-; FL80) - APRUT (K230-; FL80) - DW865 (K230-; FL80) - DW866 (K230-; FL80) - NEKIL (4000+).
OLAPO 1R	OLAPO (FL170-) - EPIDU (K230-) - ADNAL (K230-; FL80) - APRUT (K230-; FL80) - DW865 (K230-; FL80) - DW866 (K230-; FL80) - NEKIL (4000+).

CHANGES: Bearings, formations, rwy designator, general notes.

CDO: Point Merge Publication

As any terminal airspace procedure, Point Merge procedures are expected to be published in the form of a PBN STAR or approach transition, and detailed in an official aeronautical publication (AIP) including tabular description.

BIBAX 9V	(Utilisable uniquement sur instruction du contrôle pour les réacteurs et les hélices / *Use on ATC instruction only for jets and propellers*)											
	IF	BIBAX							FL240	250		RNAV 1
	TF	BIBA1		178	179.1	12.3						RNAV 1
	TF	BIBA2		233	233.7	7.0						RNAV 1
	TF	BIBA3		218	219.2	10.0						RNAV 1
	TF	BIBA4		204	204.7	10.0						RNAV 1
	TF	BIBA5		189	190.3	10.0	L					RNAV 1
	TF	KOLIV		092	093.0	40.0			FL130			RNAV 1
	TF	MOPAR		093	093.8	7.4		FL110	FL120			RNAV 1

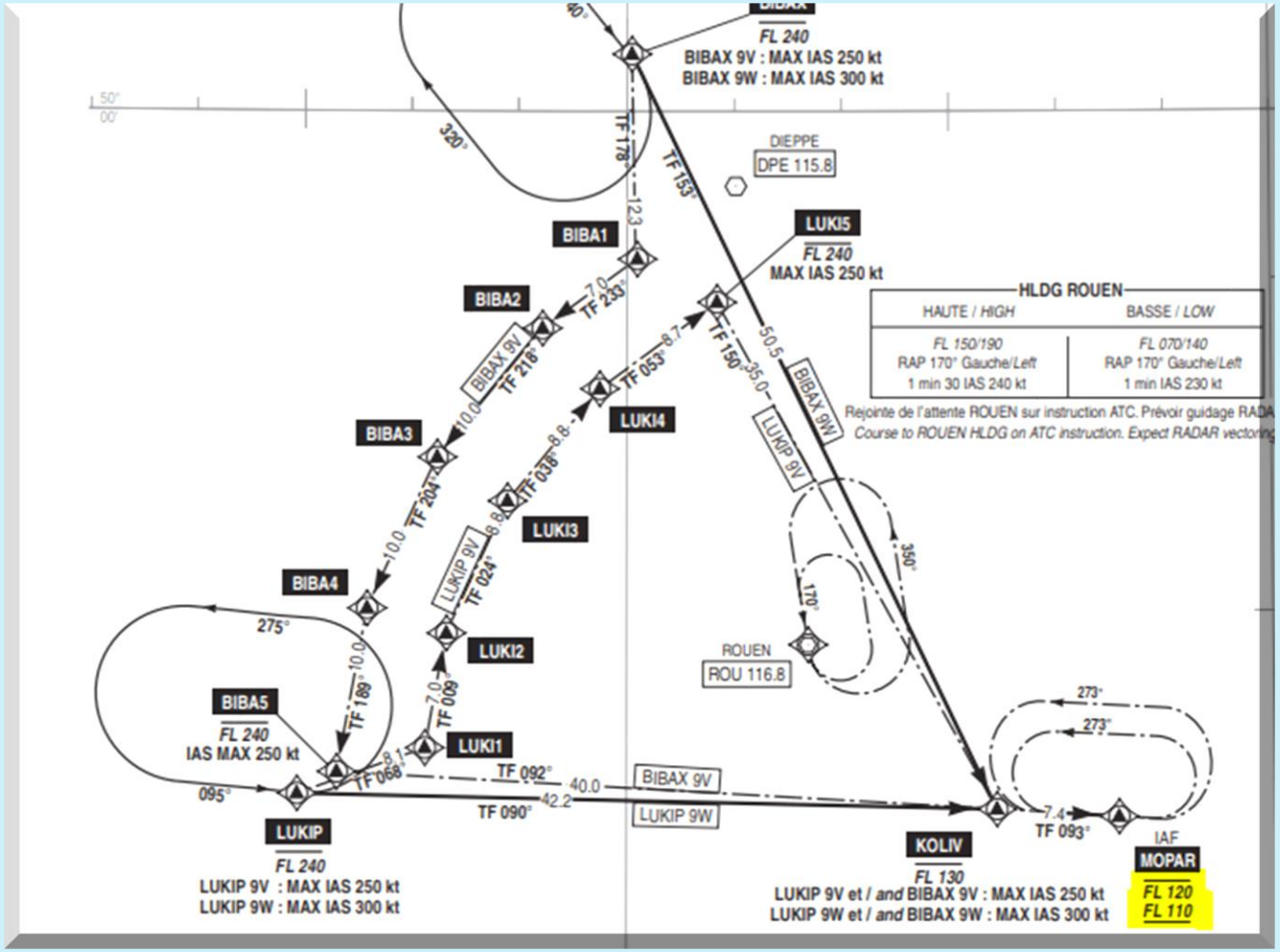
INA NIGHT MOBRO 8Y	IF	MOBRO	-	-	-	-	-	FL070 (H) (1)	FL070 (H) (1)	250	-	RNAV 1
	TF	BOV	-	092	092.9	21.4	-	-	-	-	-	RNAV 1
	TF	PG528	-	106	107.2	15.6	-	-	-	-	-	RNAV 1
	TF	PG560	-	118	118.8	19.5	-	FL070	-	-	-	RNAV 1
	TF	IF ILS/LOC 26L	-	181	182.3	11.3	-	4000	-	185	-	RNAV 1

FNA ILS CAT I ou/or CAT II et/and CAT III ou/or LOC RWY 26L												
RMK	API / *Missed approach* : RNAV 1 requis / *required*							MAG VAR 2020 1.1°E			REF NAVAID : -	
Leg sequence	Path Terminator	Waypoint Identification	Fly Over	Direction MAG (°)	Direction True (°)	Distance (NM)	Turn direction	MNM Altitude (FL or AMSL ft)	MAX Altitude (FL or AMSL ft)	MAX IAS (kt)	Vertical angle (°) / TCH (m)	NAV Spec
APCH	See chart FNA ILS CAT I ou/or CAT II et/and CAT III ou/or LOC RWY 26L											
	-	PG442	-	-	-	-	-	-	-	-	-	RNAV1
	TF	PG433	-	315	316.4	3.3	-	4000	4000	-	-	RNAV1

CDO: Point Merge Publication

Where noise considerations prevail, the merge point itself shall be positioned at a sufficiently high FL/altitude (typically at, or higher than, 6500ft above ground level).

For this purpose, a vertical restriction may be published at the merge point e.g., in the form of an FL/altitude window.



Continuous Climb Operations (CCO)

- **CCO** is not a Flight Procedure Design (FPD) criteria; it's an aircraft operating technique made possible by suitable airspace and instrument procedure design and proper ATC clearances enabling the execution of an optimized flight profile.

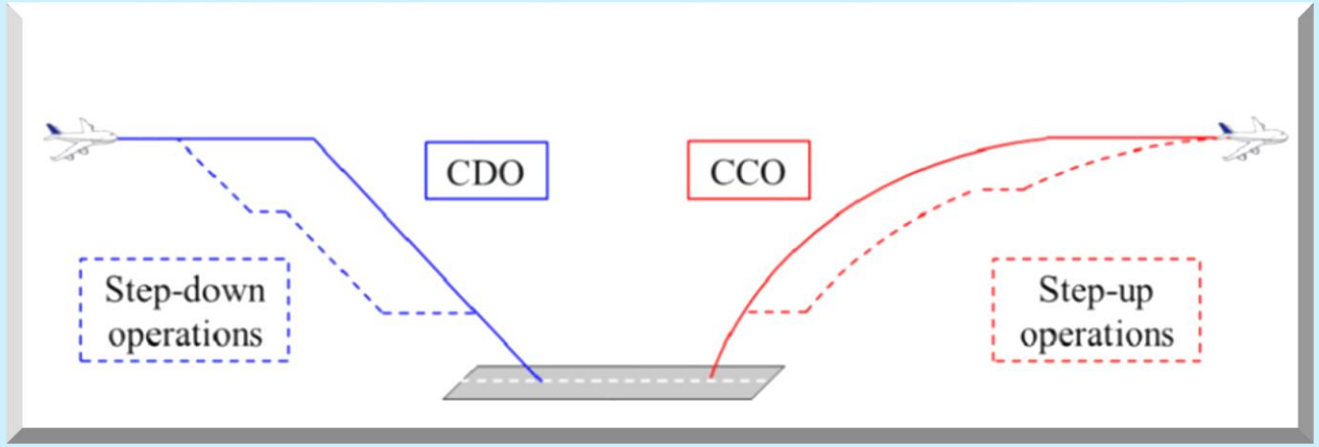
- There is a difference in design philosophy between CCO and CDO:

  - **CCO** design should consider that tactical changes to the flight path, initiated by ATC, may be desirable.
  - **CDO** aircraft should be left on the designed route and not given a vector "shortcut" because a CDO aircraft is already descending at flight idle power preventing unstable approach due to steeper angle.
  - In contrast, ATC tactical "shortcutting" of a **CCO** departure based on aircraft climb performance is desirable because it saves both flight mileage and time.
  - Therefore, the potential for tactical "shortcutting" should be considered in any **CCO** design.

CCO Design Consideration

- CCO should be codified as part of a SID so that both flight crews and controllers have a consistent procedure to refer to.

- Ideally, it is desirable that CCO will provide:
  - Shortest track distance to be flown.
  - A path to the destination/airspace exit point that supports the most optimized vertical profile.
  - An unrestricted climb to cruise flight level with no speed restrictions.



- Factors such as other traffic flows, terrain, restricted airspace, aircraft performance, and noise abatement will all serve to modify the design of the (theoretical) most efficient path.

- The instrument procedure design must balance all these factors to determine an optimal design.

- Departure procedures optimally designed for CCO should be according to the guidelines as set out in PANS-OPS (Doc 8168) and for additional information in CCO Manual (Doc. 9993).

CCO Design Options

- The following depictions provide some basic CCO design examples. Each airspace situation must be evaluated on its own.

  Basic CCO: It allows for unrestricted climb rates for all aircraft.

  It requires that a significant amount of vertical airspace be set aside to protect the climb (between 3.3% and 16%).

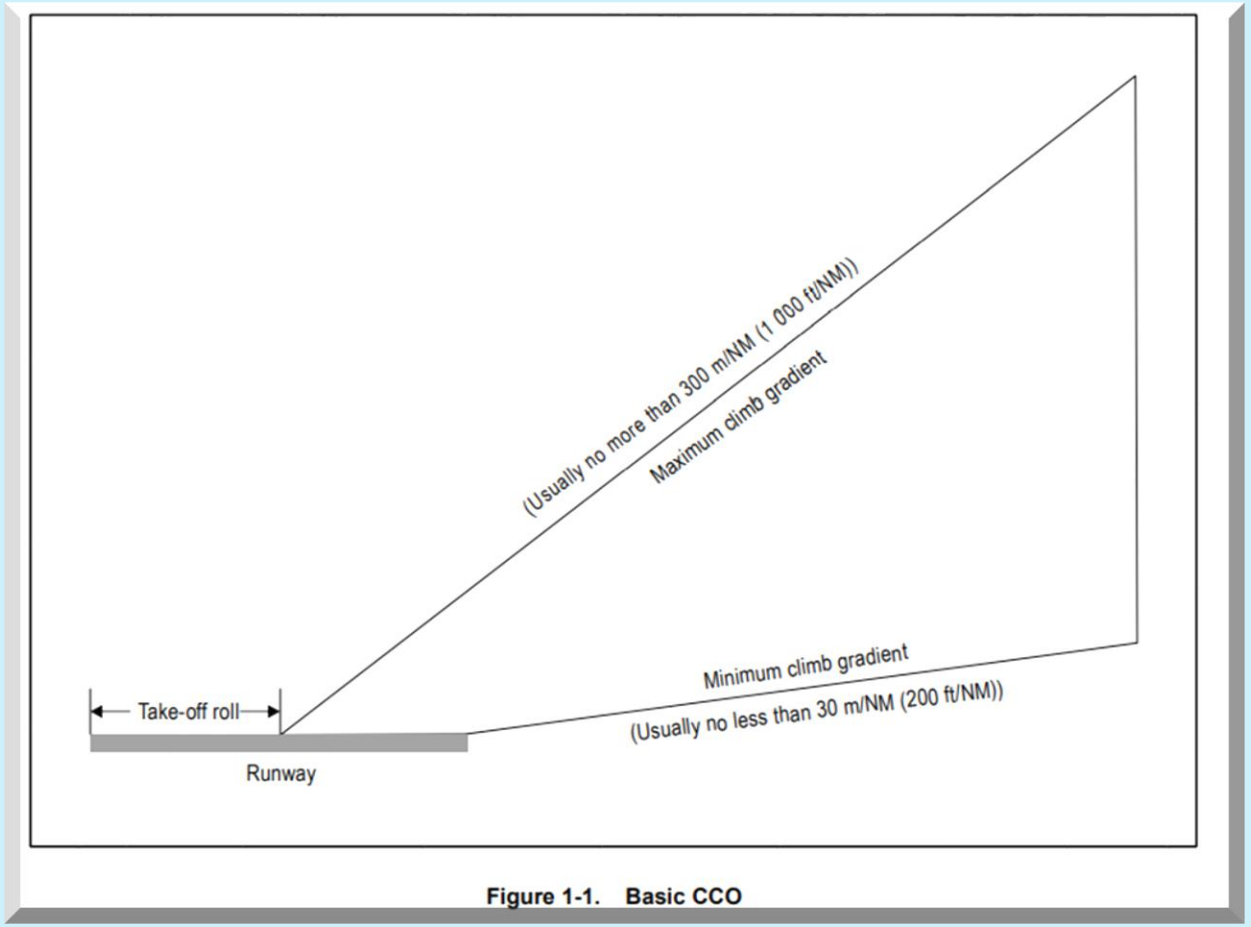


Figure 1-1. Basic CCO

CCO Design Options

Enhanced CCO design with multiple climb gradients:

- Due to terrain or airspace limitations, it may be necessary to increase the climb gradient for portion or all (entire) SID.
- This can enable design of a shorter route length for those aircraft that are capable of higher climb rates.
- In such cases, one solution is to design two SIDs that both proceed to the same exit point; one for better performing aircraft and one for aircraft that require extra distance to gain altitude.
- Another alternative is to develop different SIDs to different exit points based on aircraft performance.

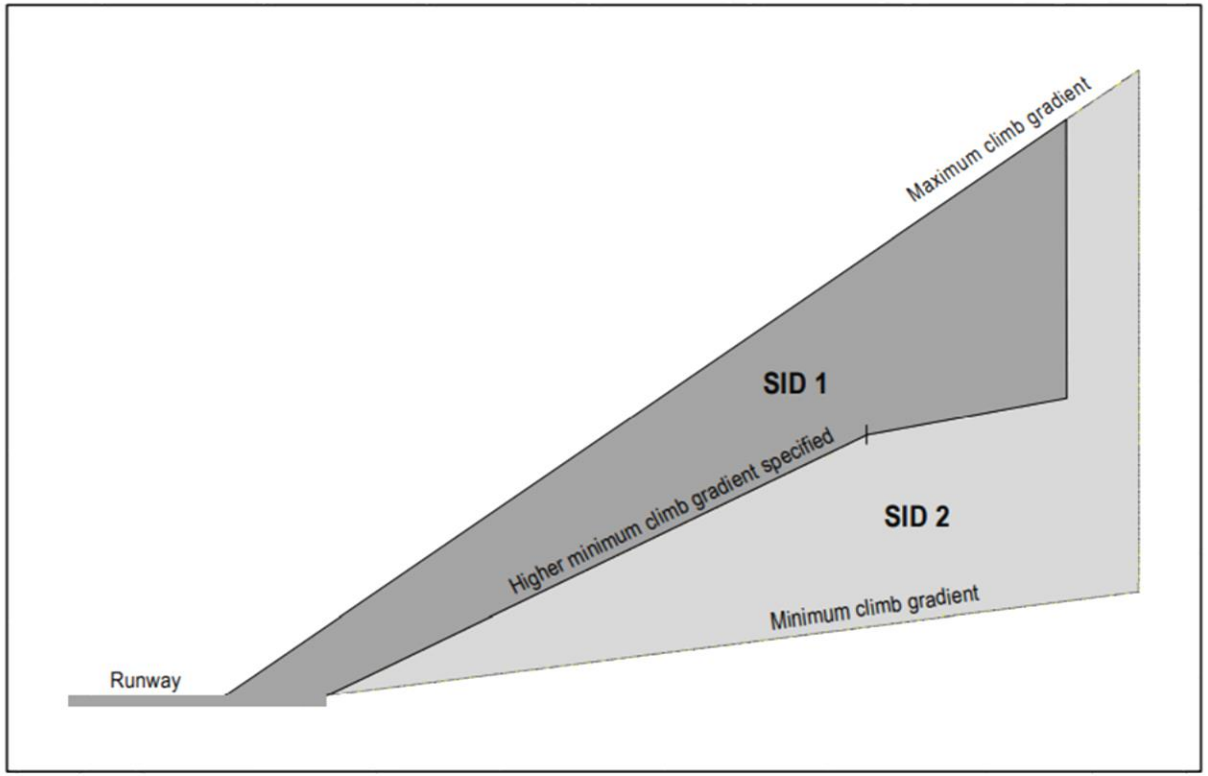


Figure 1-2. Multiple CCO SID design — profile view

CCO Design Considerations

- A design of CCO-based procedures and any airspace changes that may be required needs to be a collaborative process involving the stakeholders (ANSP, aircraft operators, airport operators, the aviation regulator, and environmental entities), as necessary.

- Expertise in FMS performance and flight procedure coding conventions (PANS-OPS (Doc 8168), Volume II) should be included on the design team as the departure procedures will be stored in a navigation database.

- As with all instrument flight procedures, the design should be standardized and conform to accepted charting and database conventions in order to support the standardization of cockpit procedures.

CCO Coding Considerations

- CCO procedures should use **Track to Fix (TF)** legs. **Direct to Fix (DF)** and **Course to Fix (CF)** legs are also used to a more limited extent and may provide operational flexibility in situations where a TF leg does not meet ops requirements.
- Where the expected fleet has sufficient capability, the use of the **Radius to Fix (RF)** leg will provide a controlled turn performance.
- However, the need for an **RF leg** capability will necessitate that an RNP navigation specification (AR DEP) be applied to the procedure.
- The flight crew has the flexibility to manage the aircraft's speed and rate of climb within the constraints of the procedure.
- For aircraft equipped with FMS and VNAV capabilities, an optimum climb can be planned and executed with a fixed lateral flight path stored in the navigation database.

CCO Charting Considerations

- It is recommended that specific information relating to the CCO be published through established channels i.e., AIS to ensure stakeholder awareness.
- Unless specifically required as a part of the instrument procedure design, there is no need to provide specific level windows or speed restrictions for CCO on charts.
- Any speed and level restrictions should be clearly depicted on the chart.
- Level restrictions should be expressed using level windows (with minimum and maximum levels), or by "*at or above*" or "*at or below*" constraints.

THANK YOU