Presented by

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Aircraft operational performance

Engine Out SID

Introduction to the concept

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Introduction

- Context
  - Regulatory requirements: JAR25, JAR-OPS, FAR25, FAR121
    - Determination of takeoff performance
    - Obstacle clearance
  - Operational requirements: Standard Instrument Departures (SIDs)

Introduction

- Standard Instrument Departures (SIDs)

  - Operational requirement, designed by the airport authorities

  - Major SID constraints are climb capability constraints
    - Climb gradients to fulfil (and corresponding rate of climb)
    - Altitude to achieve at a given point
    - Cutback imposed, minimum speed

  - Purpose of SIDs
    - To ensure obstacle clearance and respect of constraints (buildings, terrain, flights over inhabited areas…)
    - To comply with required minimum altitudes
    - To reduce noise emissions
    - For ATC purposes

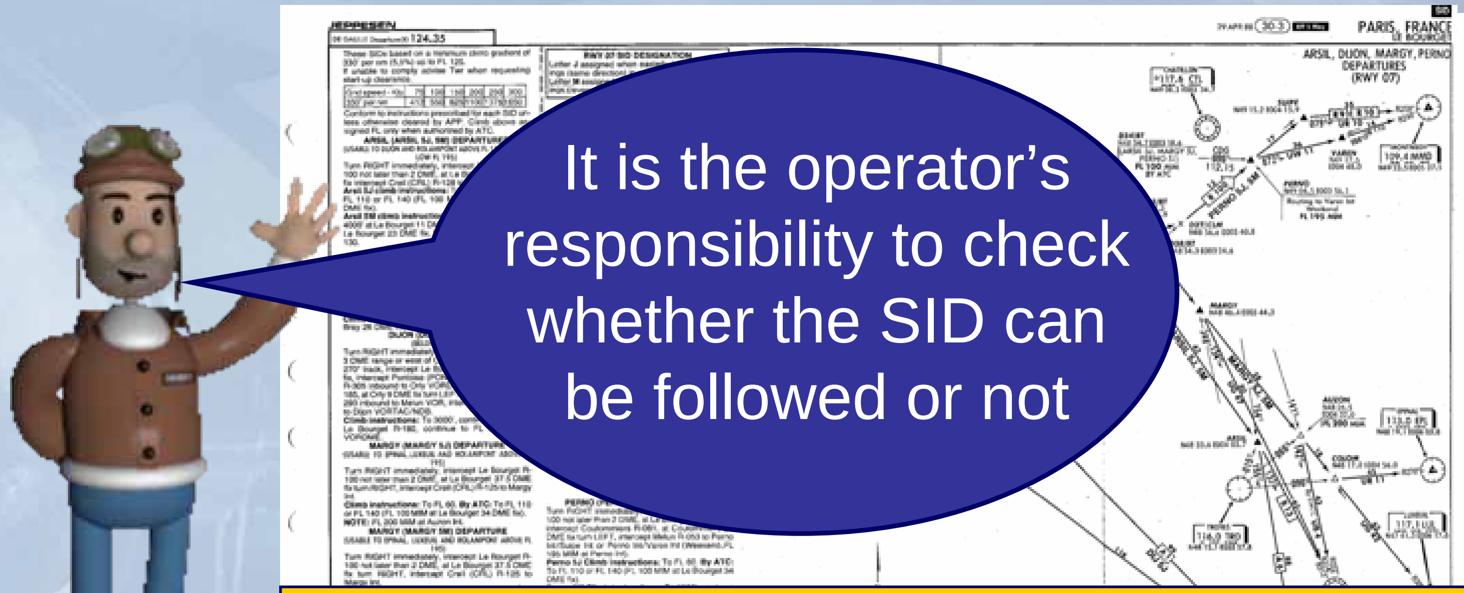
Introduction

- For a given runway, several SIDs may be defined

- The pilot chooses one depending on
  - The airway to use (route to destination)
  - Capability of the aircraft to fulfill all published constraints

Introduction

- Standard Instrument Departures (SIDs)
  - Do not consider the one engine out case unless specific notification



A SID cannot be used
if the constraints are not fulfilled

Introduction

- Standard Instrument Departures (SIDs)
  - Most of the time, the regulatory takeoff performance allows to follow the SID
  - High climb gradients may be required in mountainous area
    - Can be easily achieved with all engines running
    - Cannot be fulfilled in case of engine failure at V1

Contents

Contents

Standard takeoff analysis

- Before dispatching any aircraft from an airfield,
  - Determine the takeoff performance limited weight.
  - In case of critical airports, conduct a detailed takeoff analysis following several steps:
    - Identification of runway data
    - Computation of takeoff charts
    - Verification of the validity of the takeoff analysis
      - Obstacle clearance until the aircraft reaches a safe altitude
      - SID constraints

Standard takeoff analysis

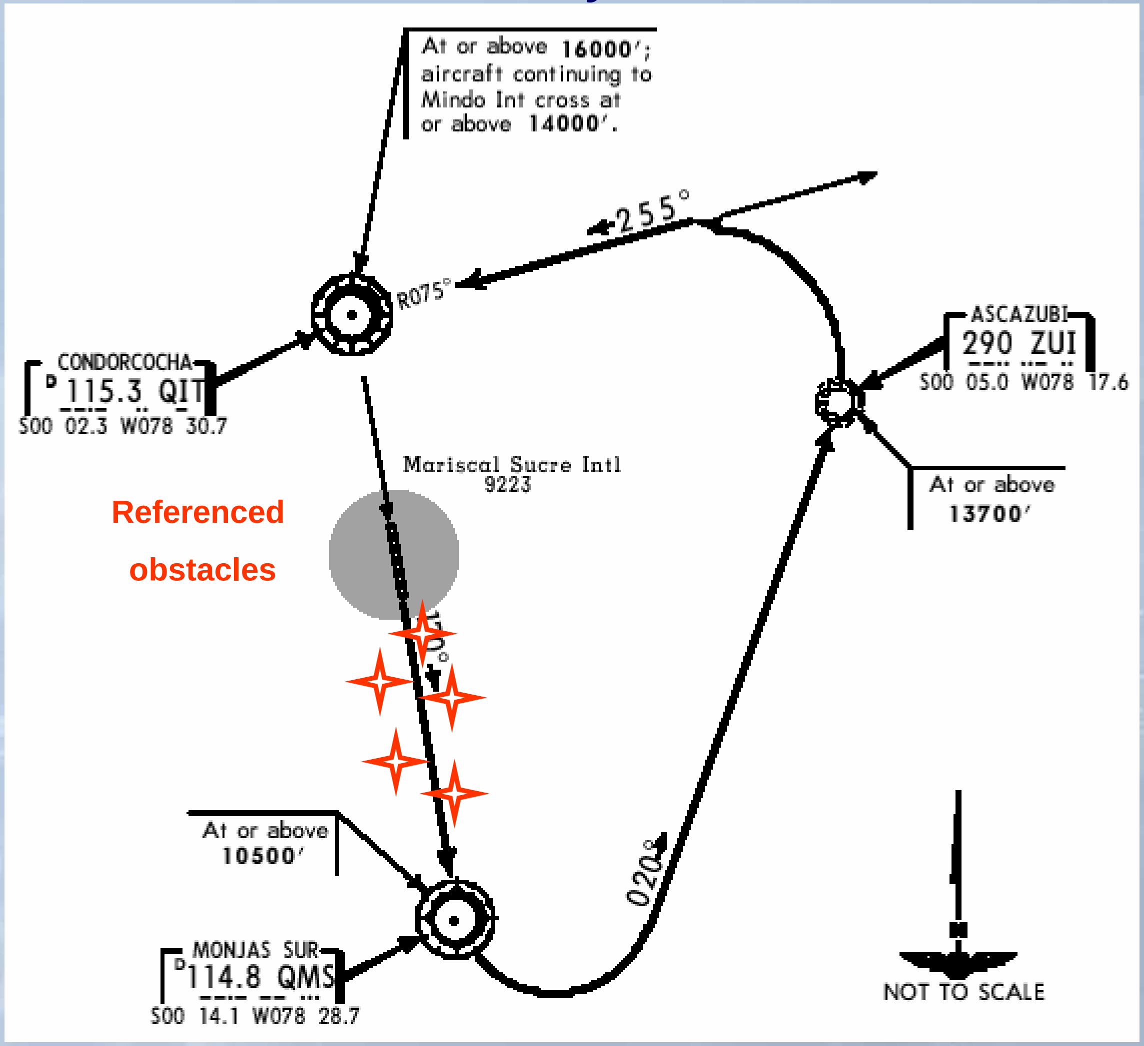
- Identification of runway data

  - Airports and airport data providers publish various documents useful for takeoff analysis
    - AIP
    - ICAO Type A, B and C charts
    - Topographical maps
    - Airport data in digital format

  - Using this data allows to identify relevant obstacles for takeoff performance analysis

Standard takeoff analysis

- Identification of runway data



Standard takeoff analysis

- Computation of takeoff charts
  - Takeoff chart is computed considering published obstacles to obtain a rough idea of TOW and speeds

A340313 - JAA	CFM56-5C4 engines	KATHMANDU	02	19.0.0 11-MAR-02 AA313C02 V 9
Wind 0 KT QNH 1013.25 HPA Air cond. Off Anti-icing Off		Elevation 4313 FT TORA 3050 M Isa temp 6 C TODA 3290 M rwy slope 0.74% ASDA 3050 M	6 obstacles	DRY TOGA

OAT C	CONF 1+F	CONF 2	CONF 3
23	230.6 3/4 133/45/53	228.9 4/4 133/44/52	226.2 4/4 132/43/50

LABEL FOR INFLUENCE DW (1000 KG) DTFLEX DV1-DVR-DV2 (KT) (TVMC OAT C) DW (1000 KG) DTFLEX DV1-DVR-DV2 (KT)	MTOW(1000 KG) codes V1min/VR/V2 (kt)	VMC LIMITATION	Tref (OAT) = 21 C Tmax (OAT) = 46 C	Min acc height 587 FT Max acc height 4565 FT	Min QNH alt 4900 FT Max QNH alt 8878 FT
	LIMITATION CODES: 1=1st segment 2=2nd segment 3=runway length 4=obstacles 5=tire speed 6=brake energy 7=max weight 8=final take-off 9=VMU			Min V1/VR/V2 = 122/24/31 CHECK VMU LIMITATION Correct. V1/VR/V2 = 0.2 KT/1000 KG	

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Standard takeoff analysis

- Verification of the validity of the takeoff analys
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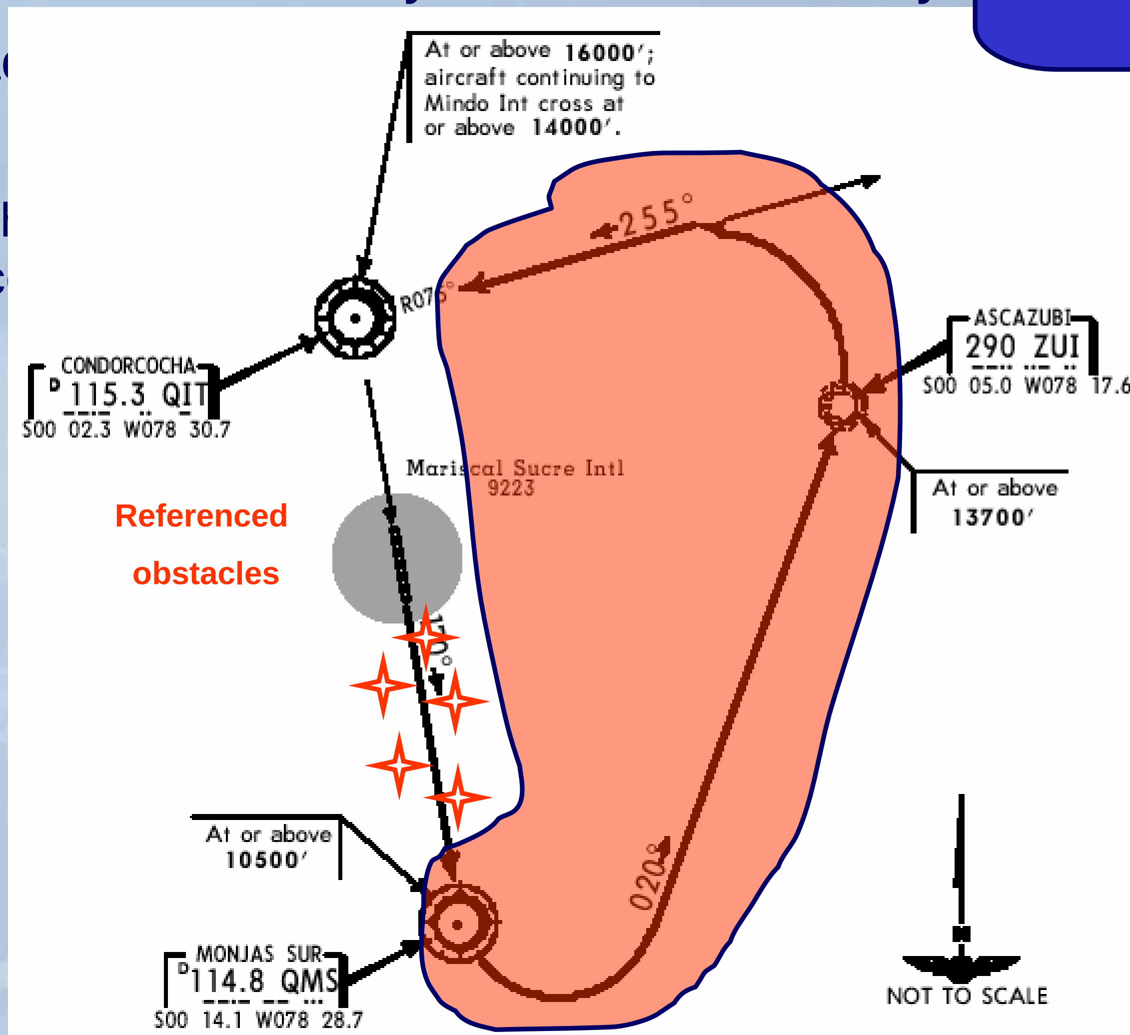

What about this area?

Standard takeoff analysis

- Verification of the validity of the takeoff analysis
  - No obstacle along the remote and curved part of the SID has been directly accounted for
  - Current regulatory performance accounts for close referenced obstacles only

THUS...

I MUST CHECK WHETHER MY AIRCRAFT CAN FOLLOW THE SID

with all engines

with one engine out

AND CLEAR THE OBSTACLES WITH THE REQUIRED MARGIN

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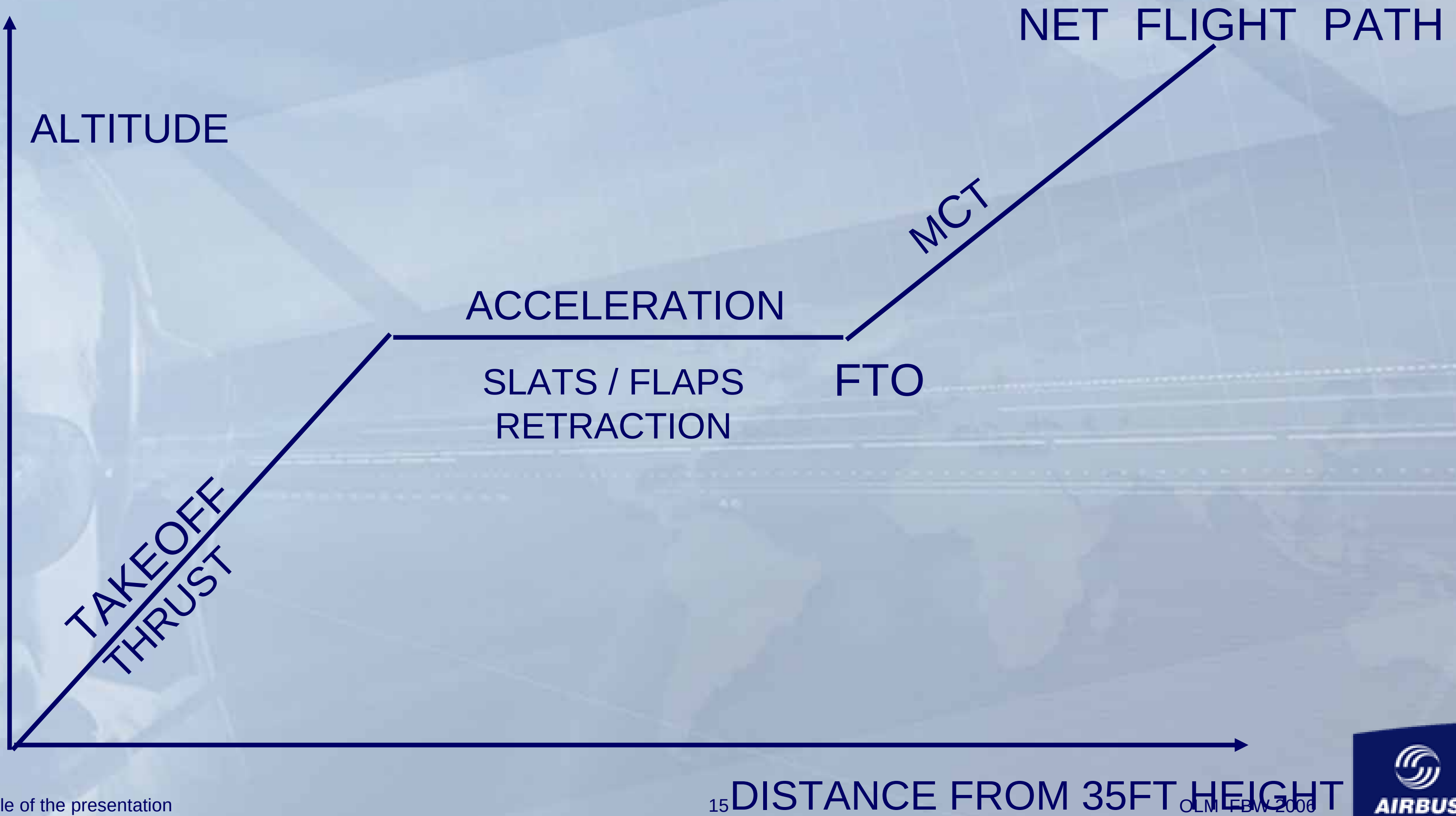
Standard takeoff analysis

- Verification of the validity of the takeoff analysis
  - The net flight path obtained from the takeoff analysis must clear the remote obstacles with the required margin



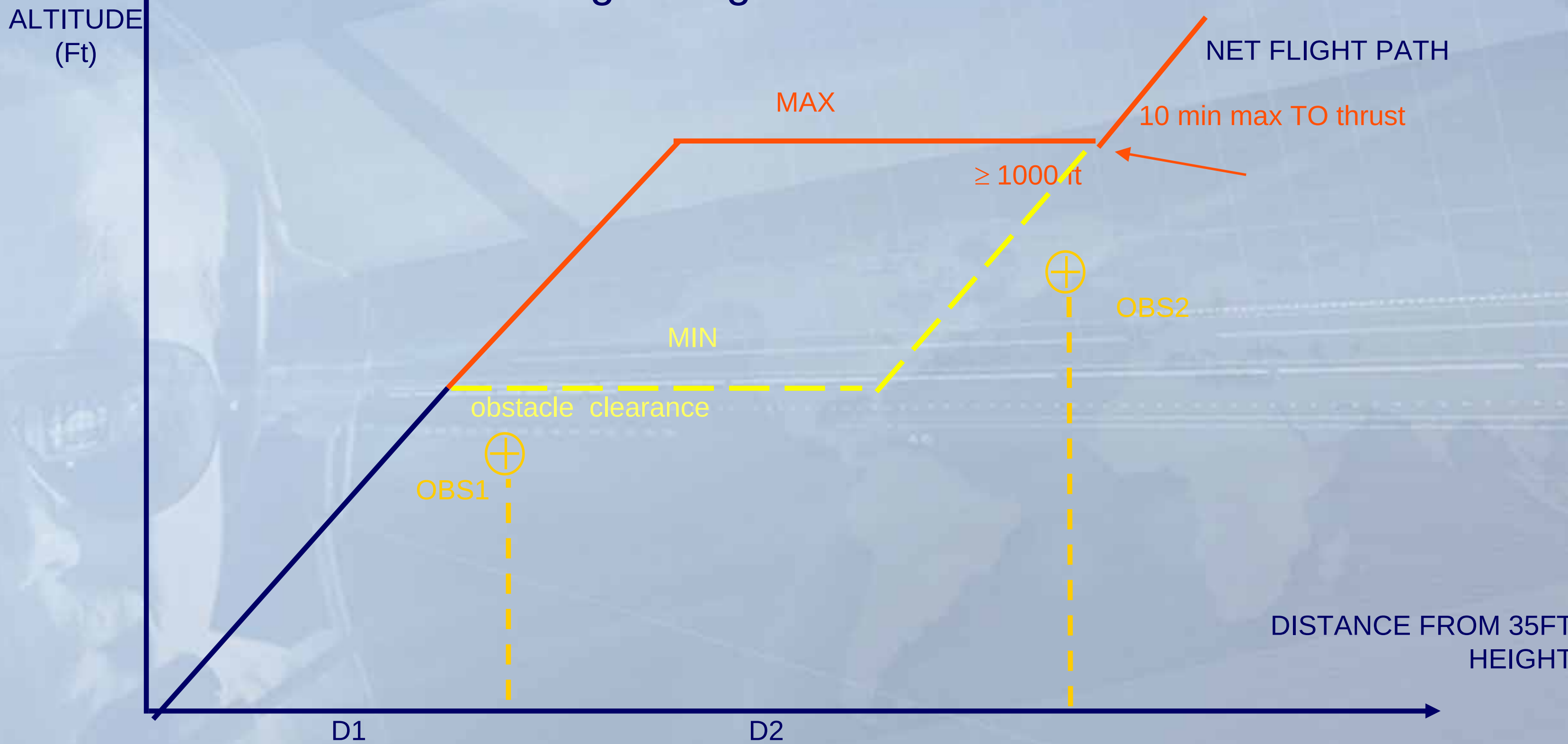
Standard takeoff analysis

- Verification of the validity of the takeoff analysis
  - The net flight path obtained from the takeoff analysis must clear the remote obstacles with the required margin

- **D1** is the necessary distance for OBS1 clearance ➡ **EOSID**

Standard takeoff analysis

- Verification of the validity of the takeoff analysis
  - The net flight path obtained from the takeoff analysis must clear the remote obstacles with the required margin
    - – Acceleration height can be optimised if necessary between minimum and maximum height as given on the takeoff chart



Standard takeoff analysis

- Verification of the validity of the takeoff analysis
  - The net flight path obtained from the takeoff analysis must clear the remote obstacles with the required margin
  - The gross flight path all engines operating must satisfy the normal SID constraints
  - The gross flight path one engine out should satisfy the normal SID constraints

If one of the above condition is not met, consider reducing the takeoff weight for the takeoff analysis

Standard takeoff analysis

- Is an engine failure procedure required?
  - No straightforward answer, without initial takeoff analysis
  - If the limiting obstacles are close to the end of the runway, is it possible to have a different path to avoid them?

Is the obtained payload satisfactory for operations or not?

Contents

Engine Out SID design strategy

- What is an EOSID?
  - Departure procedure diverging from standard departure, to be flown in case of engine failure.
  - Produced by the operator and sometimes validated by local authorities.
  - Special pilot briefing and simulator training to be considered.
  - In some cases, EOSID are published by airports

Engine Out SID design strategy

- When is the use of an EOSID necessary?

JAR-OPS 1 Subpart G

JAR-OPS 1 Subpart G — SECTION 1

JAR-OPS 1.495(c) (continued)

wingspan but not less than 50 ft above the elevation of the end of the take-off run available. Thereafter, up to a height of 400 ft it is assumed that the aeroplane is banked by no more than 15°.

1.495(d)(1) & (e)(1); or

(2) 600 m, for flights under all other conditions.

(e) When showing compliance with sub-paragraph (a) above for those cases where the intended flight path does require track changes of more than 15°, an operator need not consider those obstacles which have a lateral distance greater than:

(1) 600 m, if the pilot is able to maintain the required navigational accuracy through the obstacle accountability area (See AMC OPS 1.495 (d)(1) & (e)(1)); or

(2) 900 m for flights under all other conditions.

(f) An operator shall establish contingency procedures to satisfy the requirements of JAR–OPS 1.495 and to provide a safe route, avoiding obstacles, to enable the aeroplane to either comply with the en-route requirements of JAR–OPS 1.500, or land at either the aerodrome of departure or at a take-off alternate aerodrome (See IEM OPS 1.495(f)).

[Ch. 1, 01.03.98]

JAR-OPS 1.500 En-route – One Engine Inoperative
(See AMC OPS 1.500)

winds on the flight path;

(3) Fuel jettisoning is permitted to an extent consistent with reaching the aerodrome with the required fuel reserves, if a safe procedure is used; and

(4) The aerodrome where the aeroplane is assumed to land after engine failure must meet the following criteria:

(i) The performance requirements at the expected landing mass are met; and

(ii) Weather reports or forecasts, or any combination thereof, and field condition reports indicate that a safe landing can be accomplished at the estimated time of landing.

(d) When showing compliance with JAR–OPS 1.500, an operator must increase the width margins of subparagraphs (b) and (c) above to 18·5 km (10 nm) if the navigational accuracy does not meet the 95% containment level.

01.12.01 — 1-G-2 — Amendment 3

> (f) An operator shall establish contingency procedures to satisfy the requirements of JAR–OPS 1.495 and to provide a safe route, avoiding obstacles, to enable the aeroplane to either comply with the en-route requirements of JAR–OPS 1.500, or land at either the aerodrome of departure or at a take-off alternate aerodrome (See IEM OPS 1.495(f)).

Engine Out SID design strategy

- When is the use of an EOSID necessary?
  - When the published SID can't be flown in One Engine Out conditions.
  - When the MTOW limited by a SID with One Engine Out is not commercially satisfactory to the operator.
  - Whenever required by the local authorities.

Engine Out SID design strategy

- Purpose of an engine failure procedure
  - To avoid weight reduction when takeoff performance is limited by:
    - an obstacle
    - a climb constraint
  - To establish a new flight path
    - To avoid the limiting obstacle(s)
    - To provide more distance to climb

Engine Out SID design strategy

- EOSID to be designed considering engine failure 1s before V1
  - Most critical case

- A decision point must be defined on the take-off path
  - An engine failure beyond this point will not prevent following the SID

Engine Out SID design strategy

- Recipe for an EOSID
  - 1. Computation of takeoff charts
  - 2. Determination of the net takeoff flight path
  - 3. Determination of a pattern
  - 4. Verification of the obstacle clearance
  - 5. Determination of a decision point
  - 6. Procedure writing

Engine Out SID design strategy

- Recipe for an EOSID
  - 1. Computation of takeoff charts
  - 2. Determination of the net takeoff flight path
  - 3. Determination of a pattern
  - 4. Verification of the obstacle clearance
  - 5. Determination of a decision point
  - 6. Procedure writing

Decision Point

- According to JAR-OPS 1…

IEM OPS 1.495(f)
Engine failure procedures
See JAR-OPS 1.495(f)

If compliance with JAR-OPS 1.495(f) is based on an engine failure route that differs from the all engine departure route or SID normal departure, a "deviation point" can be identified where the engine failure route deviates from the normal departure route. Adequate obstacle clearance along the normal departure with failure of the critical engine at the deviation point will normally be available. However, in certain situations the obstacle clearance along the normal departure route may be marginal and should be checked to ensure that, in case of an engine failure after the deviation point, a flight can safely proceed along the normal departure.

LET'S SEE IT GRAPHICALLY…

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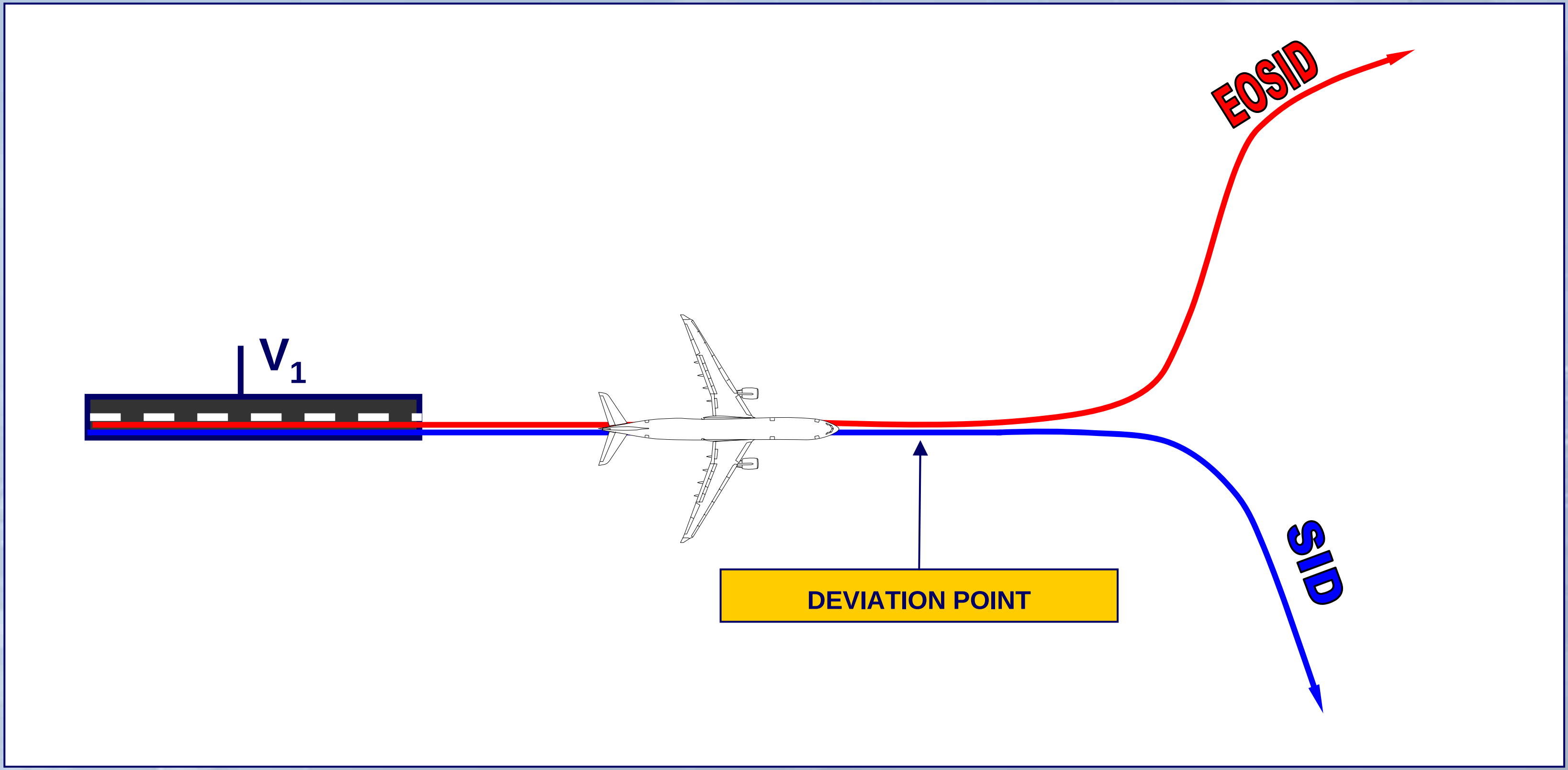
Deviation Point

- When an EOSID is considered there is a point beyond which both trajectories divert:



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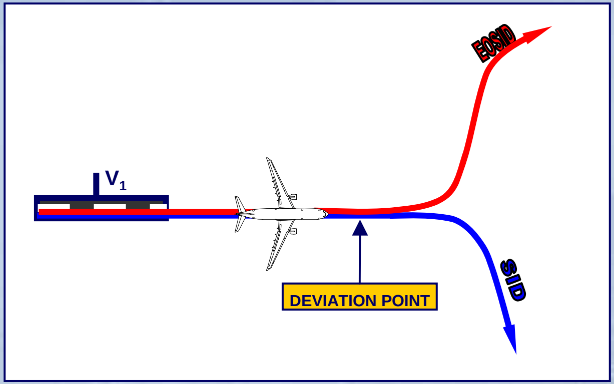
Engine Out SID design strategy

- 5. Determination of a decision point
  - If engine failure occurs at V1, EOSID is flown
  - Which procedure should be flown if failure occurs after V1?
  - Can the SID constraints be met?



Decision Point

CONCLUSION:

The DECISION POINT is always before or at the DEVIATION POINT

Engine failure before DP
EOSID

Engine failure after DP
SID

Engine Out SID design strategy

- 5. Determination of a decision point
  - If engine failure occurs at V1, EOSID will be flown
  - What will happen if failure occurs after V1 ?
  - Could the SID or the EOSID be flown ?

Decision Point

Engine failure before DP
EOSID

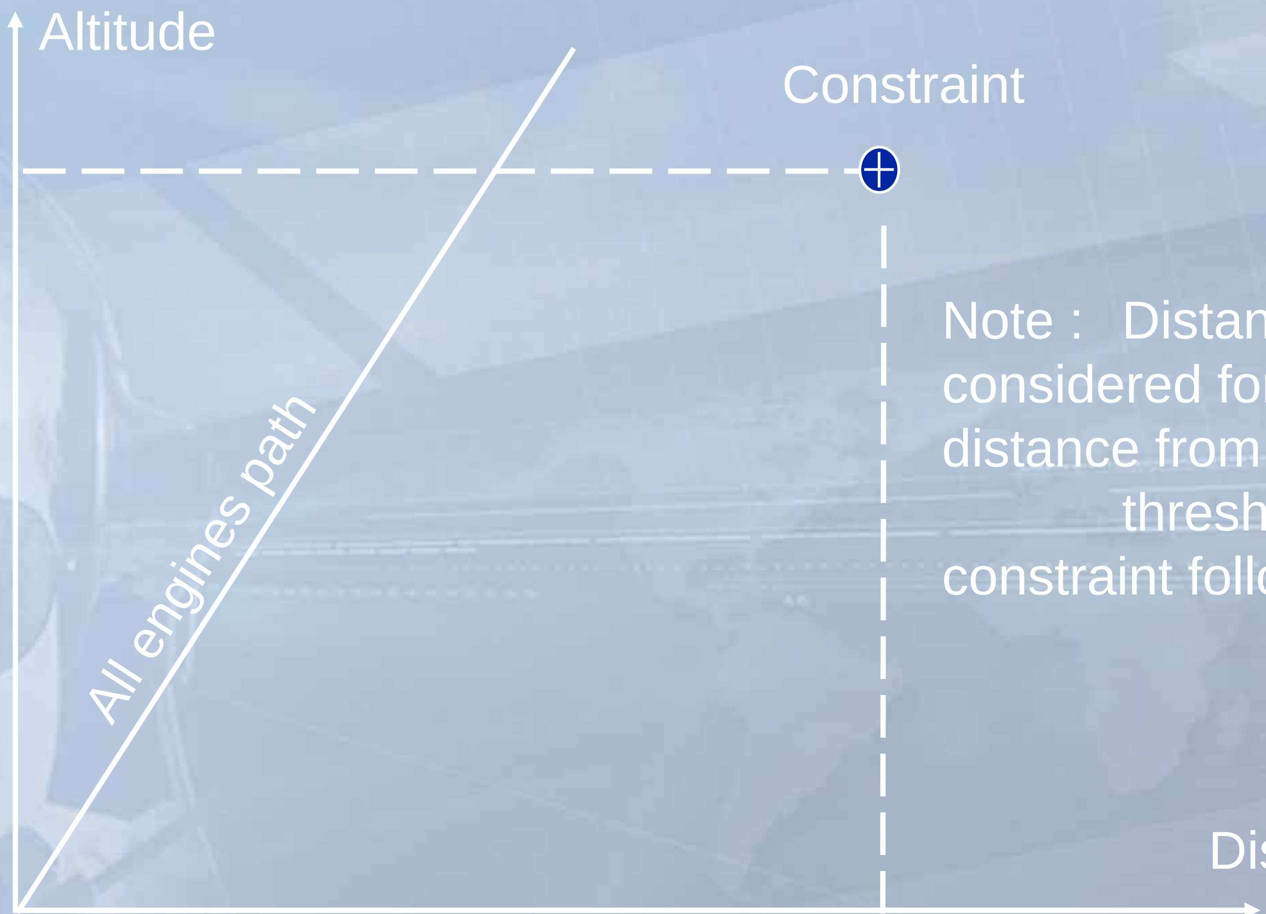
Engine failure after DP
SID

Engine Out SID design strategy

- 5. Determination of a decision point
  - Determine takeoff flight path all engines operative
    - – Noise definition manual
    - – OCTOPER
  - Draw the path on a chart
  - On the chart, place the altitude constraint

Engine Out SID design strategy

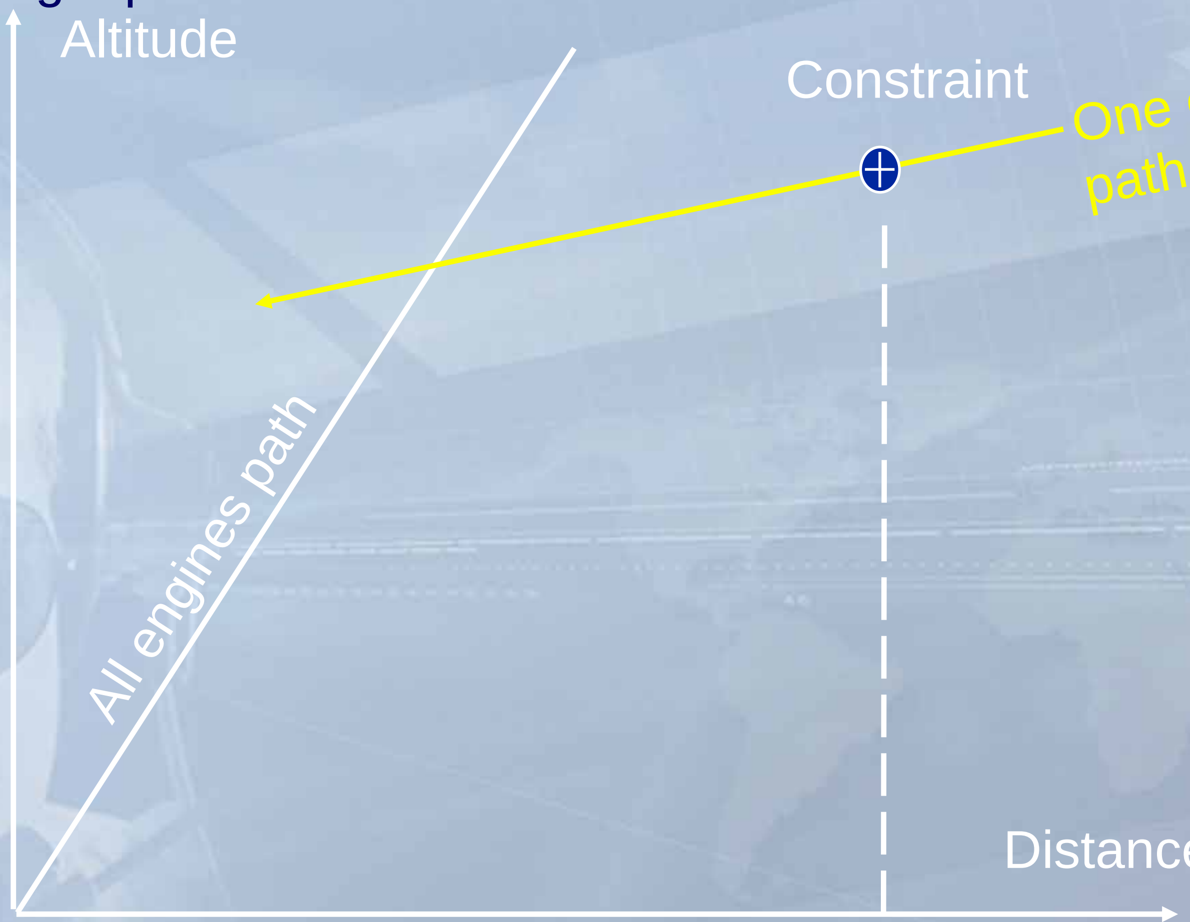
- 5. Determination of a decision point



Note : Distance to be considered for constraint is distance from runway threshold to the constraint following SID track

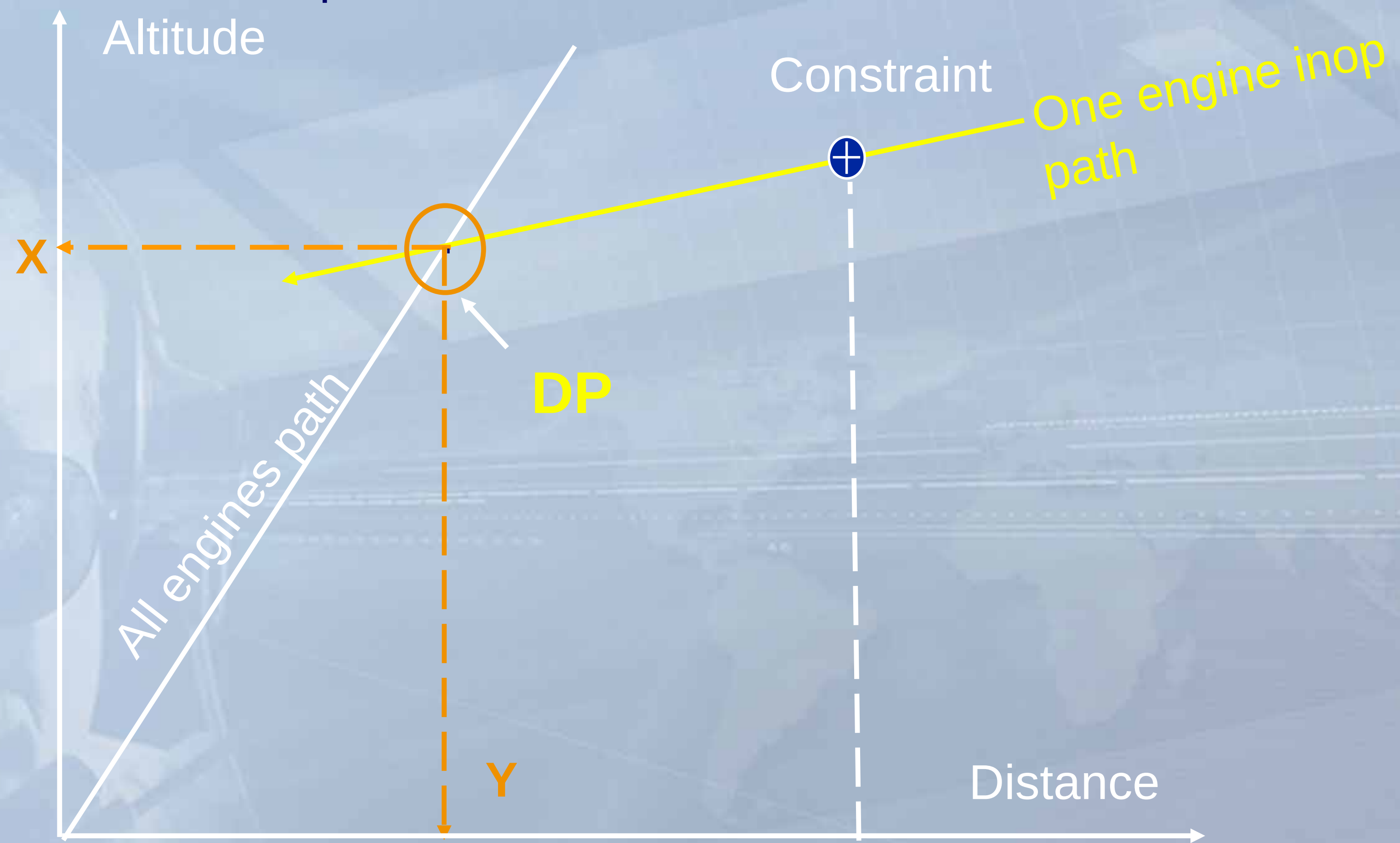
Engine Out SID design strategy

- 5. Determination of a decision point
  - Starting from constraint draw back the one engine inoperative flight path



Engine Out SID design strategy

- 5. Determination of a decision point
  - Intersection between both flight paths gives the decision point



Engine Out SID design strategy

- 5. Determination of a decision point
  - A straightforward method is to take decision point equal to deviation point
    - Easy to find
    - Does not let time to the pilot to prepare for the diversion
  - The decision point shall be validated
    - By checking the net flight path after DP
    - By ensuring obstacle clearance after DP

Engine Out SID design strategy

- Recipe for an EOSID
  - 1. Computation of takeoff charts
  - 2. Determination of the net takeoff flight path
  - 3. Determination of a pattern
  - 4. Verification of the obstacle clearance
  - 5. Determination of a decision point
  - 6. Procedure writing

Engine Out SID design strategy

- 6. Procedure writing
  - EOSID with Decision Point defined
  - Acceleration altitude should be defined for the engine failure case after DP
  - Two different parts
    - One for engine failure below DP
    - One for engine failure above DP
  - Comprehensive format for :
    - Direct use by pilots
    - FMS/FMGS data bank updating (as applicable)

Contents

FMS/FMGC considerations

- Diversion point
  - The FMS diversion point is calculated by the FMS, taking into account the different legs entered in the FMS NAV database
  - No temporary flight plan selection is possible after diversion point

FMS/FMGC considerations

- Diversion point

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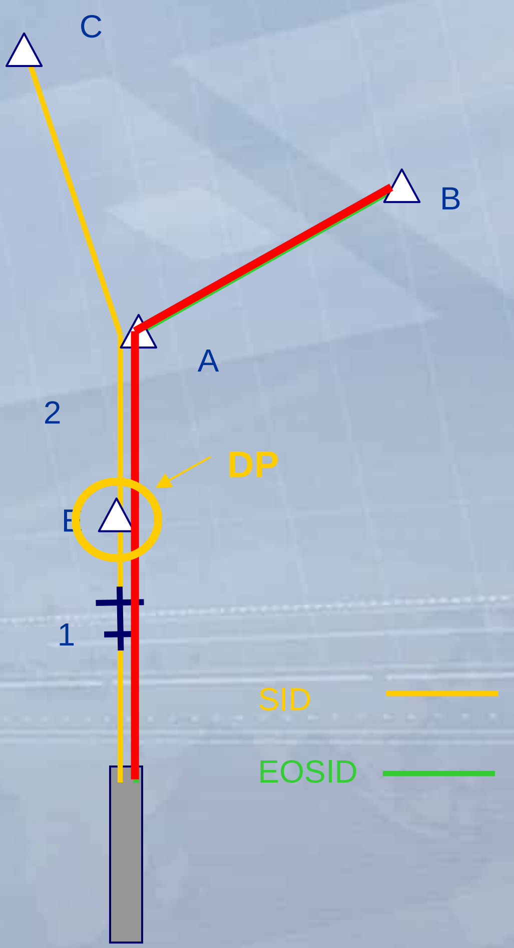
Temporary Flight Plan activation before DP

No problem !



FMS/FMGC considerations

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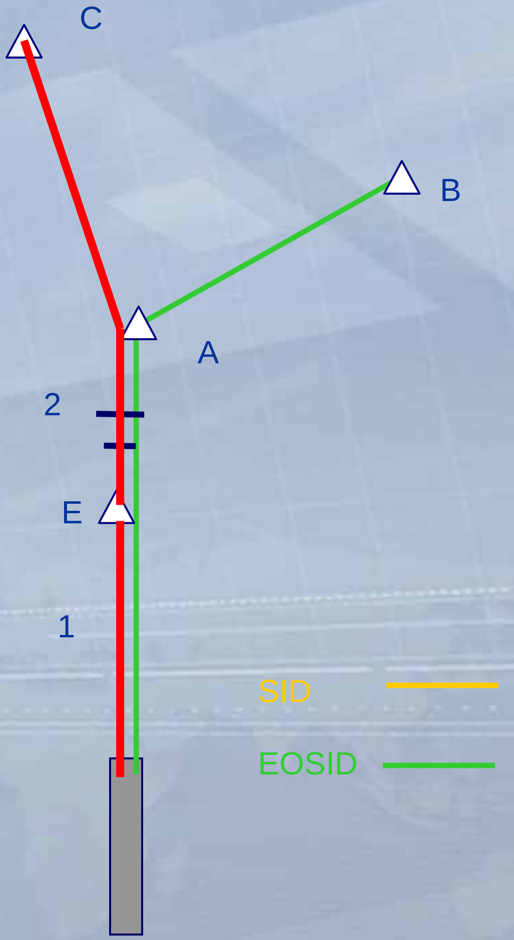

FMS/FMGC considerations

- Diversion point
  - The FMS diversion point is calculated by the FMS, taking into account the different legs entered in the FMS NAV database
  - No temporary flight plan selection is possible after diversion point
  - Thus, Airbus recommendation is:
    - Diversion point equal to deviation point
    - The SID/EOSID common legs until the flight paths separate must be of the same type and nature

Contents

Airbus tools and training

- Airbus software
  - In order to ease the design of takeoff engine failure procedures, specific Airbus software is available
    - Through the Performance Engineers Package (PEP)
      - Flight Manual (FM) component
      - Takeoff and Landing Optimization (TLO) component
      - Operational Flight Path (OFP) component
      - Airbus Departure Analysis Software (ADAS) component

Airbus tools and training

- Airbus software
  - Operational Flight Path (OFP) component
    - The OFP (also called OCTOPER) is an Airbus software designed to simulate the aircraft trajectory
      - With all engines running
      - With one engine out
    - Allows the operator to define the SID and to compute the corresponding performance of its aircraft along it
    - Allows to check the compliance with SID requirements and/or SID flyability (stall, bank angle...)
    - Capable of SID definition
  - Airbus Departure Analysis Software (ADAS) component
    - Future component specifically designed for that purpose

Airbus tools and training

- Training
  - Standard Performance Engineer’s Course
    - Theory on aircraft performance and Regulations
    - Airbus software (PEP)
  - Advanced Performance Engineer’s Course
    - Specific module for EOSID design

Contents

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Conclusion

- Operators should check constraints on published SID
  - Engine failure at V1 (compute takeoff charts)
  - After V1 (compute operational flight path with one engine out)
- Define EOSID if necessary
- Existing EOSIDs for other aircraft may be used, but obstacle clearance has to be checked
- Dispatching the aircraft as efficiently as possible must not supersede flight safety

Conclusion

- Means and tools must be implemented at all levels to give the pilots access to appropriate procedures

- Close co-ordination between
  - Operators
  - Airport authorities
  - ATC

- FMS/FMGS data bank updating or use conventional NAV aids

- Airbus focuses its efforts on this issue by proposing tools and training to help designing specific procedures

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