ISAE 2021

1MAE208 CONTROL & GUIDANCE

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Flight Management System

Vertical Functions

CONTENT OF THE PRESENTATION

Flight Management System: Vertical Functions

1) Introduction
2) Flight Preparation
3) Flight Plan Predictions
4) Flight Optimization
5) Flight Envelope
6) Atmospheric model
7) Flight Guidance
8) Performance Model

1 - INTRODUCTION

FMS FUNCTIONS

- Lateral Flight Plan
- Lateral Guidance
- Vertical Flight Plan Predictions
- Vertical Guidance

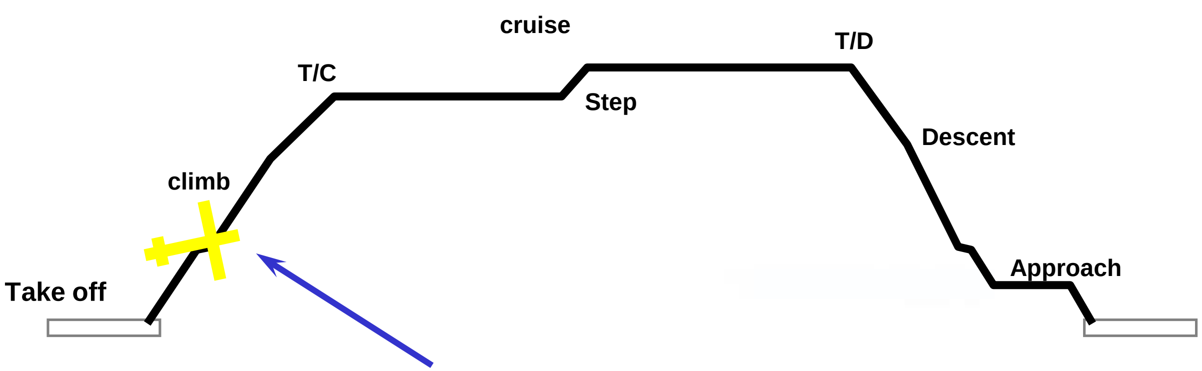
FMS VERTICAL FUNCTIONS

Flight Plan predictions

- Computation of vertical flight plan, predictions based on a aircraft performance model
- Computation of miscellaneous performance data

Flight Optimization

- Define the best flight parameter (speeds / altitude) according to specific criteria



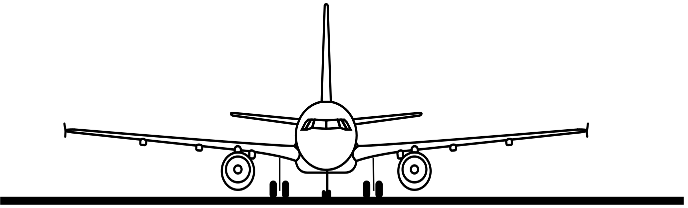
Vertical guidance

of the aircraft on the target flight plan

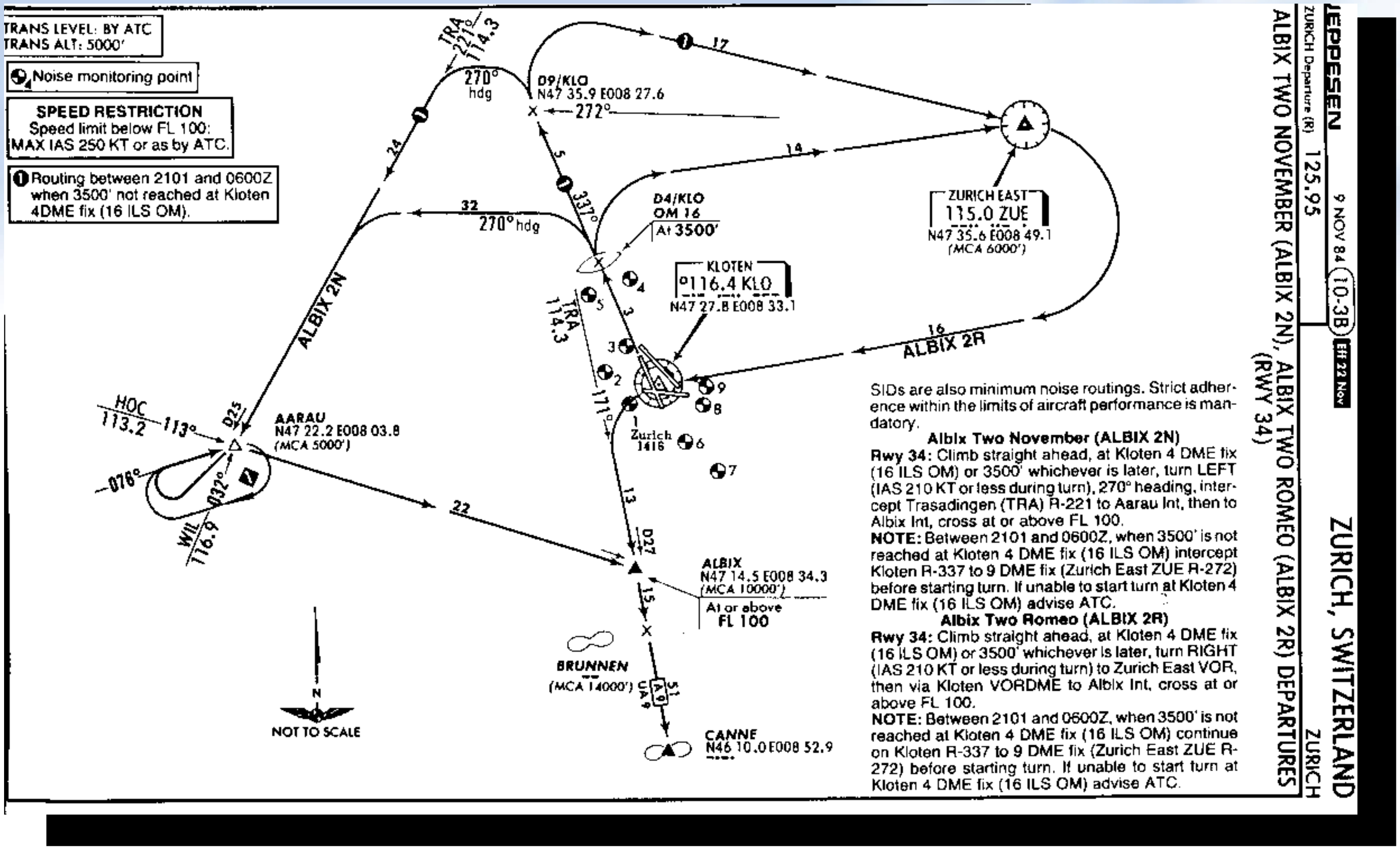
2 – FLIGHT PREPARATION

Definition

On ground:

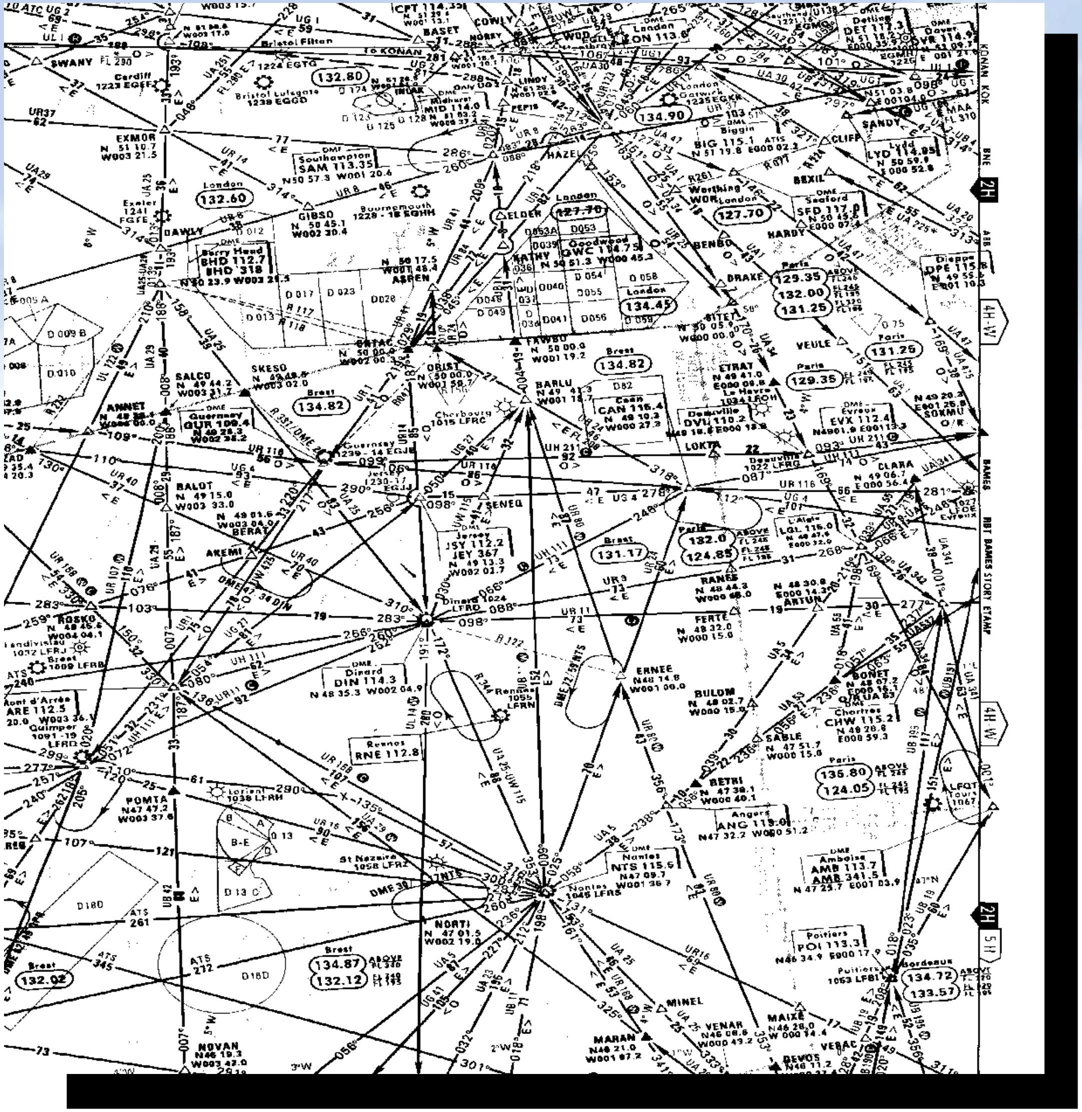


- **Flight plan construction**
- **Meteo analysis**
- **Loading analysis (fuel and commercial load)**
- **Take-off & Landing preparation**

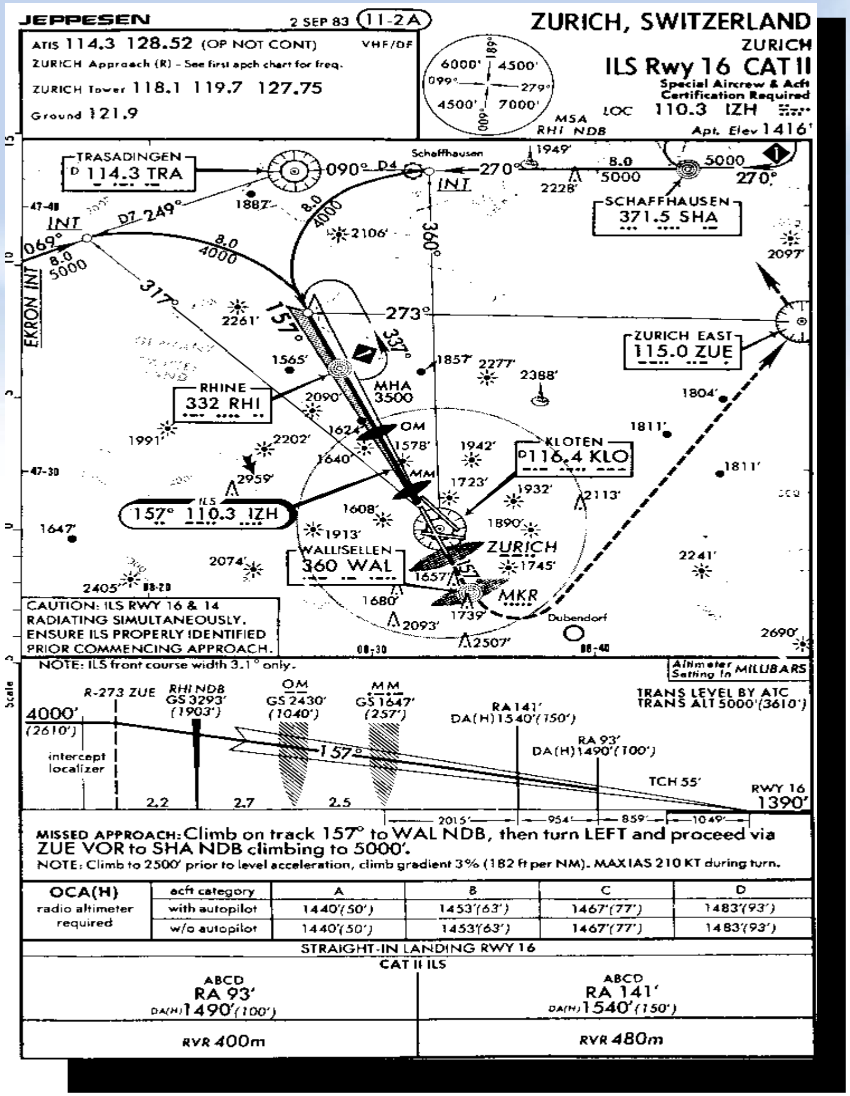


Departure and Arrival charts

2 – FLIGHT PREPARATION

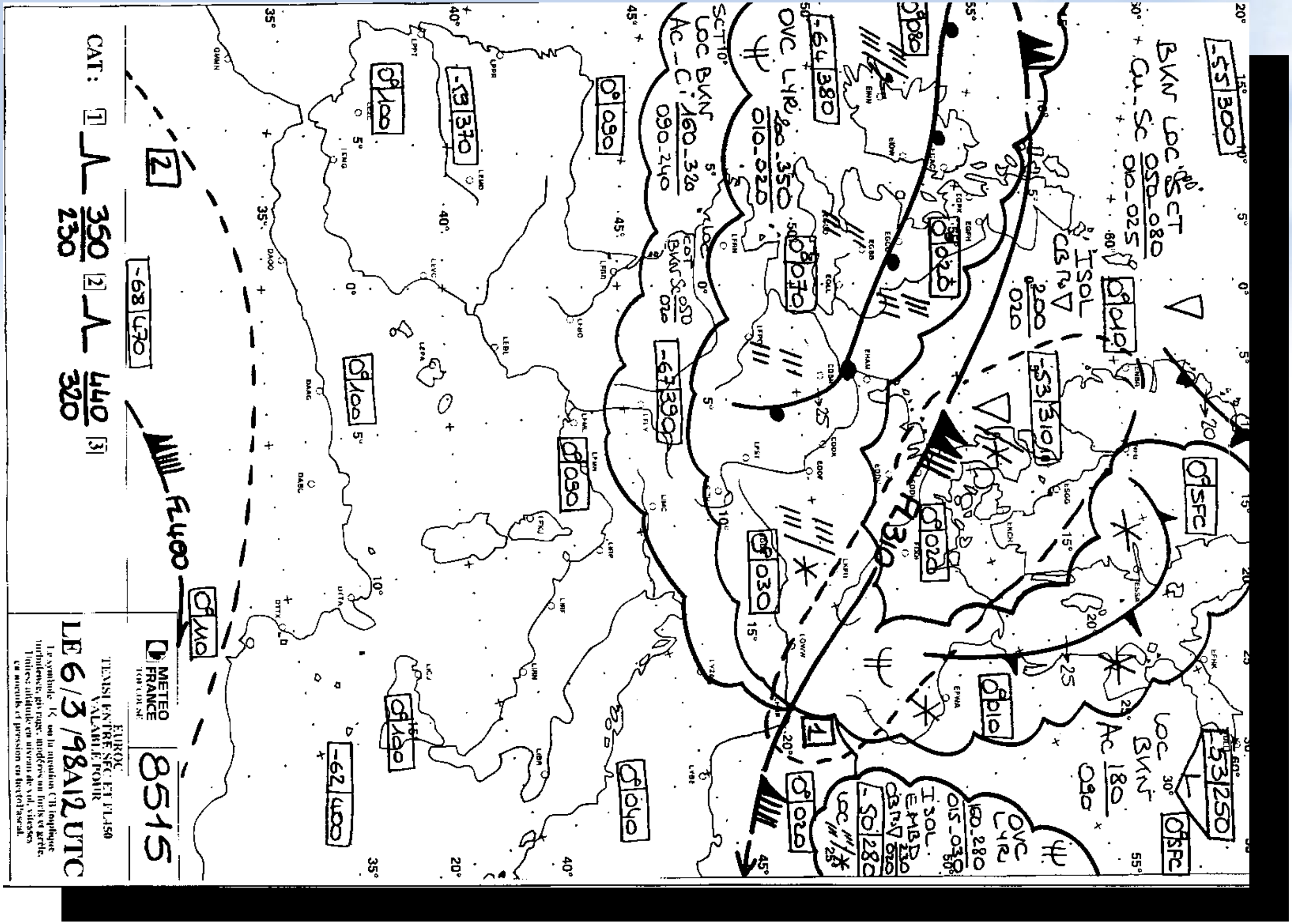


En route charts



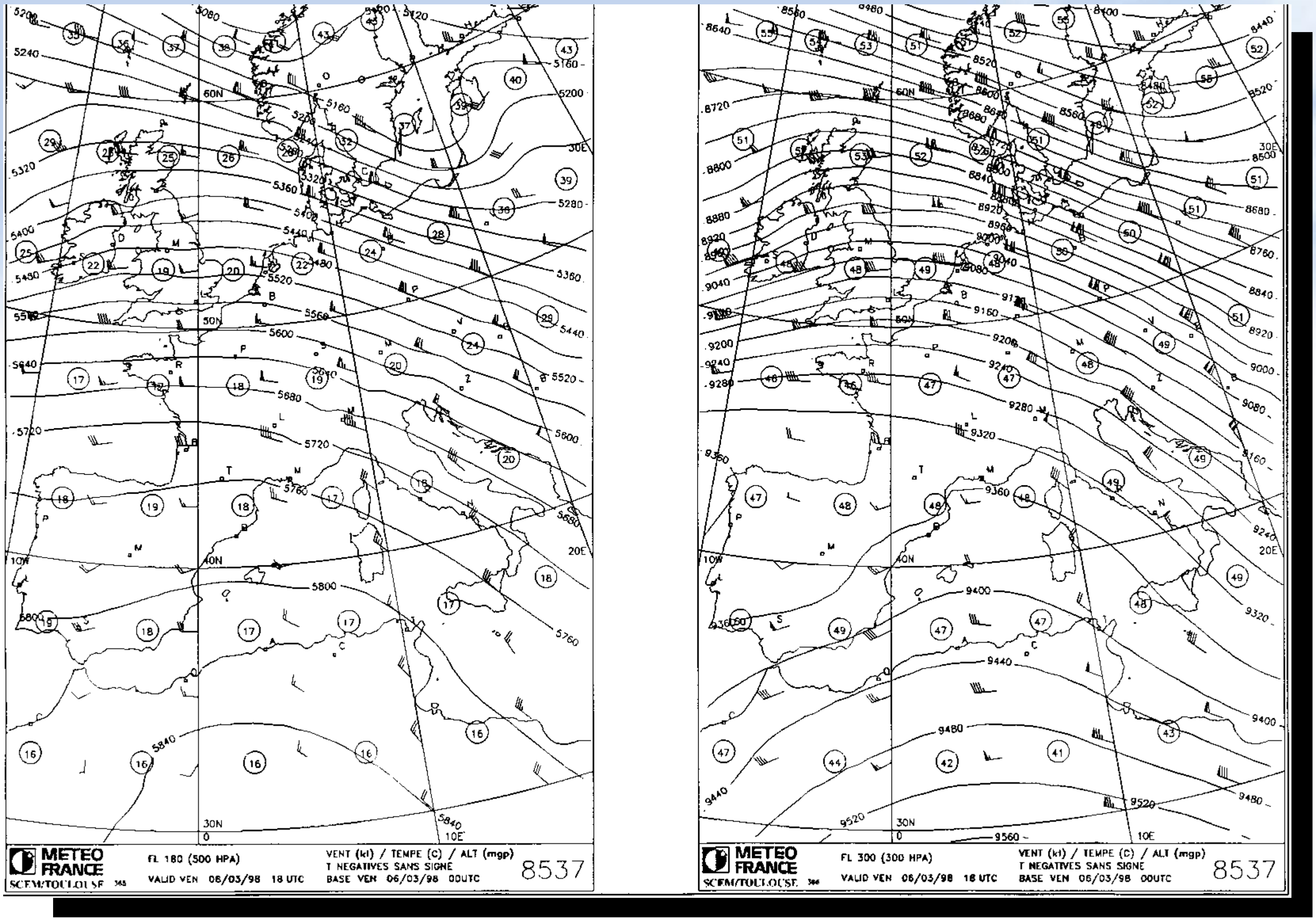
Approach charts

2 – FLIGHT PREPARATION



Meteo

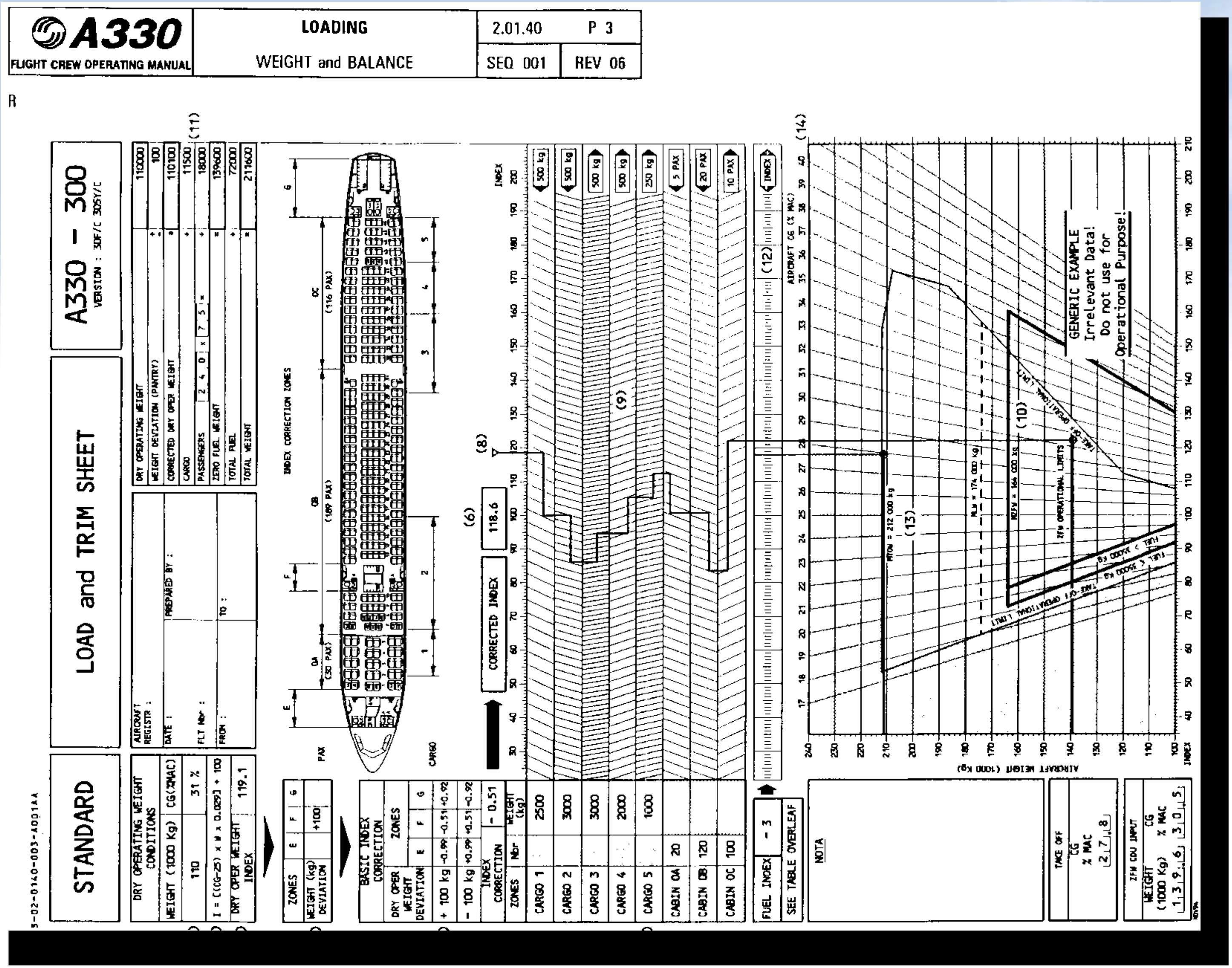
Charts


METEO FRANCE
SCEM/TOULOUSE
FL 180 (500 HPA)
VALID VEN 06/03/98 18 UTC
VENT (kt) / TEMPE (C) / ALT (mgp)
T NEGATIVES SANS SIGNE
BASE VEN 06/03/98 00UTC
8537
METEO FRANCE
SCEM/TOULOUSE
FL 300 (300 HPA)
VALID VEN 06/03/98 18 UTC
VENT (kt) / TEMPE (C) / ALT (mgp)
T NEGATIVES SANS SIGNE
BASE VEN 06/03/98 00UTC
8537

Wind Charts

2 – FLIGHT PREPARATION

1-2) Tools used for flight management



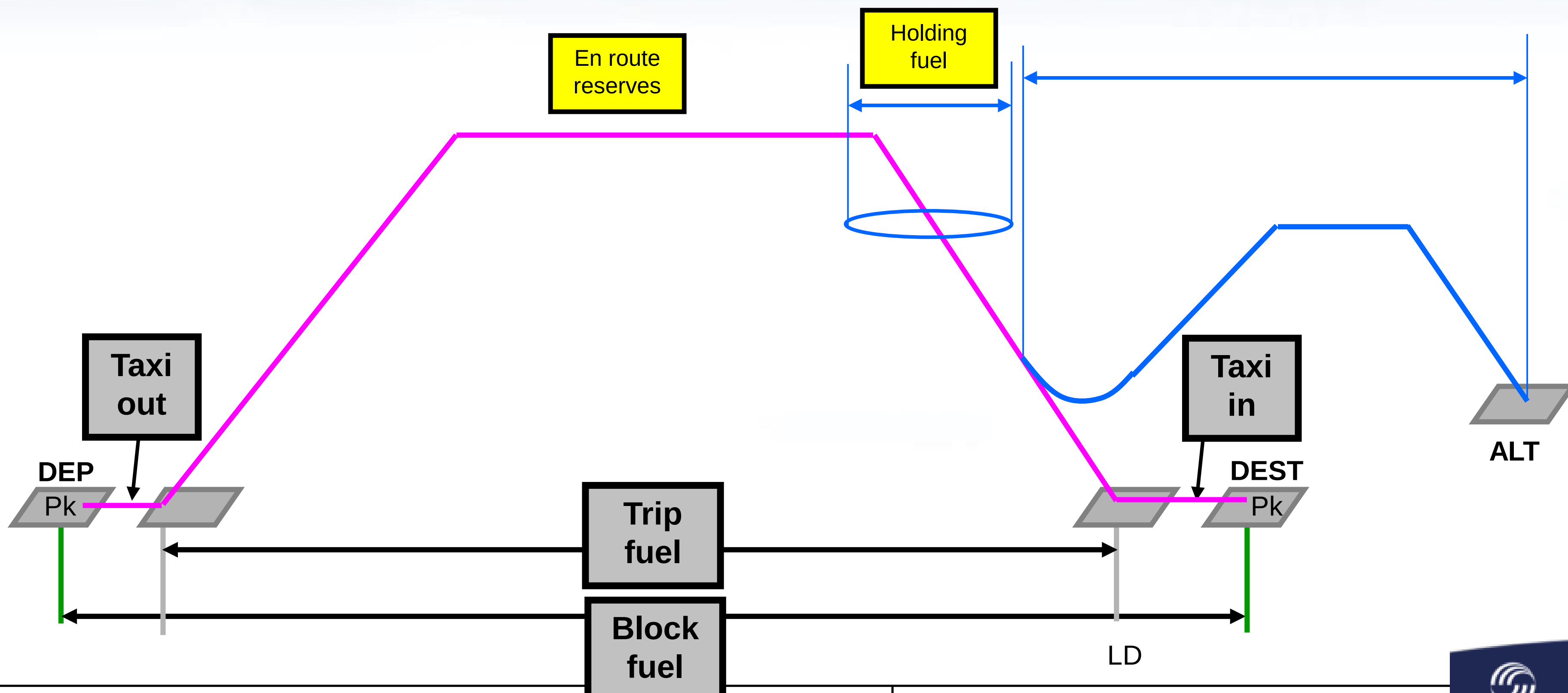
Loading

Sheet

Fuel planning Computation : Fuel policy

- Fuel quantity for a given mission is governed by operational regulations.
  - *"JAR-OPS1.255*

    An operator must establish a fuel policy for the purpose of flight planning and in-flight replanning to ensure that every flight carries sufficient fuel for the planned operation and reserves to cover deviations from the planned operation."



Flight Plan / Fuel planning Computation

- Fuel planning is based on **target route / forecast wind & temperature / aircraft performance characteristics (provided by A/C manufacturer)**.

- **Flight plan** details flight route predicted, for each waypoint:
  - Name of waypoint and airway
  - Flight level and winds, OAT, TAS, ground speed
  - Distance and time, since last waypoint and remaining to Dest.
  - Estimated burnt fuel (cumulated) and remaining FOB

WPT AWY	FLT MSA	WIND OAT	S	TAS GS	ITT OTT	IMT OMT	DST RDST	NAM RNAM	E.T. C.T.	E.TA A.TA	ECBO ACBO	EFOB. AFOB.
WSSS	ELEV	00022FT					000	000	00:00	.....	000.5	104.1
							3474	3050	00:00	.....	.....	.....
SANOS					131	131	197		00:29	.....	012.4	092.2
VEN1B					132	132	3277		00:29	.....	.....	.....
TOC					129	129	008		00:01	.....	012.5	092.1
A576					129	129	3269		00:30	.....	.....	.....
APARI	370	030/011		505	131	131	114	114	00:14	.....	015.5	089.0
A576	047	M39	1	507	132	131	3155	2732	00:44	.....	.....	.....

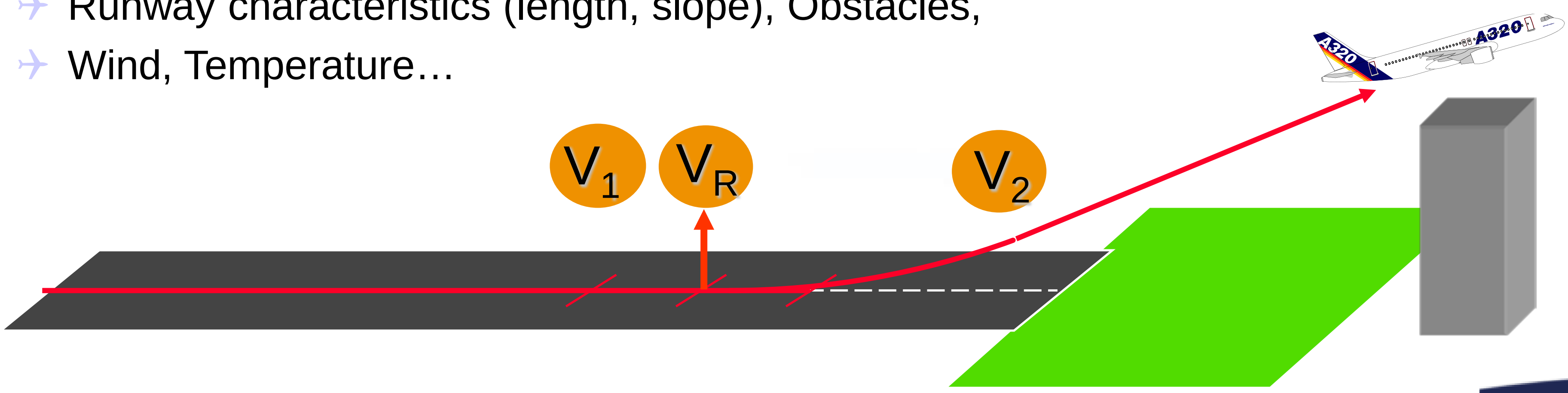
Take-Off Computation

- Computation of :
- MTOW (Maximum Take off Weight)
- V1, (decision speed)
- VR (Rotation speed)
- V2 (Take off climb speed)
- TO thrust (Flex or Derate)
- Flap configuration
- Versus:
- Runway characteristics (length, slope), Obstacles,
- Wind, Temperature…

TAKE-OFF CHART

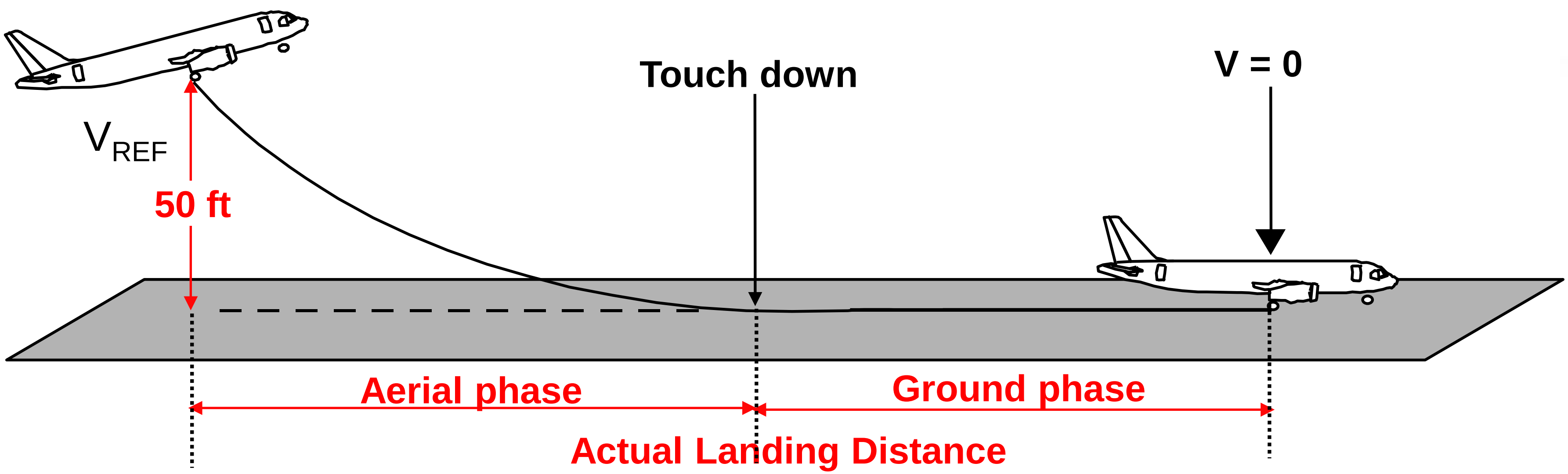
A319131 - JAA	IAE V2522-A5 engines	PARIS - (ORLY)	08	17.0.0 30-AUG-00 AD131A04 *V 9
QNH 1013.25 HPA Air cond. Off Anti-icing Off		Elevation 277 FT TORA 3320 M Isa temp 14 C TODA 3320 M rwy slope 0.07% ASDA 3320 M	4 obstacles	DRY

OAT C	CONF 1+F				
	TAILWIND -10 KT	TAILWIND -5 KT	WIND 0 KT	HEADWIND 10 KT	HEADWIND 20 KT
-6	72.0 4/4 146/46/51	73.4 2/4 148/48/53	74.8 2/4 153/53/58	75.6 2/4 157/57/62	76.3 2/4 161/61/65
4	71.6 4/4 146/46/51	73.0 4/4 147/47/52	74.4 2/4 152/52/57	75.2 2/4 156/56/60	75.9 2/4 159/59/64
14	71.2 4/4 145/45/50	72.5 4/4 146/46/51	74.0 2/4 150/50/55	74.9 2/4 154/54/59	75.6 2/4 157/57/62
24	71.0 4/4 149/49/54	72.1 4/4 145/45/50	73.6 2/4 149/49/53	74.5 2/4 152/52/57	75.2 2/4 156/56/61
34	70.8 4/4 148/48/53	71.7 4/4 145/45/50	73.1 2/4 147/47/52	74.1 2/4 151/51/56	74.9 2/4 154/54/59
44	70.5 4/4 148/48/52	71.7 4/4 150/50/55	72.7 2/4 146/46/51	73.7 2/4 149/49/54	74.5 2/4 153/53/57



Landing Computation

- **Check of capability to land at the Destination Airport**
- Computation of MLW (Maximum Landing Weight) versus:
- Flap configuration, Runway characteristics (length, slope), Obstacles,
- Wind, Temperature…



FMS PERFORMANCE COMPUTATIONS (1)

FLIGHT PLAN PREDICTIONS

- Distance
- Altitude (respect of constraints)
- Estimated time at WPoint
- Estimated fuel consumption (FOB)
- Speed (respect of constraints)
  for each Waypoint from current position till the destination.

FLIGHT OPTIMIZATION

- ECON CLB / CRZ / DES speeds
- Optimum altitude
- Optimum step, fuel and time saving
- Holding speed

SUPPORT THE CREW

- Characteristic speeds for Take off and landing (O,S,F,VAPP)
- Flight envelope
- Speed management to comply with time constraint
- Management of altitude and speed constraints in climb and descent (capability)
- T/D computation
- Descent depressurization management
- Start of deceleration / approach
- Climb / Drift down trajectory optimization with engine failure

3 - FLIGHT PLAN PREDICTIONS

FMS PERFORMANCE COMPUTATIONS (2)

DECISION HELP

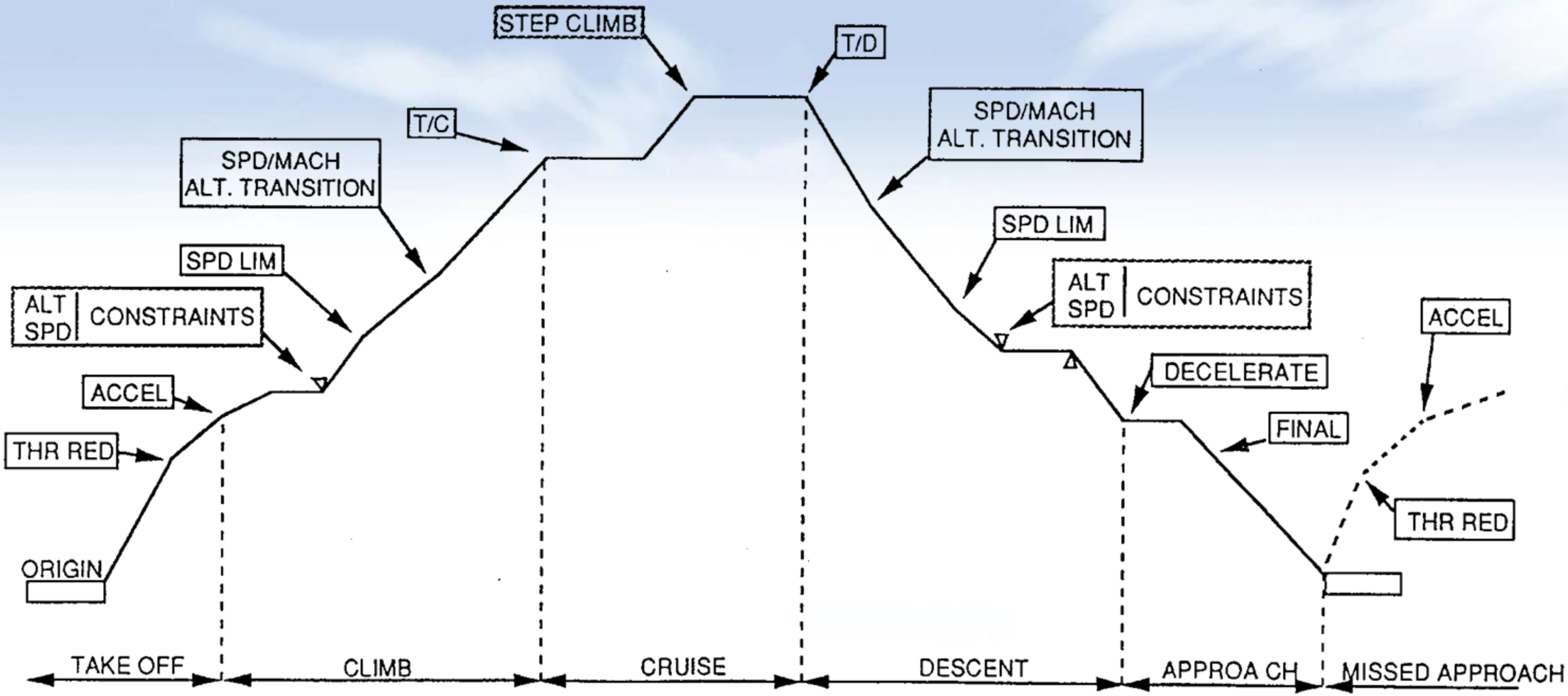
- Check of constraint capability (speed / alt)
- Time & Dist predictions to an altitude
- Equi-time point between two airports
- Required distance to land
- Direct distance to destination
- Predictions to the five closest airports
- Fuel reserve management in holding
- Engine out predictions
- Secondary Flight plan predictions

FLIGHT ENVELOPE

- Max Altitude
- Maximum speed (thrust, buffeting)
- Minimum speed (stall, buffeting).

3 - FLIGHT PLAN PREDICTIONS

The vertical flight plan is divided into flight phases as follows:



3 - FLIGHT PLAN PREDICTIONS

INITIALIZATION FOR PERFORMANCE PREDICTIONS

Flight Plan Initialisation

- **Flight Number; Company Route or City Pair**
- **Cruise Flight Levels**
- **Tropopause Alt & Cruise FL temperature**
- **Winds**

Weight computation

- **CG:** Zero Fuel Weight Centre of Gravity **(ZFWCG)**
- **Weight: ZFW** & **Block** ⇒ **Trip fuel & time, Trip Reserve,**
  Alternate trip, Hold fuel & time
  Extra fuel & time

Performance parameters setting (PERF pages)

- **Cost Index**
- **Take Off (T.O.) Shift, V1, Vr, V2**
- **Transition Altitude, Thrust Reduction Altitude, Acceleration Altitude**
- **Flexible T.O., Derated T.O. & Climb**

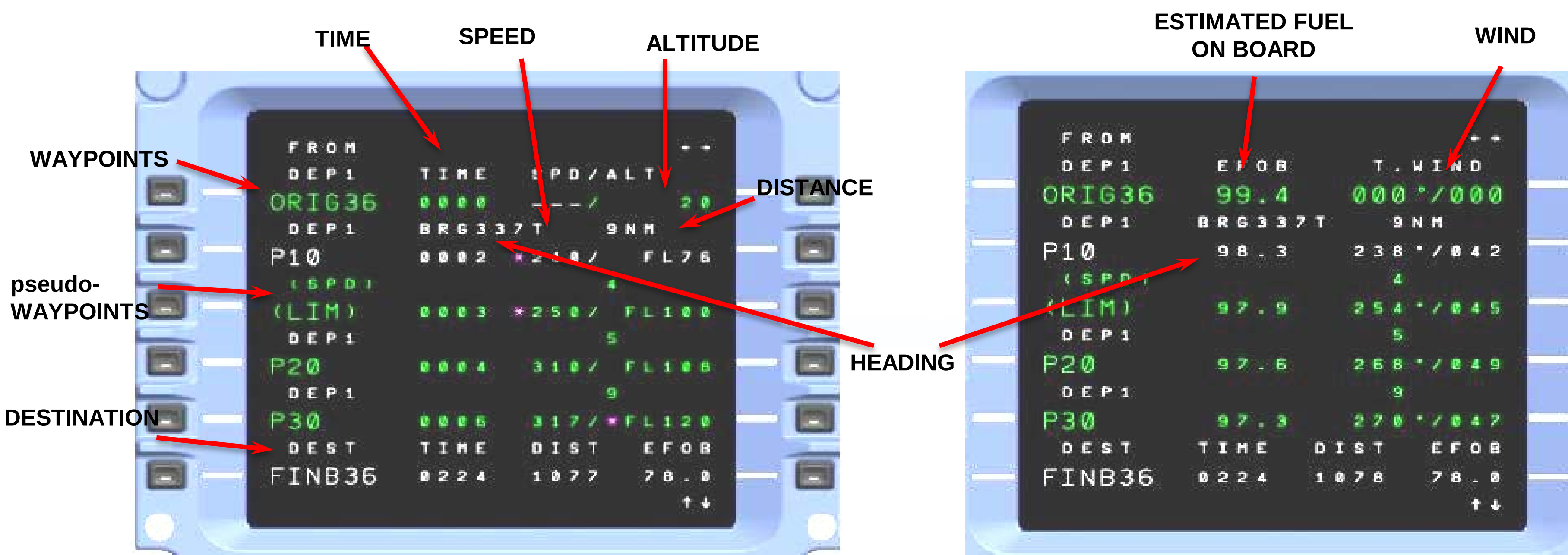
FLIGHT PLAN

F-PLN predictions

At each waypoints of the F-PLN, the FMS provides the following predictions:

- distance
- altitude
- passed time
- estimated fuel on board
- speed

Predictions based on « First Principle » technique using A/C PERF model : drag / thrust / geometric data



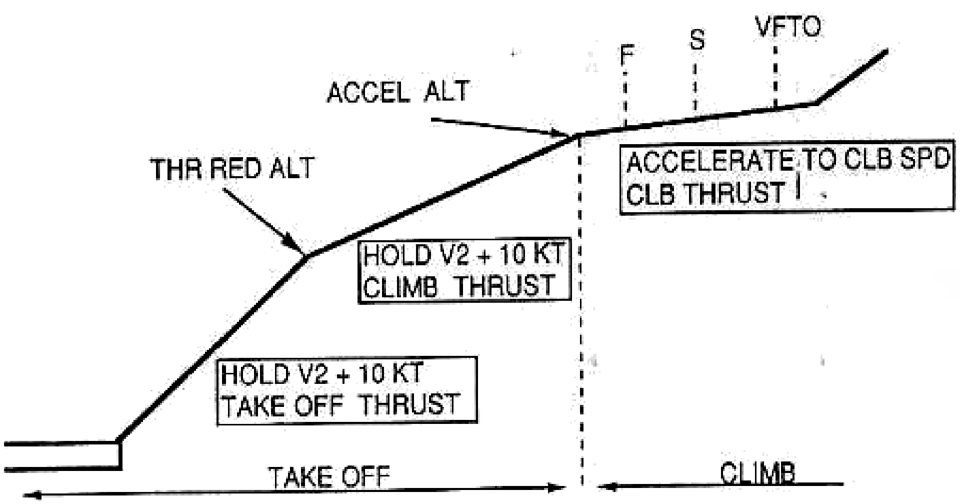
Pseudo Waypoints

ND pseudo Waypoints	MCDU pseudo waypoints & Markers
Level to FCU Altitude	Top of Climb (T / C)
Level toFM Altitude Constraint	Top of Descent (T / D)
Start of Climb	Step Climb (S / C)
Top of Descent	Step Descent (S / D)
Path intercept	Speed limit (SPD LIM)
Speed change	Decel point (DECEL)
Decel point	Too Steep Path
Constrained Waypoint	
Speed limit distance	
Time marker	
Equitime point	

TAKE OFF PHASE

Predictions based on :

- Max / Flex / Derate Takeoff Thrust & Hold V2 + 10 kt at TO CONF
- At Thrust Reduction Altitude : Climb Thrust & Hold V2 + 10 kt
- At Acceleration Altitude : acceleration to ECON CLB SPD
    - F: Flap retraction
    - S: Slats retraction



3 - FLIGHT PLAN PREDICTIONS

TAKE OFF PHASE

<u>**Predictions computations:**</u>

- **Take off distance to 35 ft** based on integration of equations of motion, using:
    - Thrust selection (Max / Flex / Derate),
    - V2 speed,
    - TO configuration,
    - Ground wind,
    - Ground temp (on Thales)
    - RWY slope (from Nav data base)

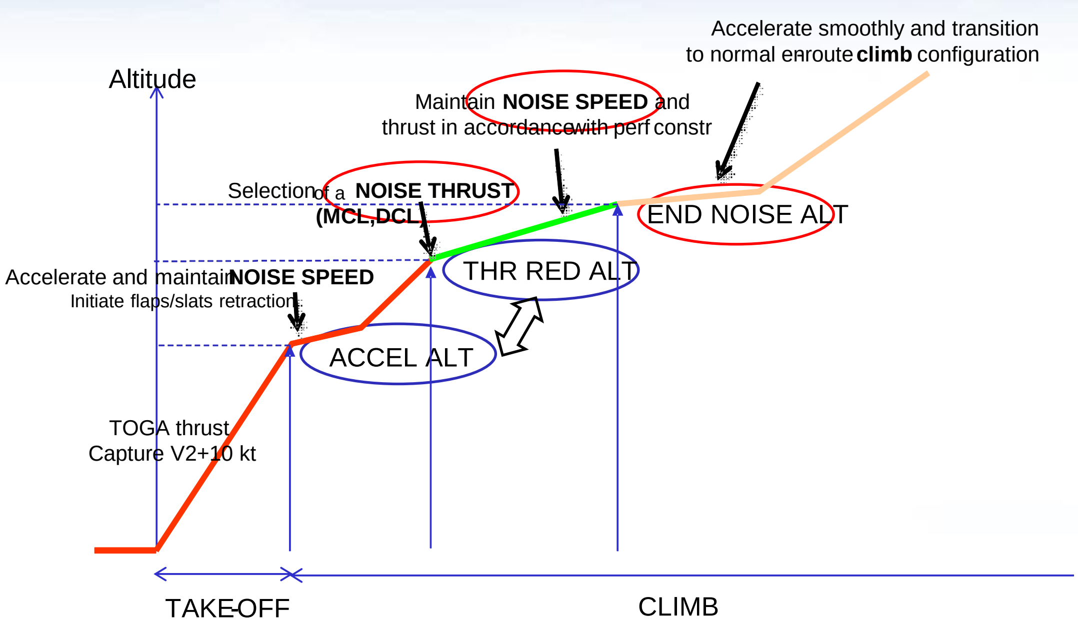
- **TO Consistency checks**:
    - V1 < Vr < V2
    - **V1, Vr, V2 speed enveloppe** (TOS1)
    - **Runway overrun** check (TOS2)
    - **A/C position** check @ takeoff (TOS2)

- **From 35ft:** integration of equations of motion & flight mechanic based on TO thrust & V2+10kt
- Allows THR RED ALT > ACCEL ALT (**NADP distant procedure**)

TAKE OFF PHASE: NADP

Evolutions on FMS A380: Noice Abaptment Departure Procedure: Reduce noice on ground

- **Full NADP managed procedure** including:
  - Reduced thrust management (N1 defined by pilot entry, defined by ground optimisation tool)
  - Optimum Noise speed,
  - Smooth thrust recovery at end of Noise Abatement procedure,



A380 FMS HMI

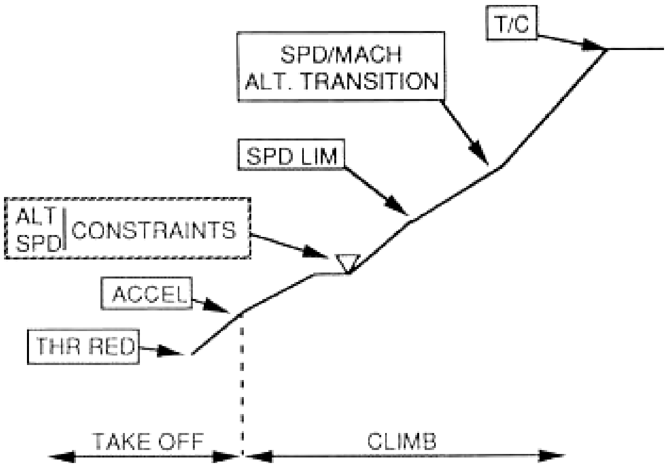
After thrust reduction the speed has to be greater than V2+10 in all cases

- Available Noise thrust: **MCL,DCL, N1**

CLIMB PHASE

- CLB SPEED:
  - ECON: optimum speed limited by SPD constraints & SPD limit
  - Preselected (limited to the CAS preselection, CLB Mach is derived from CAS)
- CLB Thrust: **Max CLIMB** or **DERATED CLIMB** (when available)
- based on integration of equations of motion & flight mechanic (drag /thrust),
- AT & AT OR BELOW ALT constraints ➔ level segment insertion

  ➔ best altitude capability is constraint missed

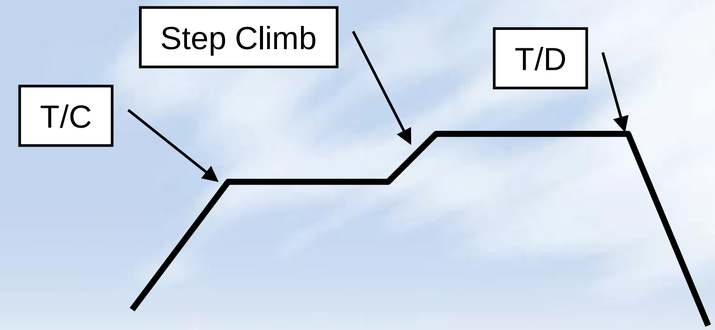


PERF CLIMB

FPLN

3 - FLIGHT PLAN PREDICTIONS

CRUISE PHASE

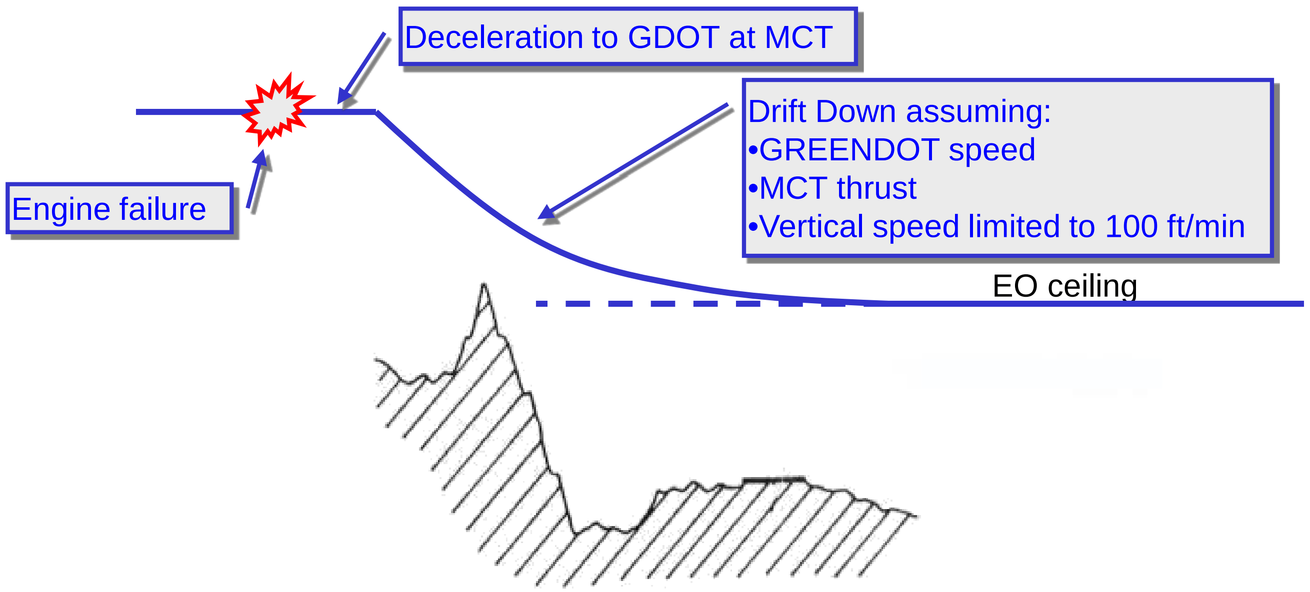


- From Top of Climb to Top of Descent.
- Speed management:
    - ECON
    - preselected for the all cruise phase
    - Constant Mach Segment (CMS) between two waypoints
- Thrust: limited to MAX CRUISE in ECON and MCL for acceleration
- 4 level change on geographical waypoints + 1 optimum step location
- Fuel predictions based on integration of equations of motion & flight mechanic (drag / thrust / Fuel Flow),

CRUISE PHASE

Engine out: « Drift Down » trajectory

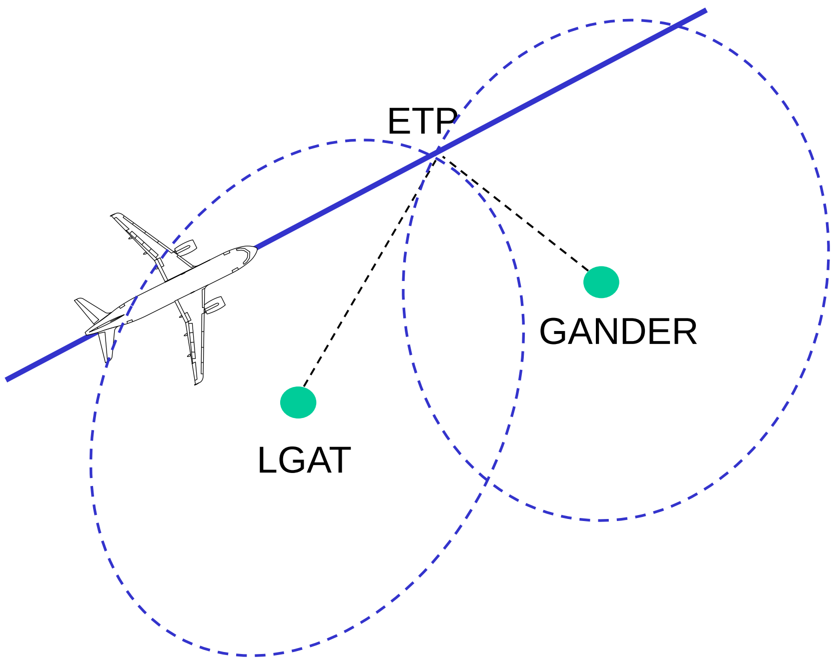
• When engine failure occurs above EOMAXALT: the FMS computes a « Drift Down » trajectory to meet the engine out ceiling altitude.
• The DRIFT DOWN speed (Greendot) allows to keep the aircraft as high as possible assuming Max Continuous thrust on available engine(s)

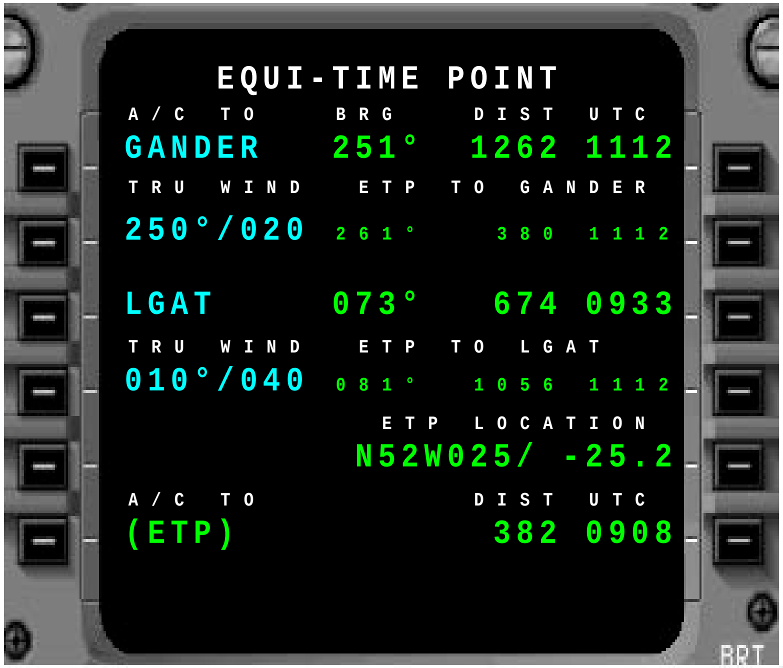


CRUISE PHASE

Equi-time point

• The FMS computes the position on the flight plan of the « EQUI-TIME » point between the two selected airports,
•The FMS computes the predictions of time to go to the selected airports.



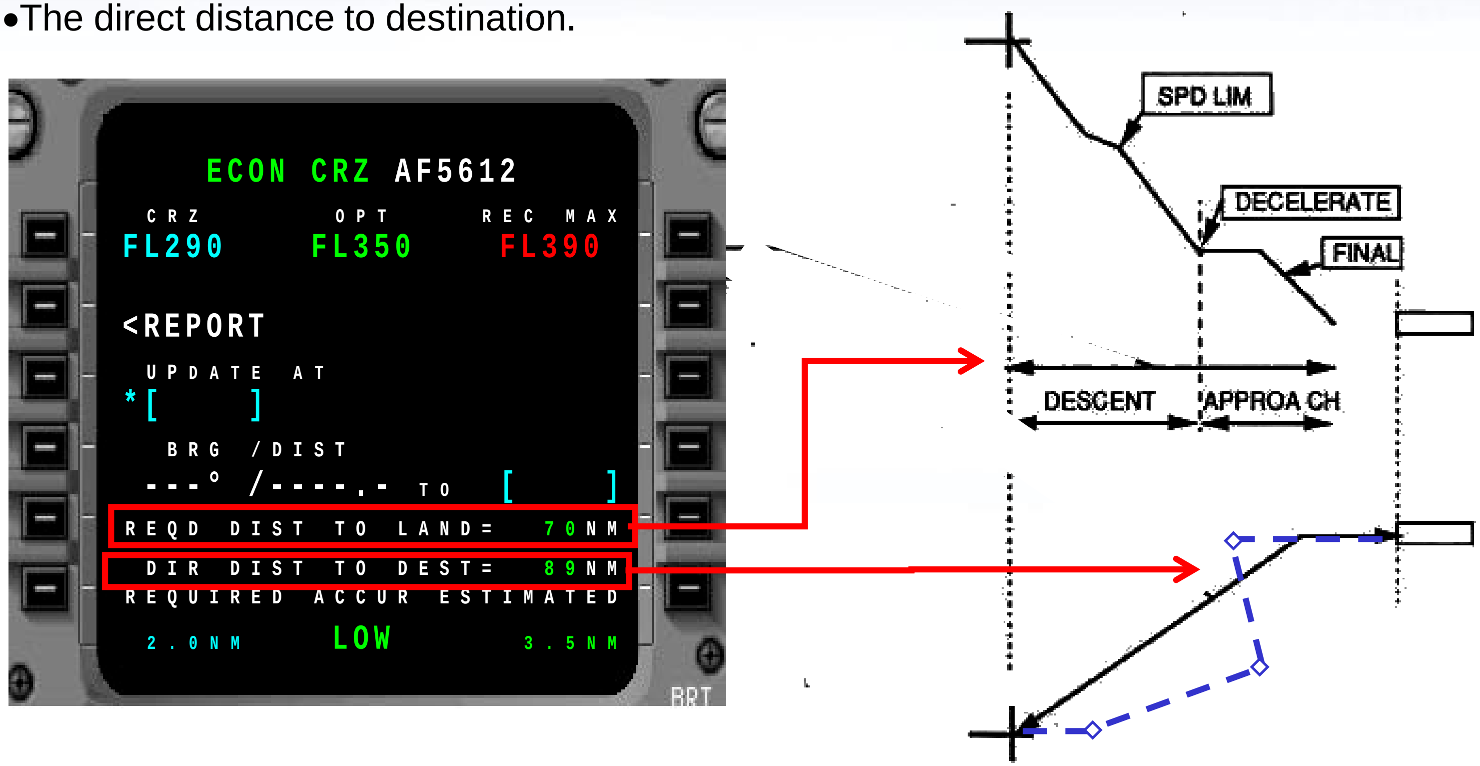


CRUISE PHASE

Required distance to land / Direct distance to destination

During cruse or descent, the FMS computes:

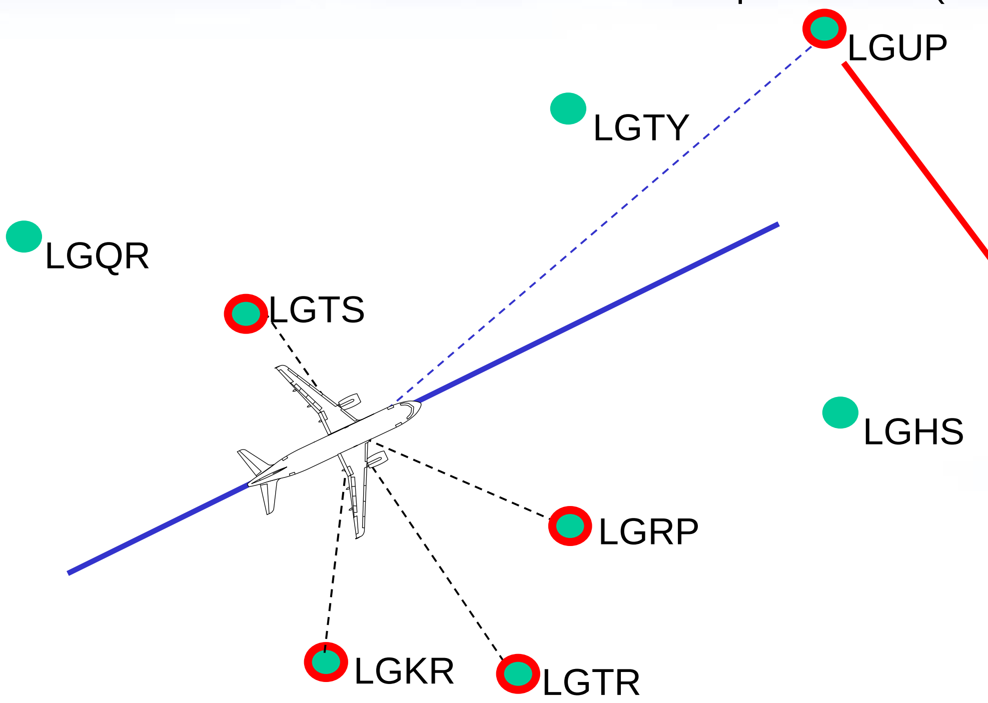
- the required distance to descent to destination altitude using planned descent speed and without any constraint.
- The direct distance to destination.

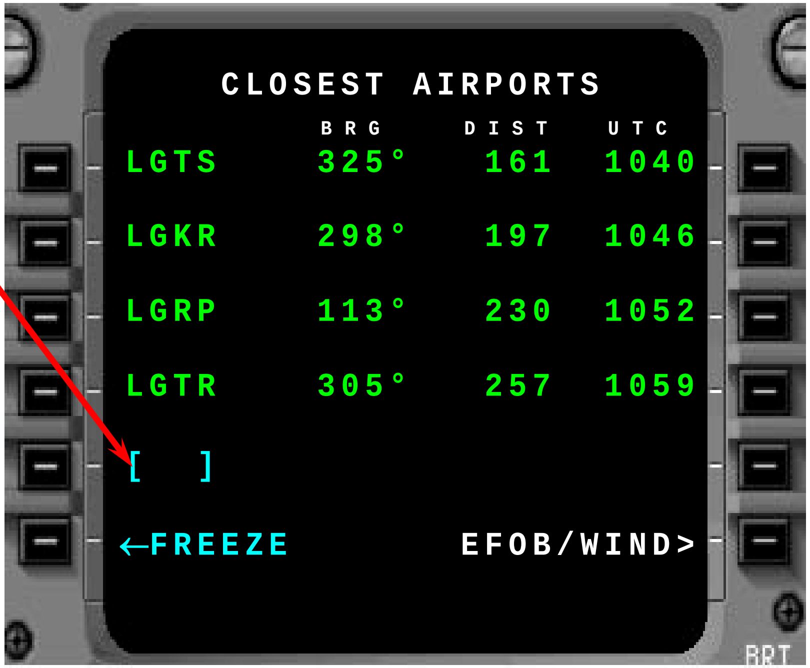


CRUISE PHASE

Five closest airports predictions

- The FMS selects the forth closest airports from Nav Data Base,
- The crew may select a fifth airport,
- The FMS computes the estimated time and fuel at the destinations.
- The current wind / temperature is used for predictions,
- Predictions are based on current cruise speed mode (selected / managed)





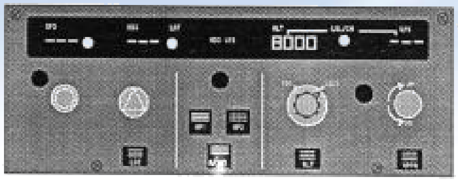
3 - FLIGHT PLAN PREDICTIONS

DESCENT PHASE

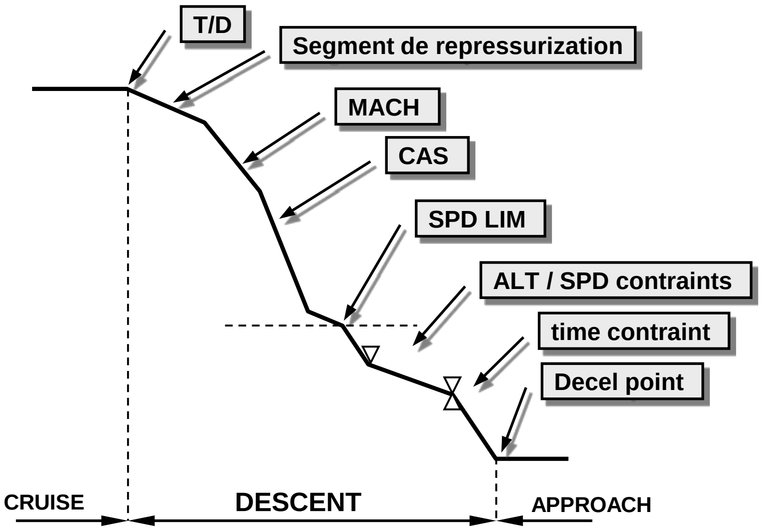
Flight Plan predictions

Objective: define T/D position so as to meet all the descent constraints with min cost.

- Descent from T/D down to approach entry point,
- DES SPEED:
    - •ECON: optimum speed limited by SPD constraints & SPD limit
    - •Preselected MACH and / or CAS: auto speed mode, the constraints are managed.



- Des thrust: **IDLE+Ɛ** (additional guidance margin)
- **Backward integration** based on equations of motion & flight mechanic (drag /thrust),



PERF DES

FL PLN

3 - FLIGHT PLAN PREDICTIONS

DESCENT PHASE

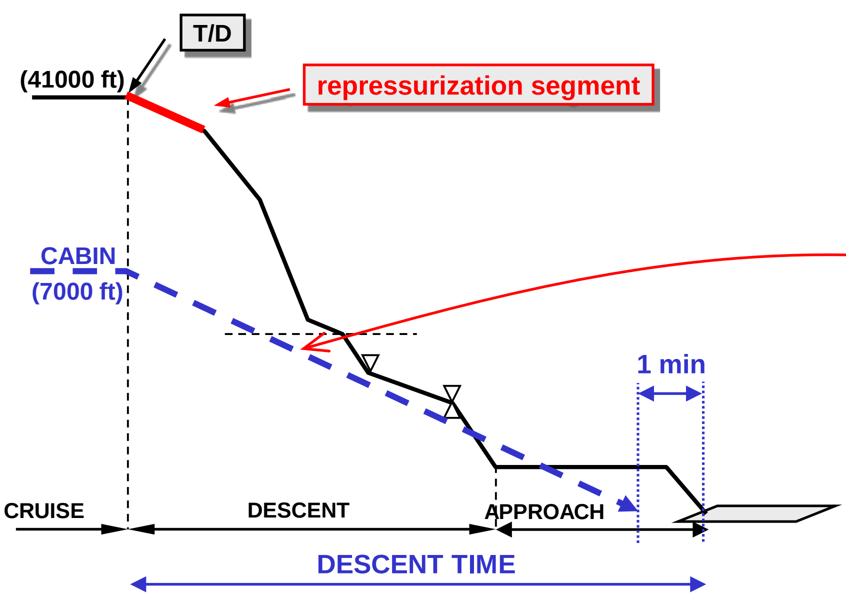
Repressization segment

Objective: increase the descent time to match the Cabin Descent Rate target

- The crew defines the “DES CABIN RATE” [default: –300ft/min sea level reference]
- The FMS inserts a repressurization segment so as to get :

  Descent time = (DEST pressure - CRZ CABIN pressure) / CAB RATE + 1min

- The descent time takes into account any descent constraints (alt, speed, approach phase…)
- The repressurization segment is a **constant vertical speed** [-1000 ft/min ; -1500 ft/min]

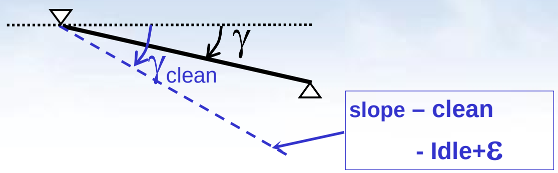


PERF CRZ

DESCENTE PHASE

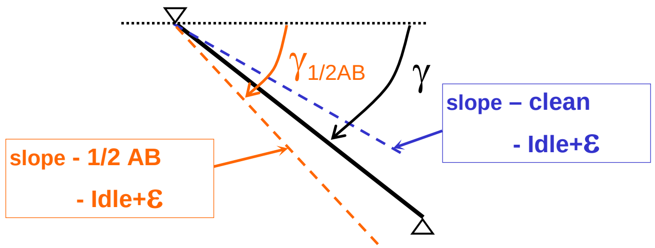
Altitude constraints management

- Between two altitudes constraint, the trajectory is a straight path : “geometric path”
- The flyability of geometric path is checked before flying



“Normal“ path $\gamma > \gamma_{Lisse}$

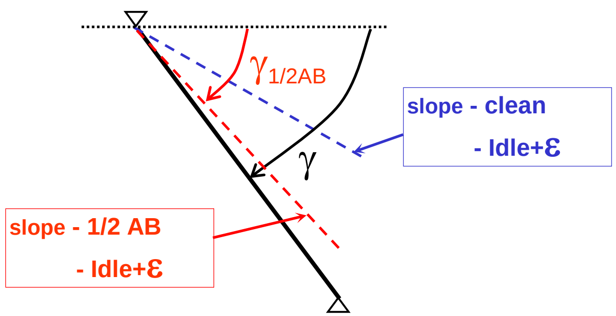
➔ the path can be flown in **clean configuration**.



"AIRBRAKE " path $\gamma_{Lisse} > \gamma > \gamma_{1/2\ AF}$

➔ the path can be flown **using airbrakes**.

➔ “**MORE DRAG**” message comes when flying the leg



"TOO STEEP“ path $\gamma_{1/2\ AF} > \gamma$

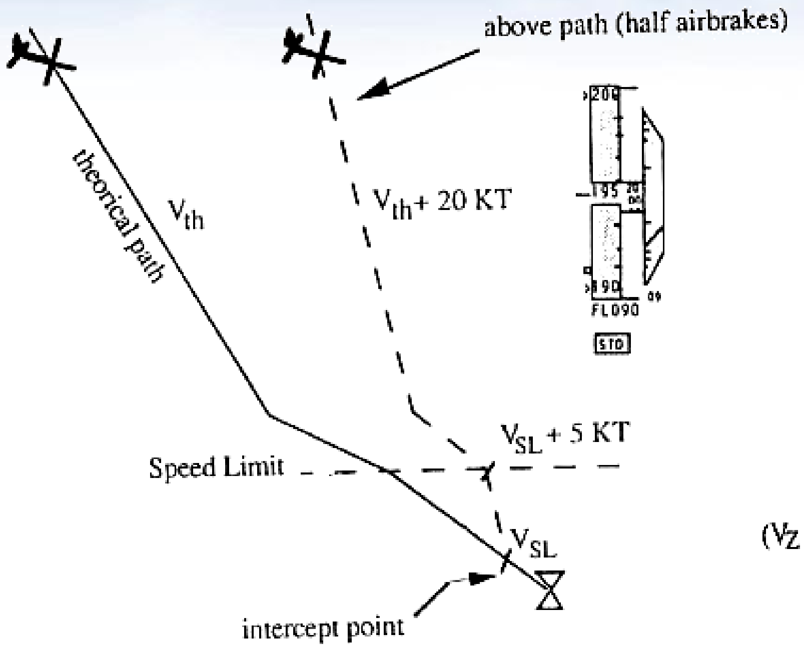
➔ the path **can not** be flown **even with half airbrakes**

➔ no predictions on this leg, the crew is informed since PREFLIGHT

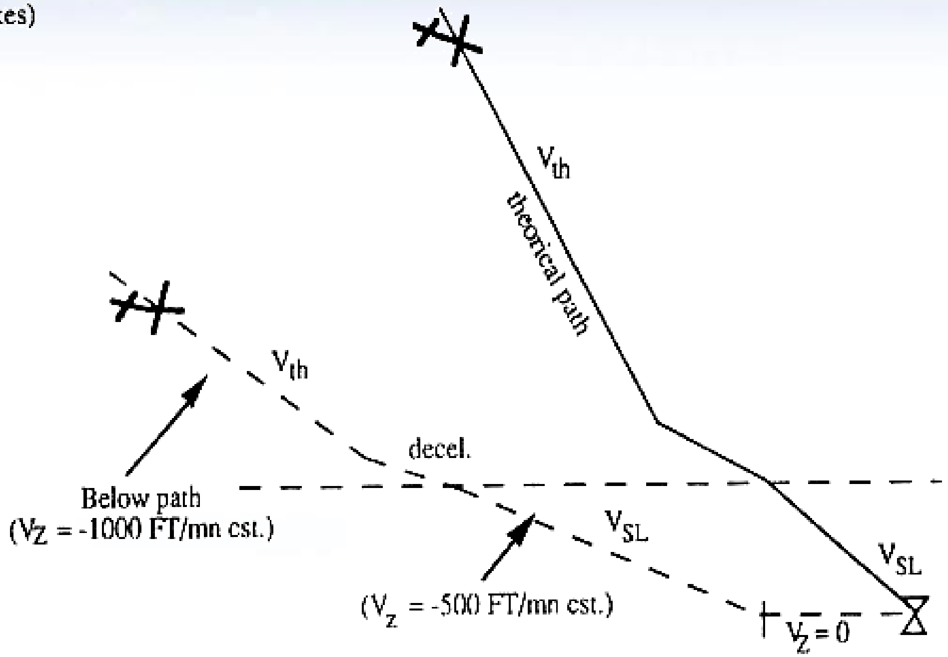
PHASE DE DESCENTE

Return to path predictions

➔ **When A/C is below theoretical descent path :**



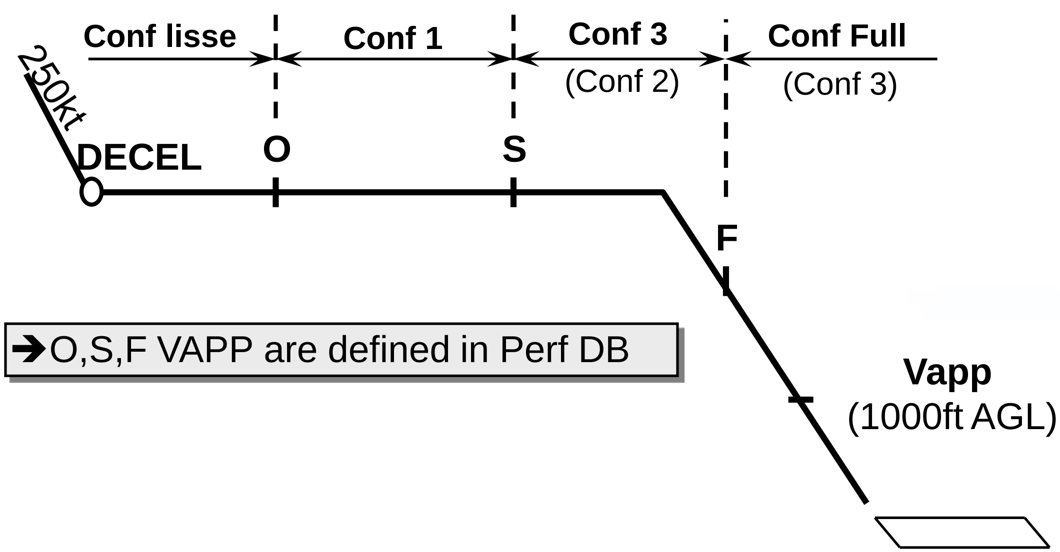
➔ **A/C above theoretical descent path :**



➔ message "**EXTENDED SPD BRK**" when the intercept point is at less than 2 MN from a ALT Constraint

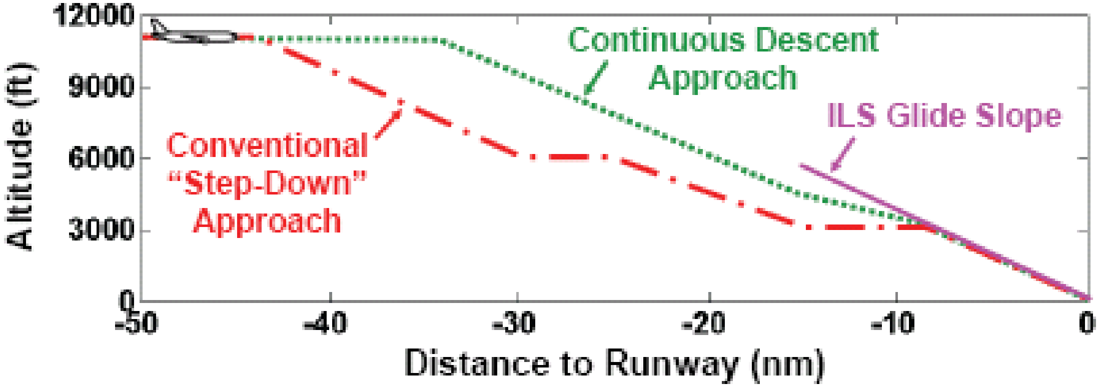
APPROACH PHASE general overview

DECEL: start of deceleration phase from descent speed to Vapp,
O: Slat extension speed,
S: First Flap selection (conf 2) then Landing gear
then second Flap selection (conf 3) if landing in conf FULL
F: Landing conf selection,
Vapp: Approach speed (at 1000Ft AGL).



APPROACH PHASE Continuous Descent Approach:

- Objective: **remove the level flight in approach**
- Benefit: **noise reduction**



➔ *FULL GEOMETRIC PATH IN APPROACH*
➔ Configuration change displayed on Nav Display

Adjustment of the FMS Perf model

→ Airline adjustment of the Fuel Consumption:

PERFORMANCE FACTOR

- → WFE = WFEmodel * (1+ PERF FACTOR/100)
- → range: [-9.9 ; +9.9], unit : %
- → Applied for climb / cruise / descent fuel computations

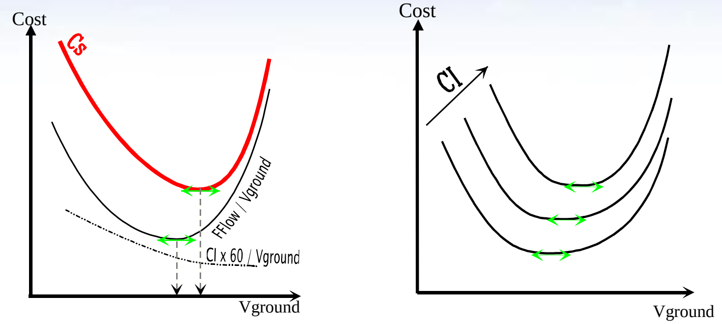
DEVIATION BETWEEN FMS and individual aircraft (aircraft aging)

→ Defined for each individual aircraft, measured by various possible methods such as APM analysis (Aircraft Performance Monitoring software) and valid for a given period.

Replaced by the CPDB (Customization Perf Database) on L3/S6 for A380/A350 (First FP1): not only correct fuel flow but also:

- Vertical Profile
- Flight Envelope
- Optimum Speeds

FLIGHT OPTIMIZATION



Important

OPTIMIZATION: FLIGHT AT MINIMUM COST

Total trip cost: $C = C_F \times Q_F + C_T \times T + C_C$

$C_{F:}$	Fuel cost ($/Kg)
C_T:	Hourly cost (maintenance flying personnel wage) ($/min)
Q_F:	Fuel consumption on the trip (Kg)
T:	Flight time (min)
C_F:	Constant cost (airport tax…) ($)

Flight parameters: SPEED & ALTITUDE

Parameters that depend on the flight parameters : **Q_F** et **T**.

Equivalent specific cost: $C_S = C/(C_F \times Dist)$: cost per unit of distance

$C_S = (FF + CI \times 60)/V_{ground}$ with **$CI = C_T / C_F$** : COST INDEX (Kg/min)

FF: Fuel Flow (Kg/h)

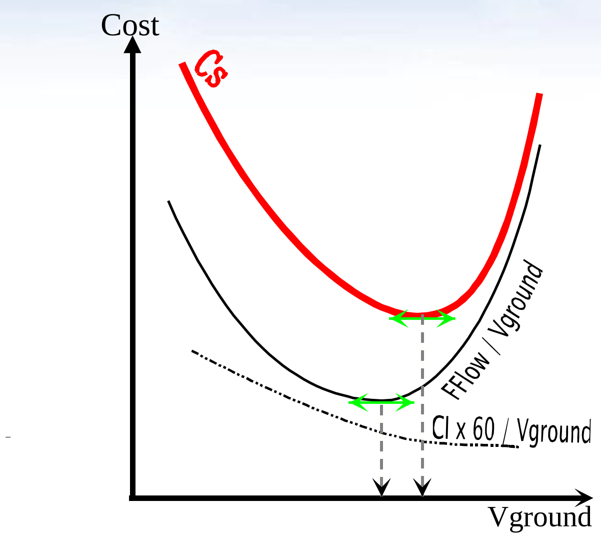
Vground: ground speed (Kt)

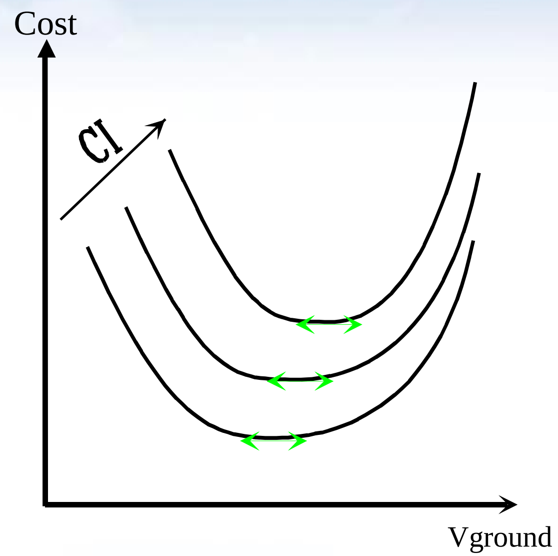
CI = 0. ← *Minimum consumption, Maximum Range speed*

CI = 999 ← *minimum trip time, Maximum speed*

OPTIMUM CRUISE SPEED

- Allows to minimize the cost of the flight versus CI criteria and local flight conditions
- Speed defined by the minimum Specific Cost





Depends on:
- CI
- GW
- Altitude
- Wind
- Temperature

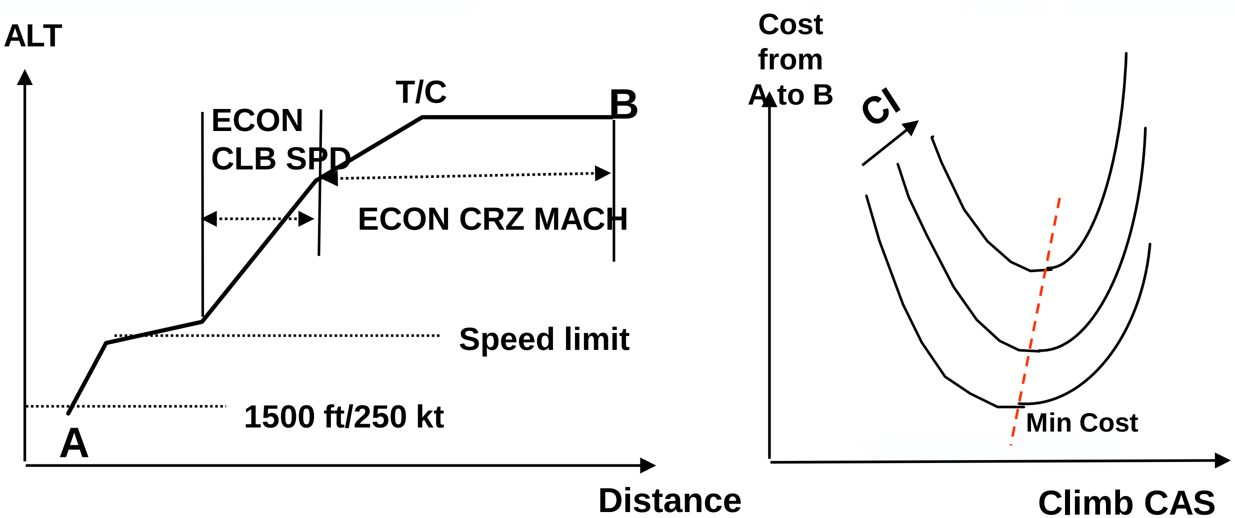
➔ *Complex computation → Precomputed speed (tabulated / polynomial)*
➔ *Limited to Greendot ; VMO-10kt / MMO-0.02 ; MCR thrust (MMO-0.015 for A340-500/600 / A380)*
➔ *Changing speed during the flight according to predicted / measured conditions*

OPTIMUM CLIMB SPEED

Climb at CAS / MACH that minimize the **flight cost**

➔ **CLB ECON MACH equal to OPTIMUM CRZ MACH**.

➔ OPTIMUN CLB CAS minimize the cost on a fixed distance including the climb phase (A/B)



CLB CAS depends on:
- CI
- GW
- CRZ FL

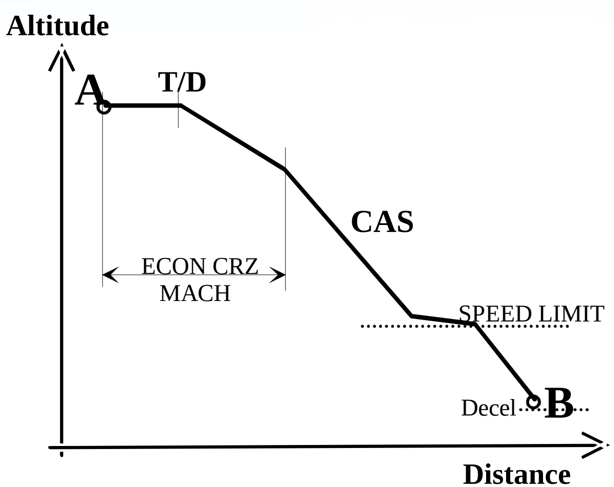
➔ *Complex computation* ➔ *Precomputed off-line speed*
➔ *Limited to 250kt and VMO-10kt or MMO-0.02*
➔ *CAS/MACH is frozen at the beginning of the climb*

OPTIMUM DESCENT SPEED

Climb at CAS / MACH that minimize the **flight cost**

➔ **ECON DES MACH equal to OPTIMUM CRZ MACH**.

➔ **OPTIMUN DES CAS** minimize the cost on a fixed distance including the descent phase (A/B)



ECON CAS depends on:
- CI
- GW
- CRZ FL

➔ *Precomputed speed*
➔ *Limited to 270kt and VMO-10kt or MMO-0.02*
➔ *CAS/MACH Econ frozen at 40NM before descent*

OPTIMUM SPEEDS WITH ENGINE FAILURE

With an engine failure the aircraft performance is degraded. In this case the trajectories is optimized versus obstacle avoidance in climb and cruise.

CRUISE BELOW EOMAXALT :
ECON CRZ speed adapted to Engine Out based on CI

DRIFT DOWN (engine failure above EOMAXALT):
"DRIFT DOWN" speed associated with MAXCont rating allows to keep the higher altitude on the trajectory:

➔ OBSTACLE avoidance strategy

CLIMB (engine failure below EOMAXALT) :
GREENDOT speed is designed to keep the highest altitude during the climb.

➔ OBSTACLE avoidance strategy

DESCENT:no performance issue: same ECON SPD as with all engines operative.

Optimization with time constraint: RTA

A time constraint can be introduced on a waypoint (or at destination)

- **Before take off** the FMS compute the take off time, with respect of entered CI. When the Take off time is missed, the FMS determines the Econ speed profile that match the time constraint (by iteration on an internal CI)→ This allows to minimize the fuel consumption with a time constraint.

- **In Flight** the FMS determine the Econ speed profile that match the time constraint (by iteration on an internal CI)
Rmq: the Econ Des speed is anyway frozen at 40NM before T/D.

- When the time constraint is missed (speed profile on the limits of the min or max speed envelope) the « **best time capability** » is displayed in F-PLN page.
The CRZ speed envelope with RTA is [Greendot ; MMO- ΔMMO, MCR thrust]

Holding speed

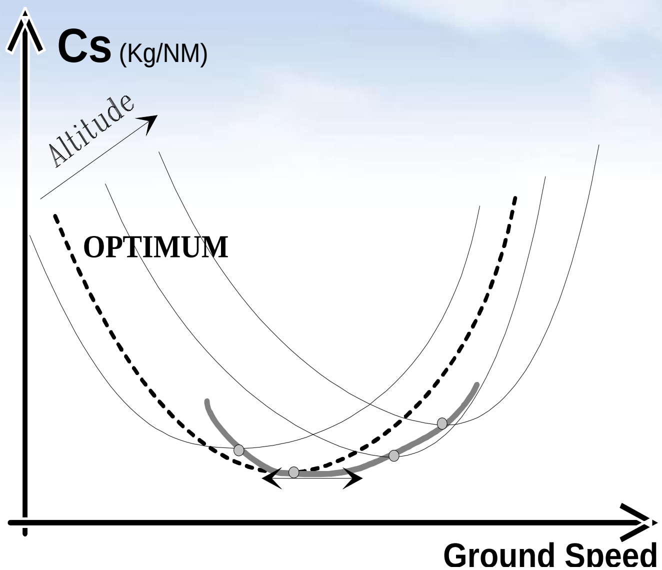
The FMS Holding speed is the "**Max Endurance speed**" that is optimized to minimize the **Fuel consumption per flight hour**.

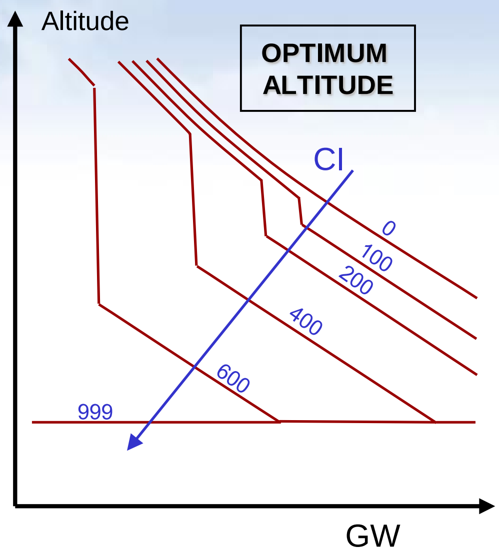
- **It depends on :**
  - **Flap configuration,**
  - **A/C Weight**
  - **Altitude**

➔ **It is precomputed and stored in the Perf Data Base**

OPTIMUM CRUISE ALTITUDE

Altitude that minimize the specific cost at the optimum speed.





depends on:
- CI
- GW
- **vertical wind profile**
- **vertical temperature profile**

- ➔ OPALT is a « in-line » computation
- ➔ OPTALT is continuously computed, rounded to 100ft.
- ➔ The flight time must at least 5min
- ➔ Anticipation of predicted wind on 500 NM ahead
- ➔ ***Accuracy of computation depends on completeness / accuracy of wind / temp entries***

FLIGHT ENVELOPE ON THE FMS

- Maximum Altitude
- Speed envelope

MAXIMUM ALTITUDE :

RECMAXALT all engines operative is defined by:

- can be reached with a minimum of 300ft / min
- allows a level flight at a speed higher or equal to Greendot and with a thrust lower than Max Cruise
- allows a buffet margin of 1.3g at least,
- below Max Certified altitude

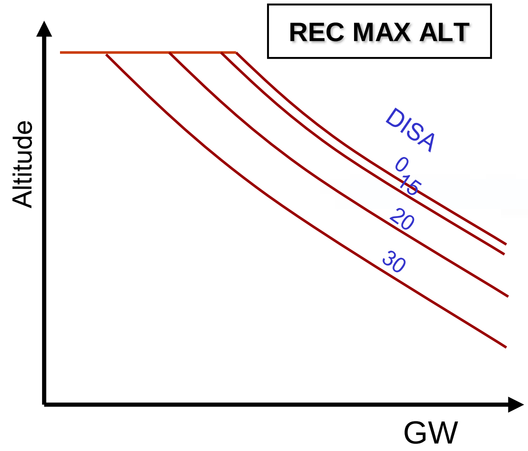
EOMAXALT is defined by:

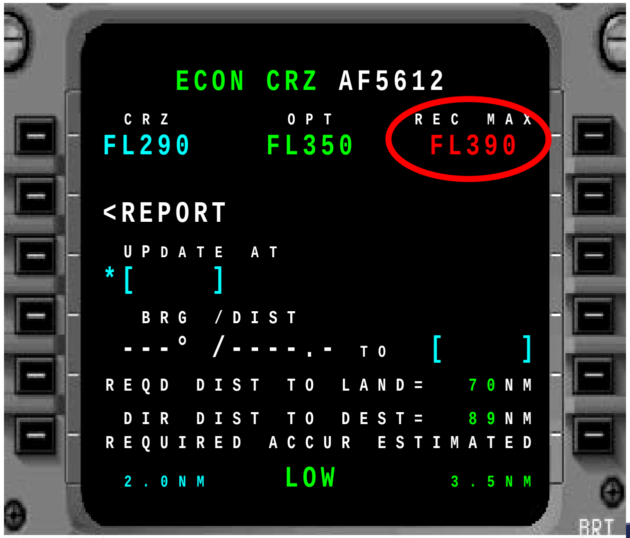
- Allows a level flight at a LRC speed with a MAX Cont rating on the operative
- Allows a buffet margin of 1.3g at least,
- Below Max Certified altitude

➔ RECMAXALT is continuously computed versus:
  * GW
  * Temperature

➔ RECMAXALT is computed for the best climb speed

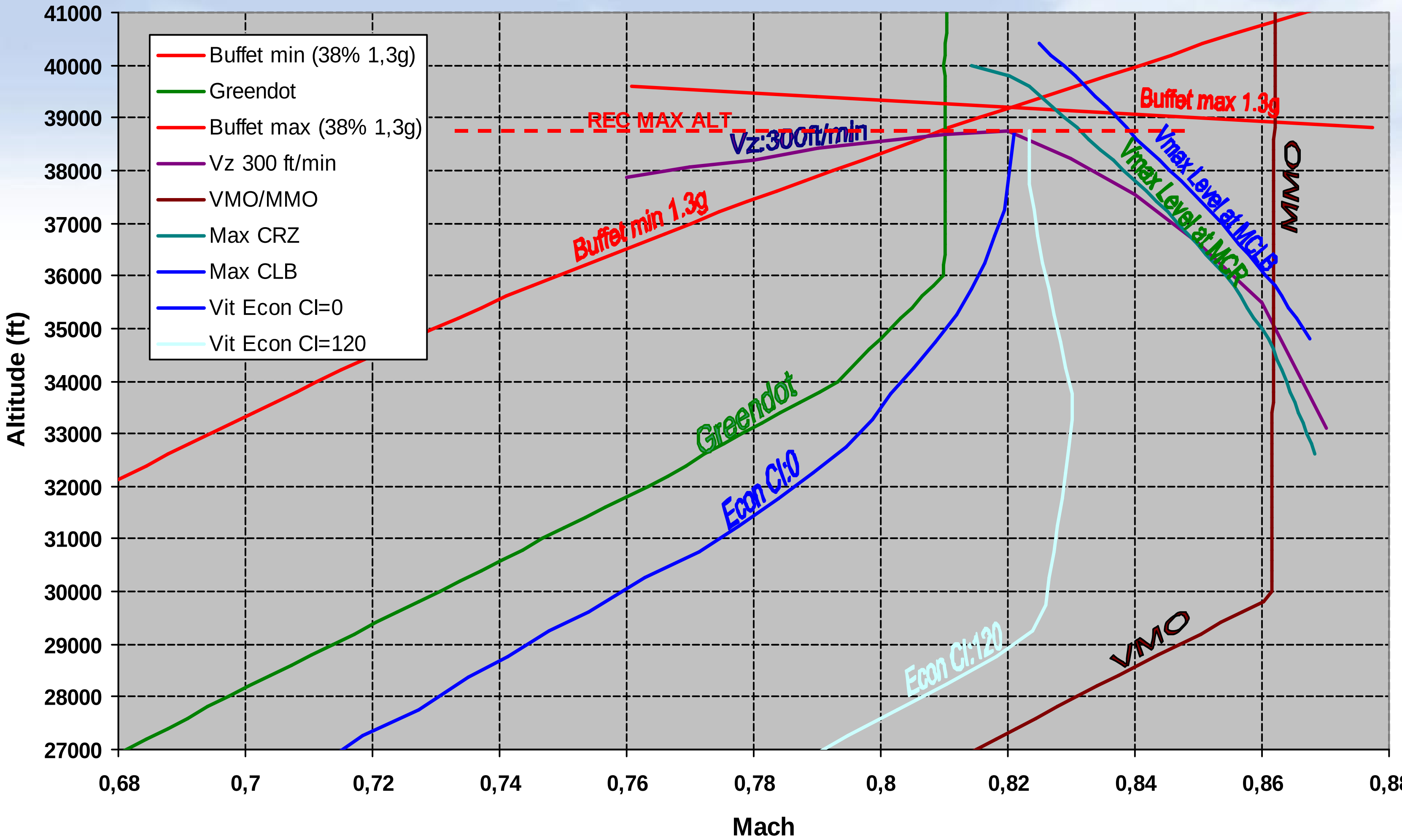
➔ RECMAXALT is a precomputed data



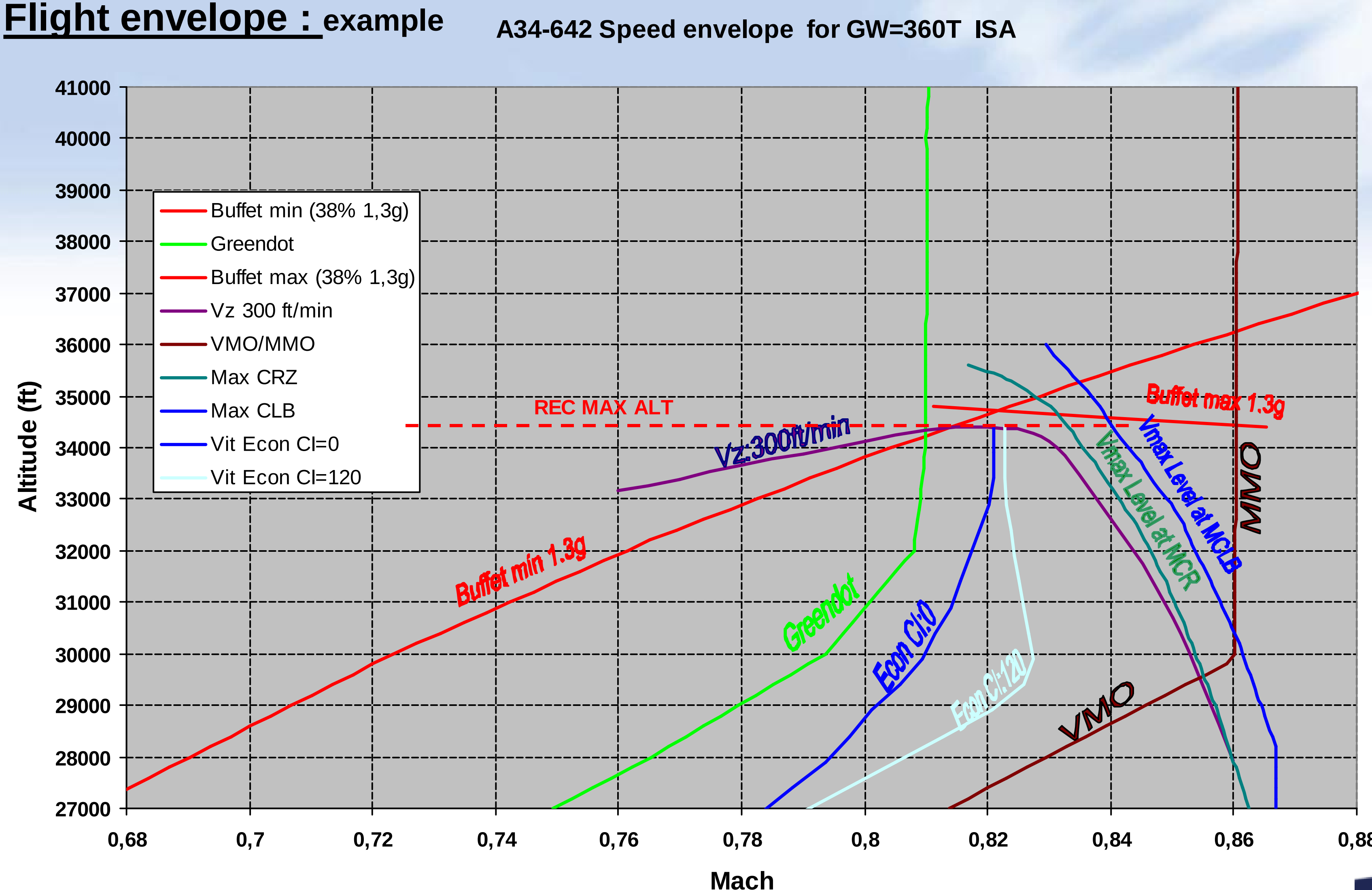


Flight envelope: example

A340-642 Speed envelope for GW=290T ISA



Flight envelope : example



ATMOSPHERIC MODEL ON THE FMS

Critical for predictions accuracy (fuel / time / trajectory)

- **Forecast Wind**
- **Forecast temperature**

FMS2 FORECAST WIND ENTRY:

➔ wind defined in bearing & velocity

➔ Possible insertion of the «TRIP WIND » on INIT page in Preflight
➔ Insertion of the destination wind on PERF APPR page
➔ Possible more detailed wind entry (more accurate):

Climb:

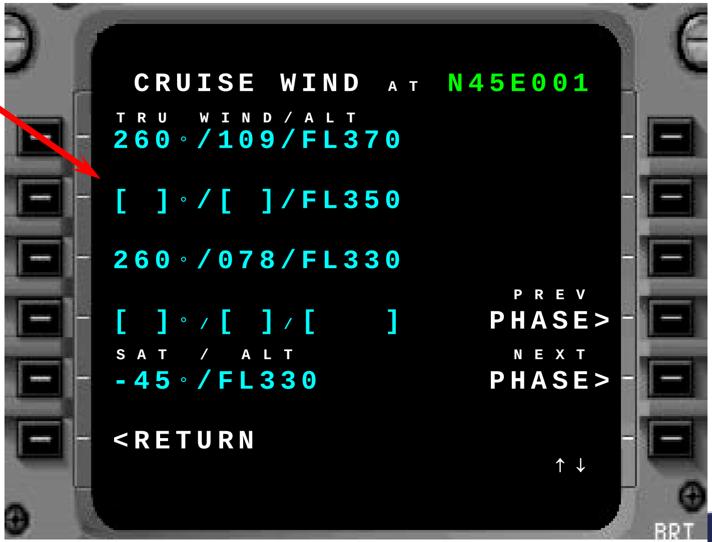
- on 4 altitude (FL)
- on ground
- possible reuse of "HISTORY WIND" recorded in descent.

Cruise:

- on each WPT of the cruise at the CRZFL
- **on 4 altitudes**

Descente:

- on 4 altitudes (FL)
- on ground (on PERF APPR page)
- measured wind is recorded in descent



➔ Manual entry on MCDU

➔ Uploaded by ACARS

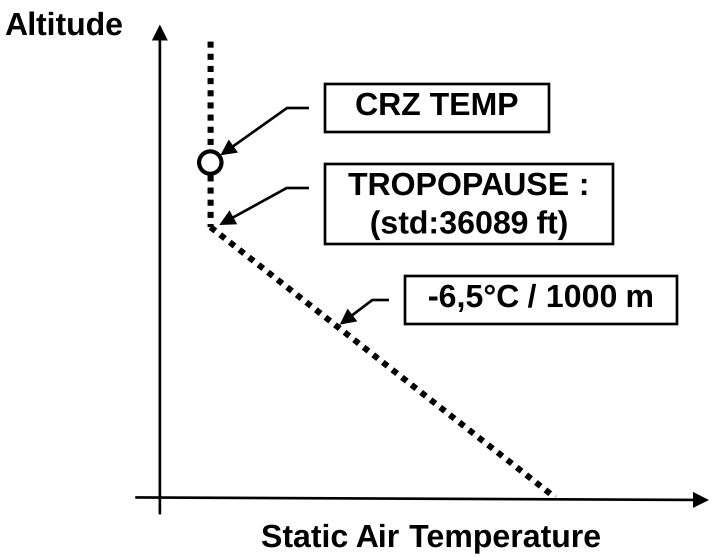
➔ Mesured wind is used to adjust forecast wind (predicted wind)

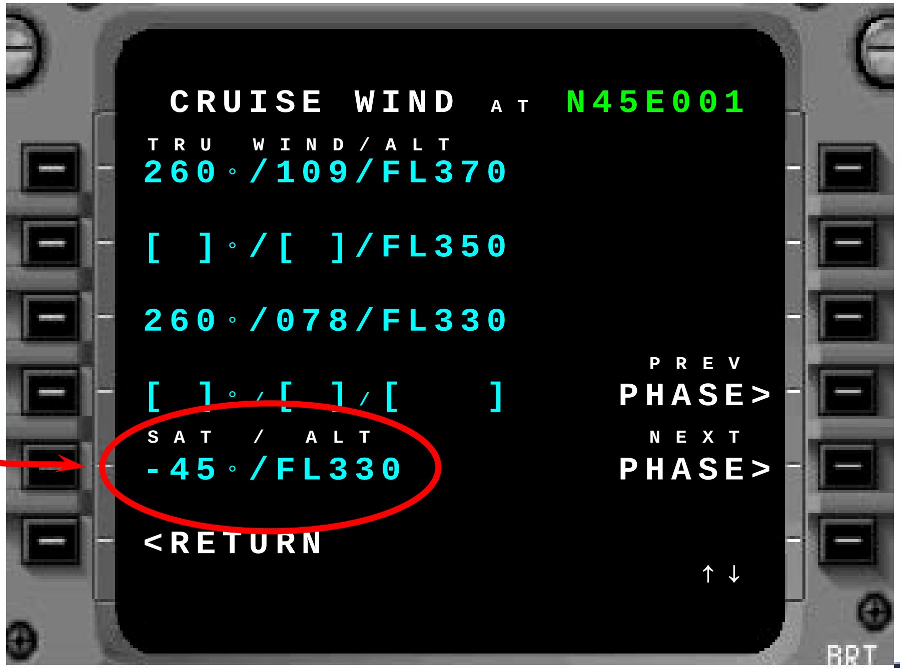
FMS TEMPERATURE MODEL :

The temperature is ddefined in SAT (Static Air Temperature)

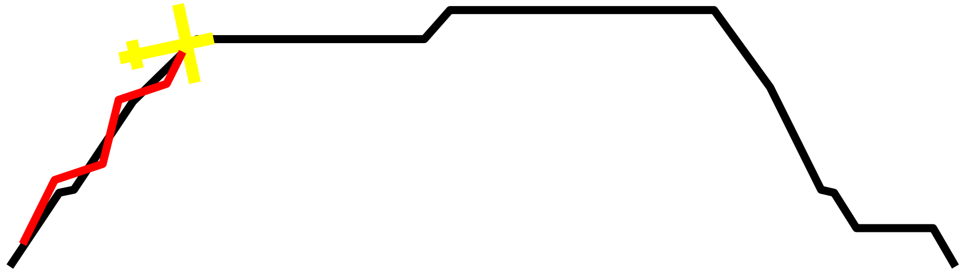
- One temperature can be defined for all the trip (TRIP TEMP): **ALT / TEMP / TROPOPAUSE**
- **Only one Tropopause setting for the trip**
- At each Waypoint: the TEMP at CRZ FL.

➔ The vertical temp profile is fixed by the pilot entries.





VERTICAL GUIDANCE

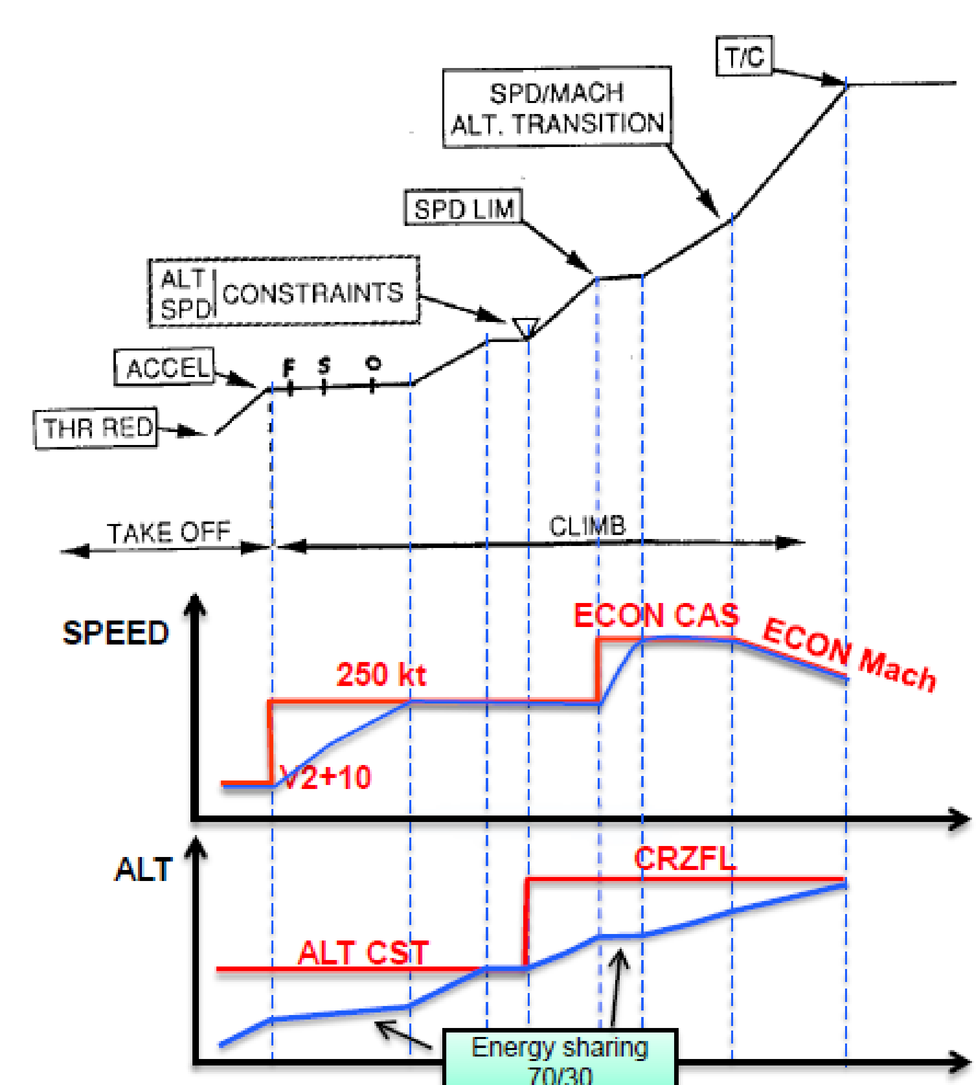


CLIMB GUIDANGE

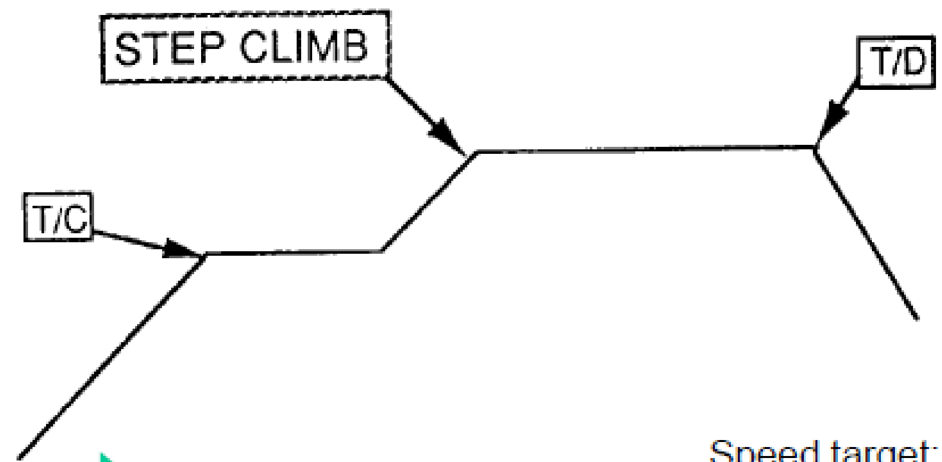
FMS
Vertical path

FMS Guidance
Targets

Guidance



LEVEL FLIGHT IN CLIMB OR CRUISE



Pilot action:
- Select CRZFL
- Select SPD mode auto

FMS sent to Auto-Pilot :

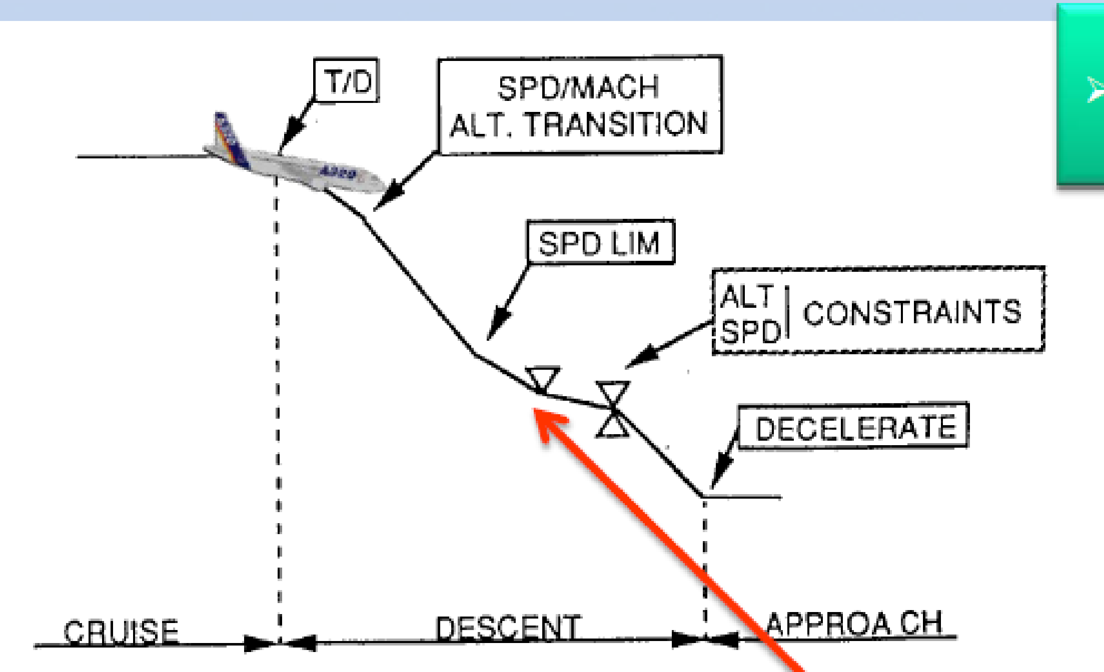
Speed target: CRZ ECON speed
ATHR: The speed target is controlled by the thrust

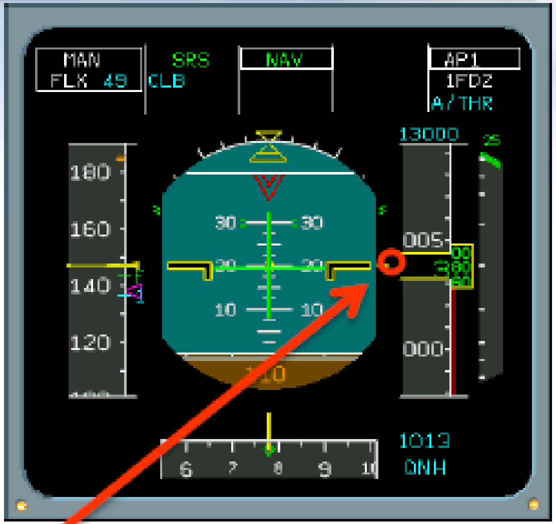
Altitude target: CRZ FL planned in FMS or FCU ALT
PA: The altitude target is controlled by the elevators

DESCENT GUIDANCE

Pilot action:

- Select Dest Alt / Engage DES
- Select SPD mode auto

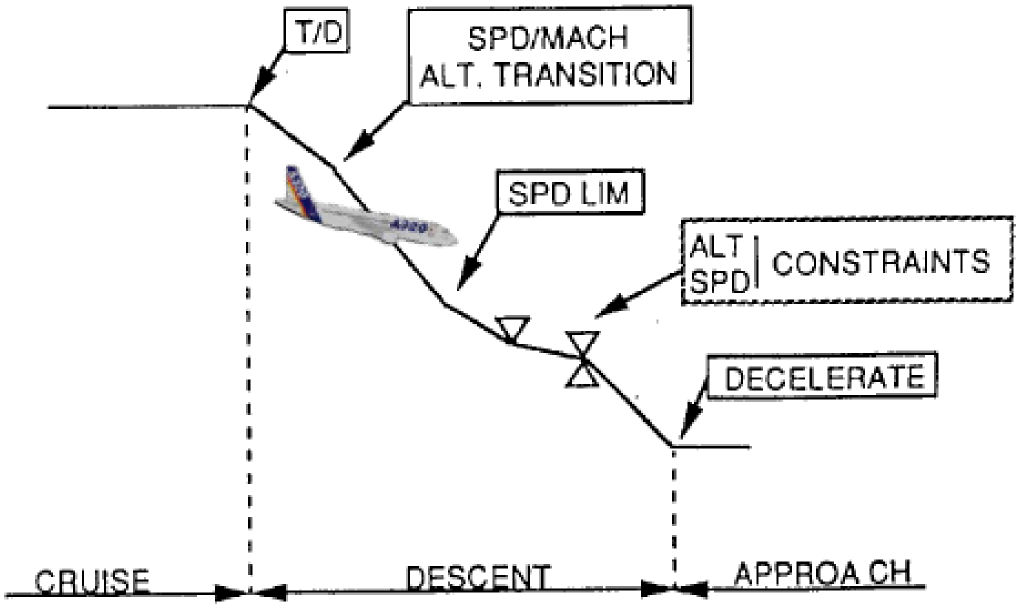


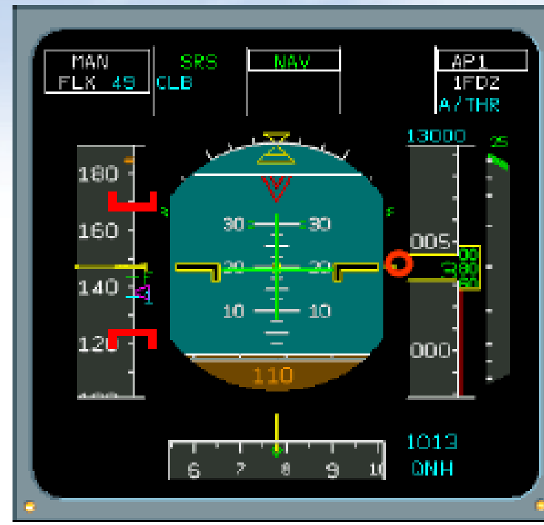


Vert Path Target

FMS uses the computed DES path as GUIDANCE PATH

DESCENT GUIDANCE





A/C ON path, FMS computes targets:

Pitch target: in order to follow the vertical path
PA: The pitch target is controlled by the elevators
VPATH mode

Thrust target (N1) : Idle + Delta (Idle if overspeed)
ATHR: The thrust is controled by FMS based on Perf Model

DESCENT GUIDANCE

Guidance mode VPATH/THRUST → VPATH: the A/C is following the computed FMS vertical path

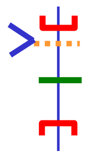
→ THRUST: the FMS sends the thrust target to the engines (N1 or EPR)

The descent speed is free around the target speed; inside a ±20Kt range or ±5Kt when overflying a speed constraint.

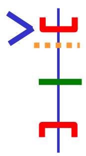
The FM sends - to the FADEC the thrust setting parameter: IDLE+ε used to compute the descent path

- to the FG a target slope.

REVERTION GUIDANCE MODE IN DESCENT



VPATH / IDLE

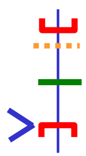


SPEED / IDLE:

→ target = DES SPD +20kt / Idle thrust

→ A/C leave the theoretical path (above path)

→ “return to path” predictions are displayed.



VPATH / SPEED:

→ the AUTOTHRUST adjust the thrust to keep the target speed on the path.

FMS PERFORMANCE MODEL

- Elaboration of FMS models
- Qualification of FMS models

8 - FMS PERFORMANCE MODEL

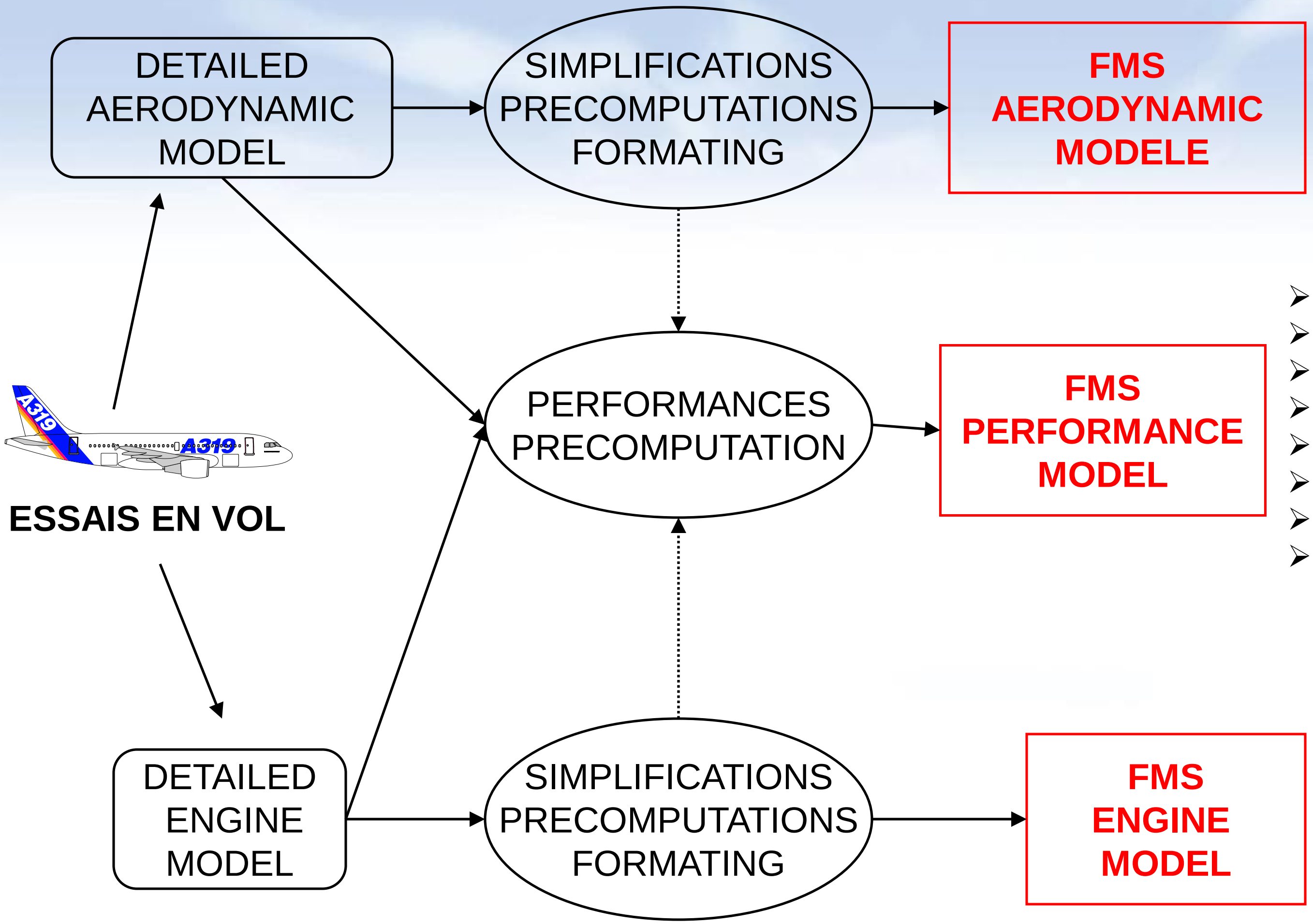
REQUIREMENTS ON FMS PERFORMANCE MODEL

- ➔ Representative of the official Aircraft Performance Documentation (FCOM)
- ➔ Consistent with Fixed FMS format (contractual technical specification)
- ➔ Compliant with DO200A regulation (assurance quality)

==> **REQUIRE SPECIFIC ELABORATION PROCESS**

8 - FMS PERFORMANCE MODEL

Elaboration Process

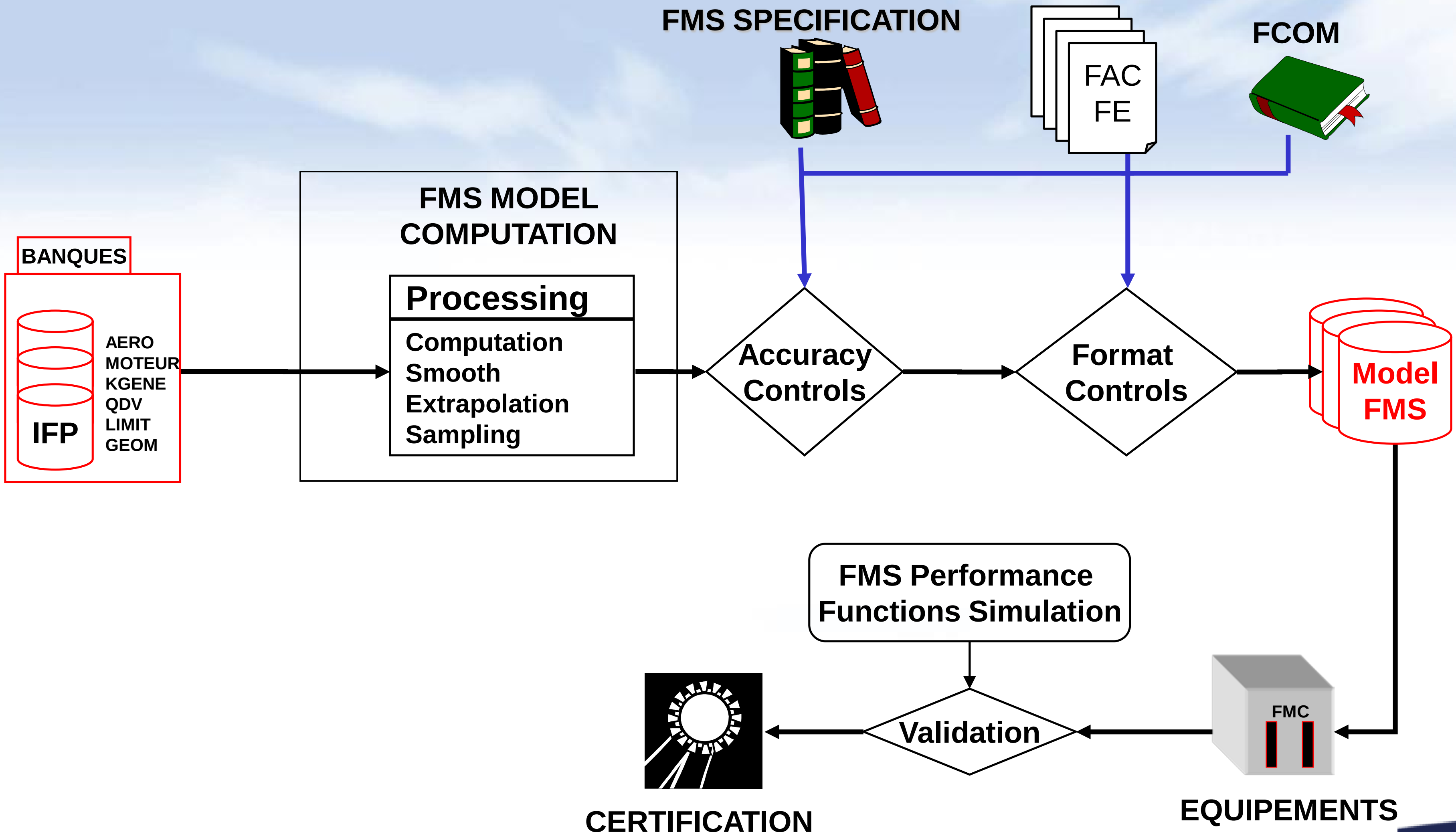


- DRAG polar clean / high lift.
- Airbrakes drag.
- Dissymmetric drag (engine failure

- Min speed. stall / buffet.
- Max speed. buffet / thrust.
- Operational speeds O,S,F.
- Holding speeds.
- Optimum CLB / CRZ / DES
- MAX Alt all engines / eng failure
- Take off run
- Alternate allowances.

- TSP Take off, Max Climb, Derate, Max Cont,, Idle.
- TSP / Thrust.
- TSP / Fuel Flow.
- Idle / descent margins.
- Engine windmilling drag.

FMS PERFORMANCE MODEL PROCESS

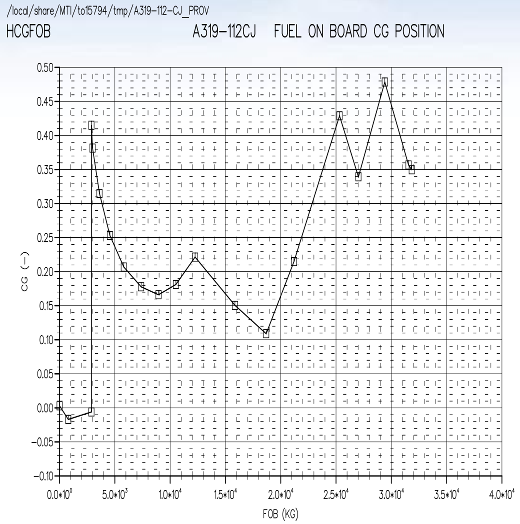


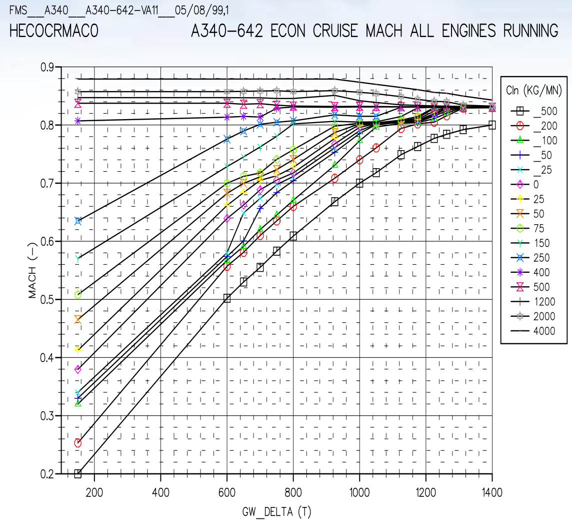
8 - FMS PERFORMANCE MODEL

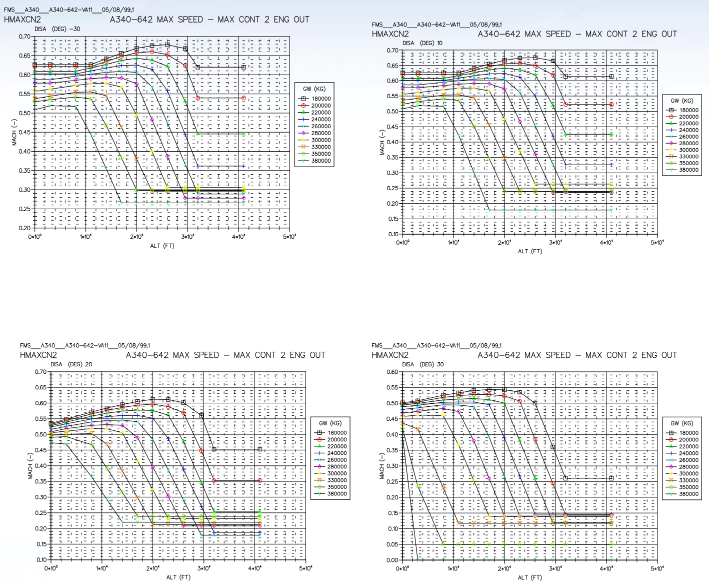
EXEMPLE OF DATA FORMATING

TABLES

CURVE : f(x) **NETWORK : f(x,y)** **SUPER NETWORK : f(x,y,z)**







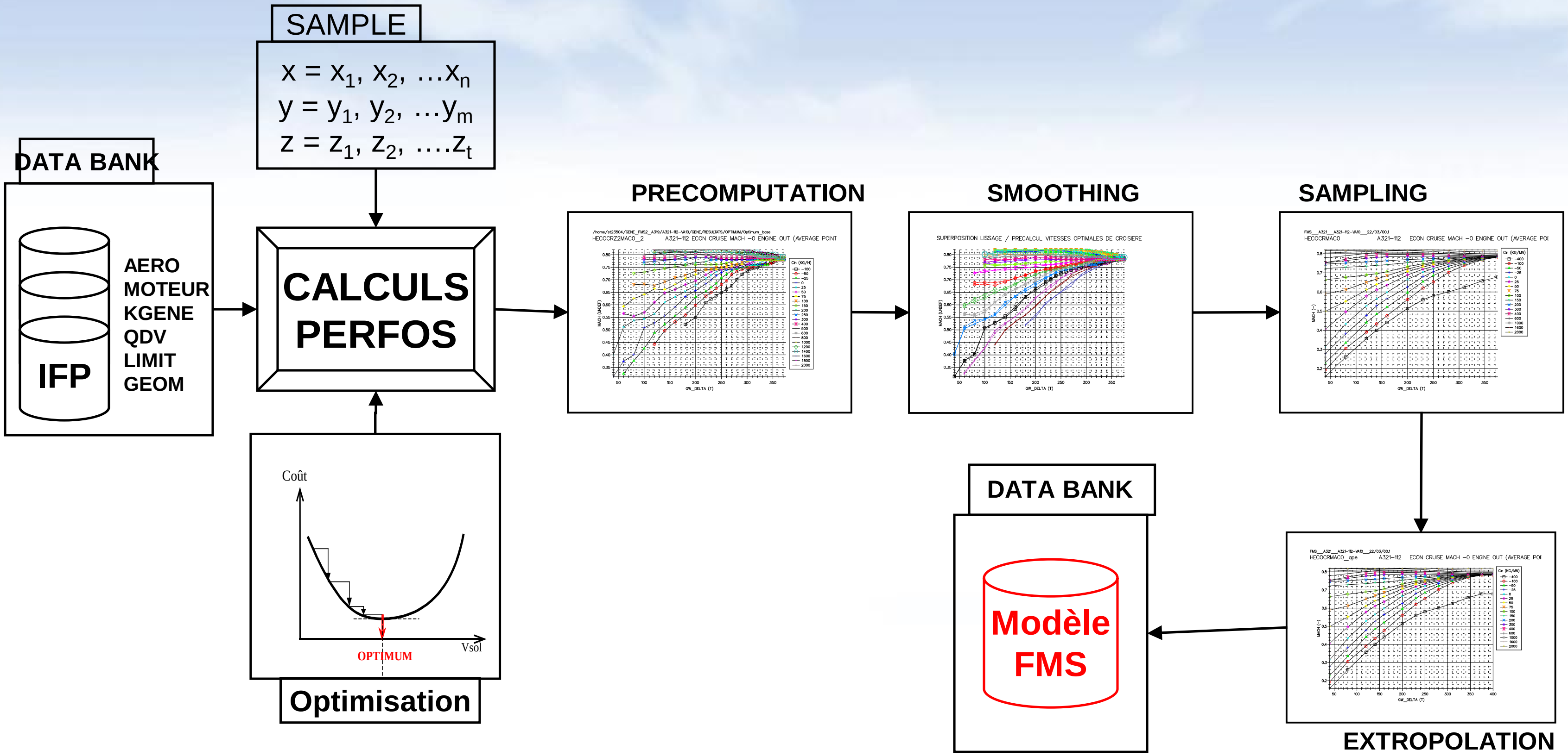
POLYNOMIAL FUNCTIONS

$$\textbf{Econ Descent Speed} = k_0 + k_1 \times GW + k_3 \times ALT + k_4 \times CI_{PF} + k_5 \times CI_{PF}^{\,2}$$

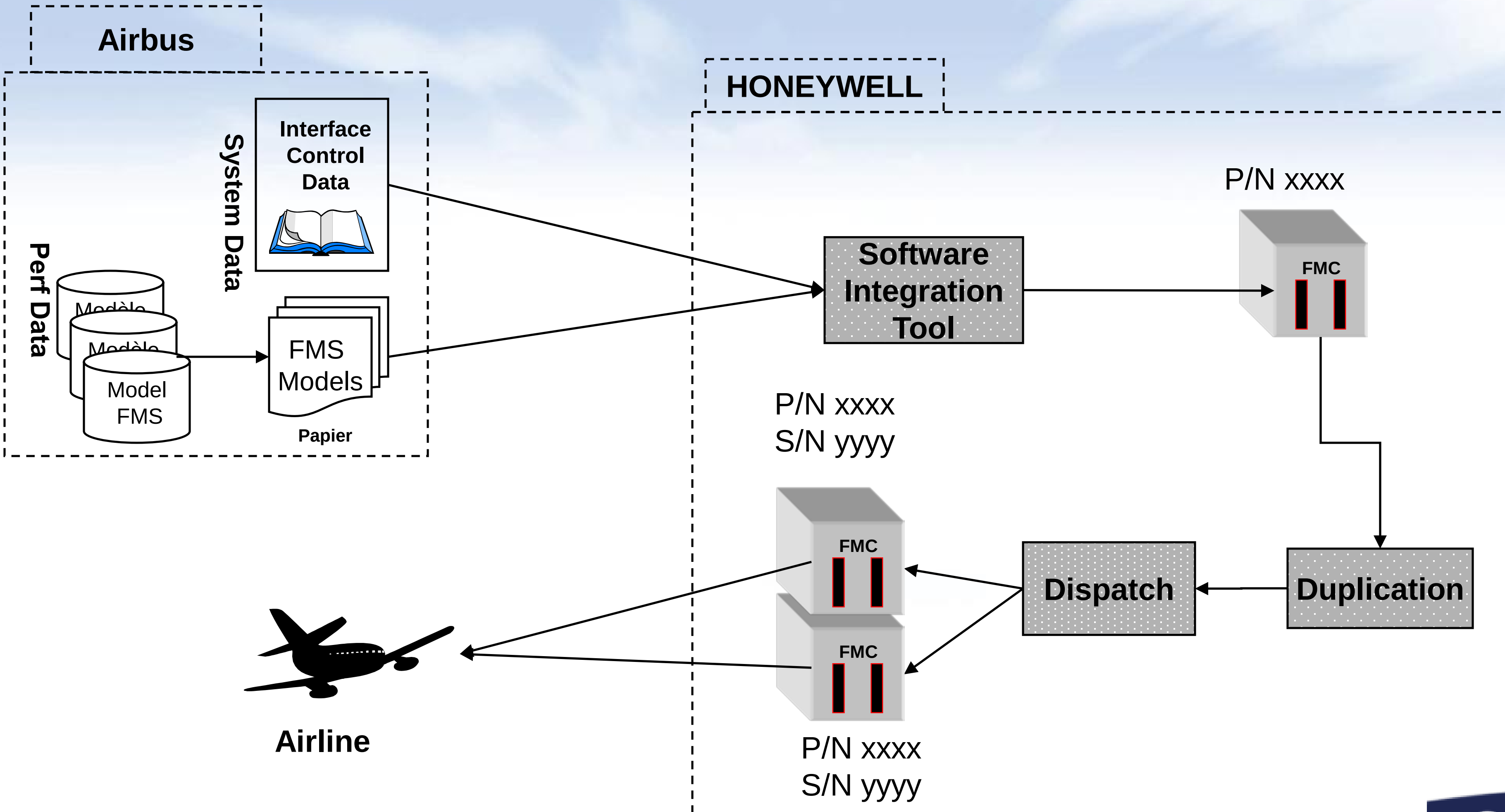
$$\textbf{Climb Fuel burn} = \left[d_1 + Max\left(0, \left(\Delta ISA - d_2\right) \times d_3\right)\right] \times GW \times \Delta ALT$$

Data Process

Ex: ECON CRZ SPEED

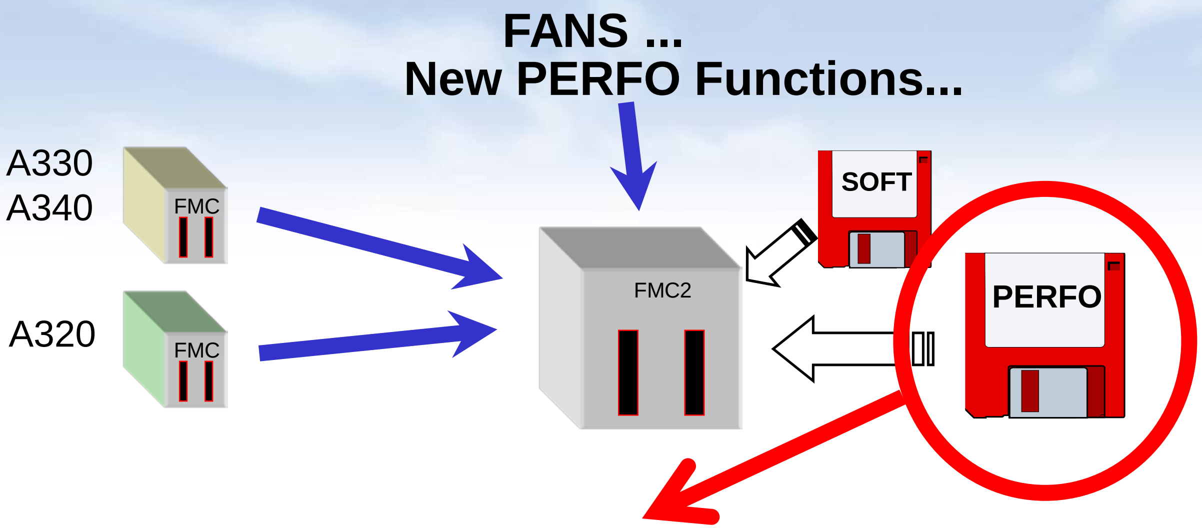


INTEGRATION PROCESS FMS 1st Generation



8 - FMS PERFORMANCE MODEL

Integration Process on 2nd generation FMS

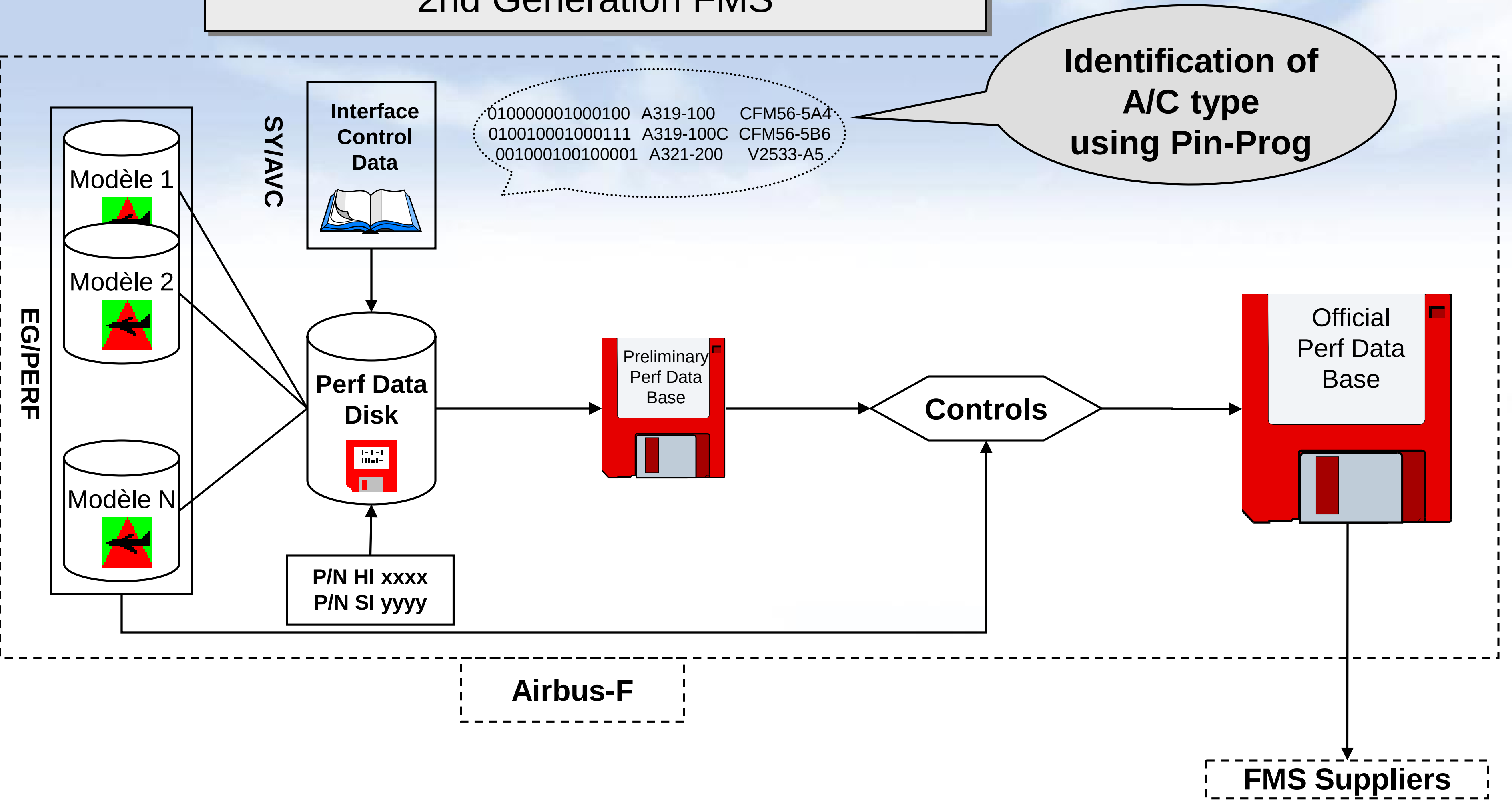


Objectives:
- reduce the update & integration cycle of the Perf Data Base

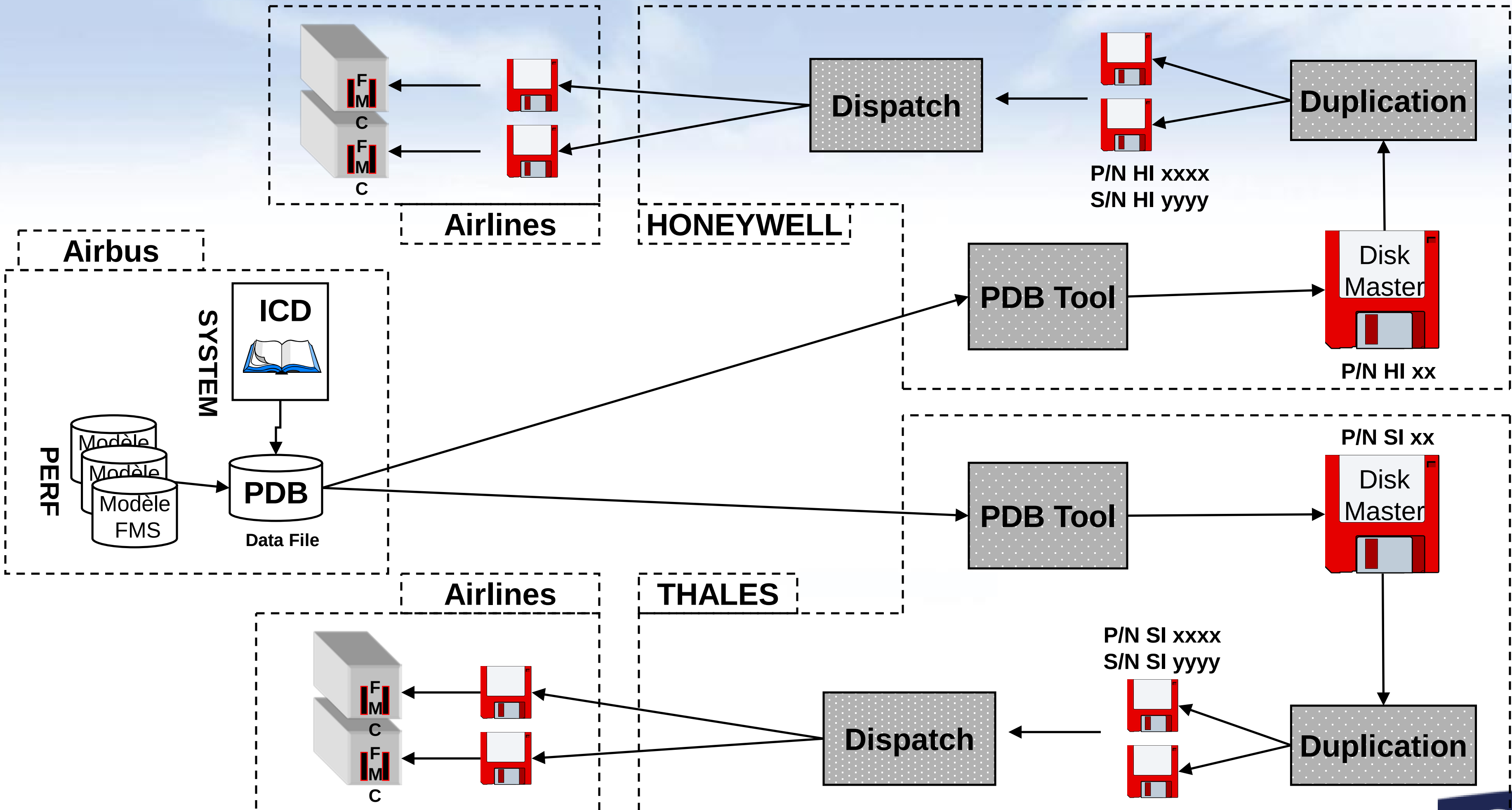
Leads to:
- physical independancy between software and data base
- reduce validation cycle on the equipment
- right level of quality integrity of the Perf Data Base

8 - FMS PERFORMANCE MODEL

ASSEMBLE and DELIVERY PHASES
2nd Generation FMS



Integration Process on 2nd generation FMS



DO200A APPLICATION

DO200A scope:

« Minimum standard for all Phases of the data process applicable to the processing of aeronautical data, including quality assurance and quality management… »

-**DO200A: Quality requirements on Data Elaboration Process so as to guarantee:**

- ✓ **Accuracy:** the data is consistent with the FCOM (inside tolerances)
- ✓ **Resolution:** consistent with originated data and FMS requirements
- ✓ **Assurance level:** confidence that the data is not corrupted while stored or in transit
- ✓ **Traceability:** ability to determine the origin of the data
- ✓ **Timeliness:** level of confidence that the data is applicable to the period of intended use
- ✓ **Completeness:** all of the data needed to support the function is provided
- ✓ **Format:** the data meets the FMS requirements

8 - FMS PERFORMANCE MODEL

- Qualification requirements -

classification	description	Software DO178	Aeronautic data DO200A
catastrophic	No safe flight and landing	A	1
hazardous	• Large reduction in safety margins • The crew could not be relied on to perform their tasks • Potentially fatal injuries	B	
major	• Significant reduction in safety margins • Significant increase in crew workload • Possibly including injuries	C	2
minor	• Slight reduction in safety margins • Slight increase in crew workload (routine flight plan changes) • Some inconvenience to occupants	D	
no safety impact	Do not affect : • Operational capability • Increase workload	E	3

FMS Perf Model classification

validation by application (eg: flight tests)

Referentiel required

validation or verification required

important STEP

No requirement

No referential required

AIRBUS

AN EADS JOINT COMPANY
WITH BAE SYSTEMS