Flight Control and Guidance (from the pilot's perpective, part 1) *Welcome!*

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SUPAERO

About this classroom (MAE208 course)

What will be taught in this classroom is:

- a quick overview on how to deal with the autopilot and FMS in a commercial aircraft from the pilot's perpective
- a very basic knowledge based on the Boeing 737NG systems
- how to manage a flight (with no abnormals) from A to Z regarding automation and lateral/vertical guidance for all phases of flight (more focus on descent)
- an opportunity to "fly" the B737NG on Flight Simulator

What will NOT be given throughout this classroom is:

- the access to a fully realistic flight simulation due to the available version of Flight Simulator 2004 that provides only a restricted utilization of FMS and/or LNAV/VNAV modes

Course breakdown

	03/02/2021 (16h – 18h30)	04/02/2021 (8h15 – 11h30)	05/02/2021 (8h15 – 11h30)
Whole class	**Part 1 : Flight control** (classroom)		
Group 1		**Part 2 : FMS** (computer room, training session on FS2004)	
Group 2			**Part 2 : FMS** (computer room, training session on FS2004)

Objectives

At the end of this presentation you will:

- Know and be confident in B737NG automatic control systems
- Know and be confident in how automation is used for operational needs, in particular LNAV/VNAV and FMS
- Know more about task sharing (between Cpt and FO) in a cockpit during normal operations

Table of Contents (part 1)

Chap1: Introduction

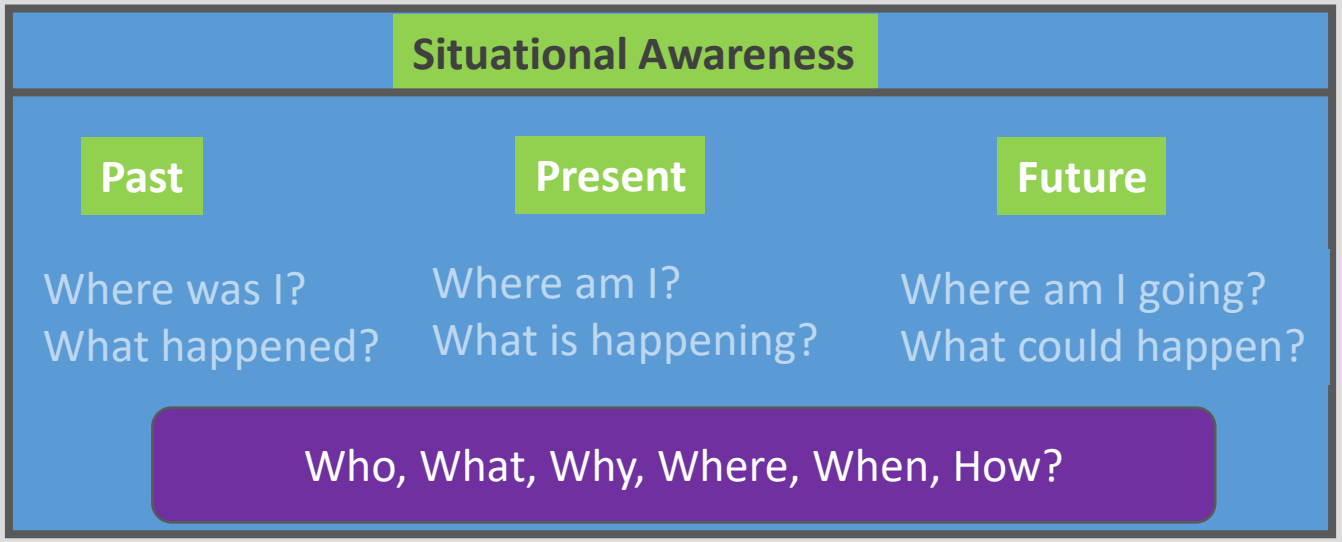
How to fly an aeroplane (automatic control)?

Why do aircraft have autopilot (automatic control)?

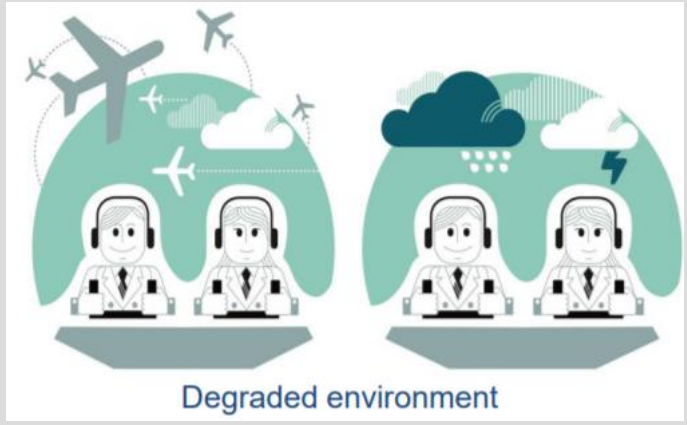
- In normal situations, computers have always been more precise than human pilots
- The automation reduces workload
- The automation gives you time to increase your situational awareness, and also more time for other onboard tasks like communication, weather avoidance, flight planning, …

Situational awareness

Situational awareness is your best survival tool



Crew Workload

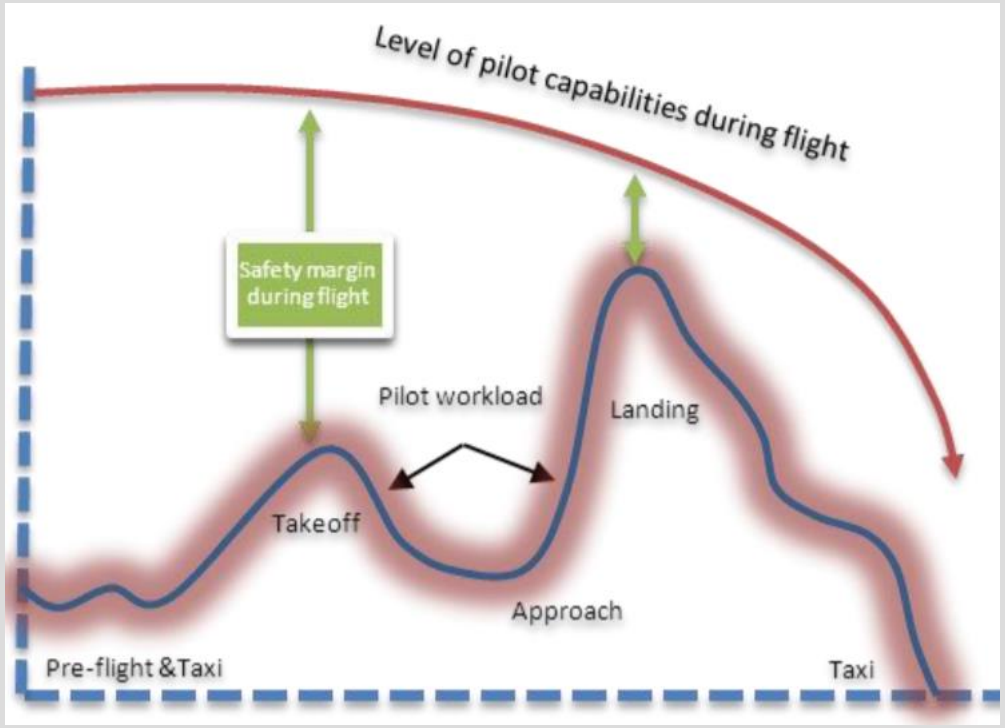


High-density traffic

Bad weather

Emergencies

Errors and inappropriate reactions are more likely to occur when the workload in the cockpit is high



Caution!

Workload management in a 2-man flight deck must be carefully done.

Sometimes automation (specifically the FMS) increases the workload!

Golden rule: back to basics!

Until the 80’s, most airliners were three-man flight deck aircraft: **the captain, the first officer and the second officer or flight engineer.**

The later was monitoring the airplane's instruments and calculating figures such as ideal takeoff and landing speed, power settings and fuel management.

- The flight engineer was replaced by computerized systems
- For instance, the Boeing 747 went from around 980 switches at the beginning (747-100) to 365 when the 747-400 was released

What's an autopilot on a commercial aircraft?

- The automatic control system is divided into 4 parts (in blue)

The FMS

Fully integrated Lateral/Vertical navigation system (LNAV/VNAV) and Performance system (1st input source for the FD)

Mode Control Panel - MCP

2nd Input source of path and target data (speed, altitude) for the flight director

The Flight Director – FD

Provides Pitch/Roll command magenta bar cues for heading, climbing, maintaining a certain altitude, …

The Autopilot – AP

Provides Pitch/Roll commands for elevator and ailerons

The Autothrottle – AT

Provides thrust control

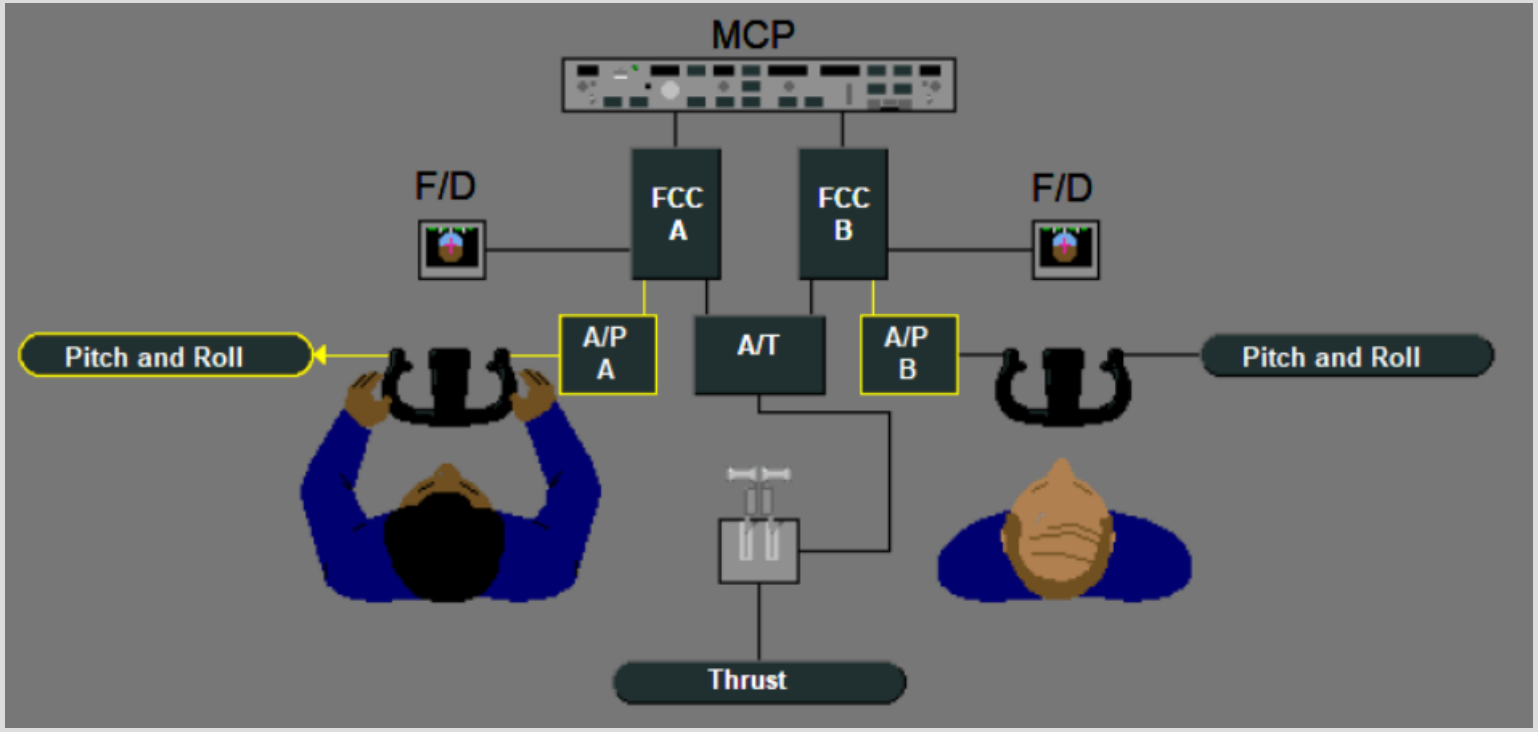
How do all these modules look like?

- Mode Control Panel (MCP)

Most autoflight system modes are changed with the MCP

We also find **LNAV and VNAV buttons**
(when activated, the FMS controls the aircraft)

- The Autopilot (AP)

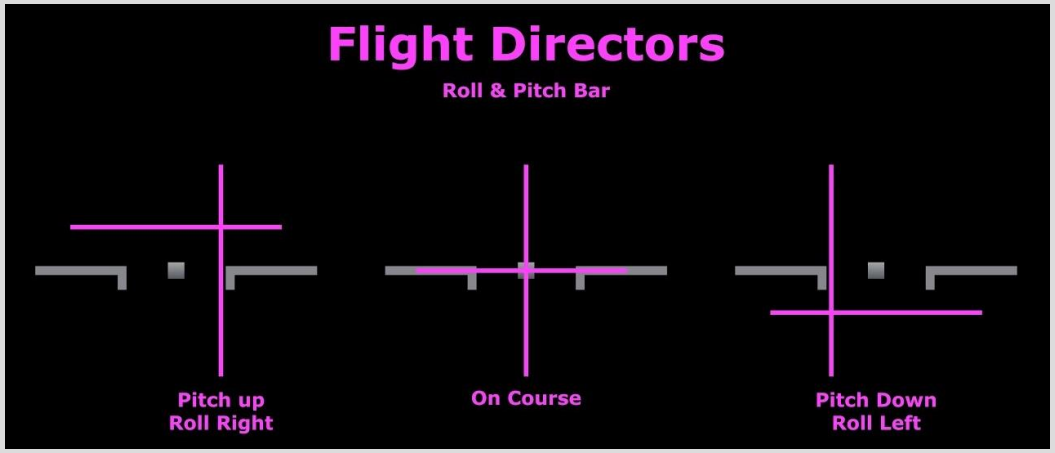


There are 2 autopilots on the B737 (named A and B)

Each autopilot is controlled by a Flight Control Computer/FCC (FCC A for autopilot A, FCC B for autopilot B)

The **FCCs calculate thrust, pitch and roll parameters for the autoflight system**

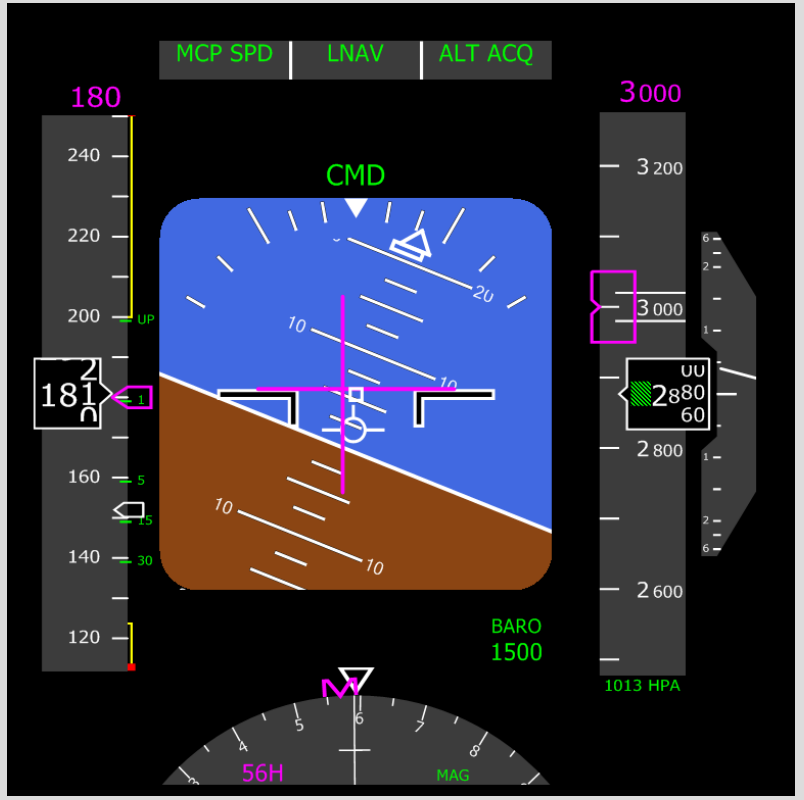
- The Flight Directors (FD)

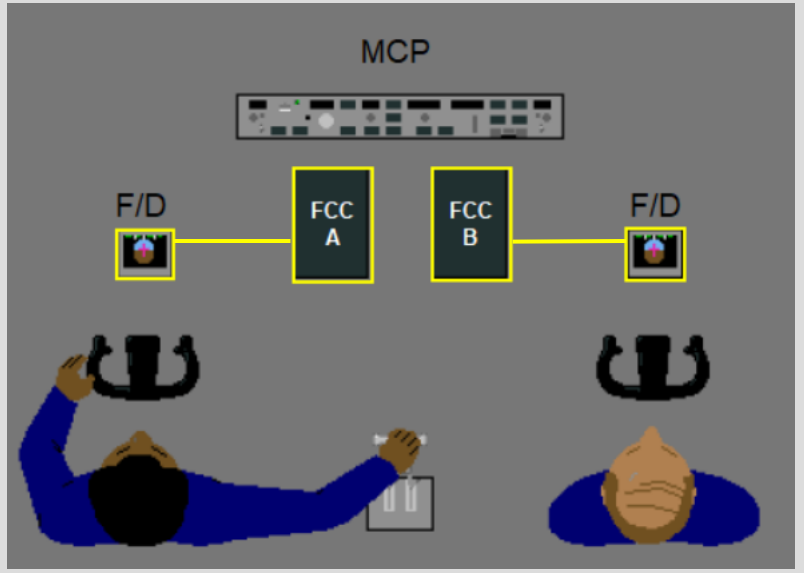


The magenta command bars tell you what to do

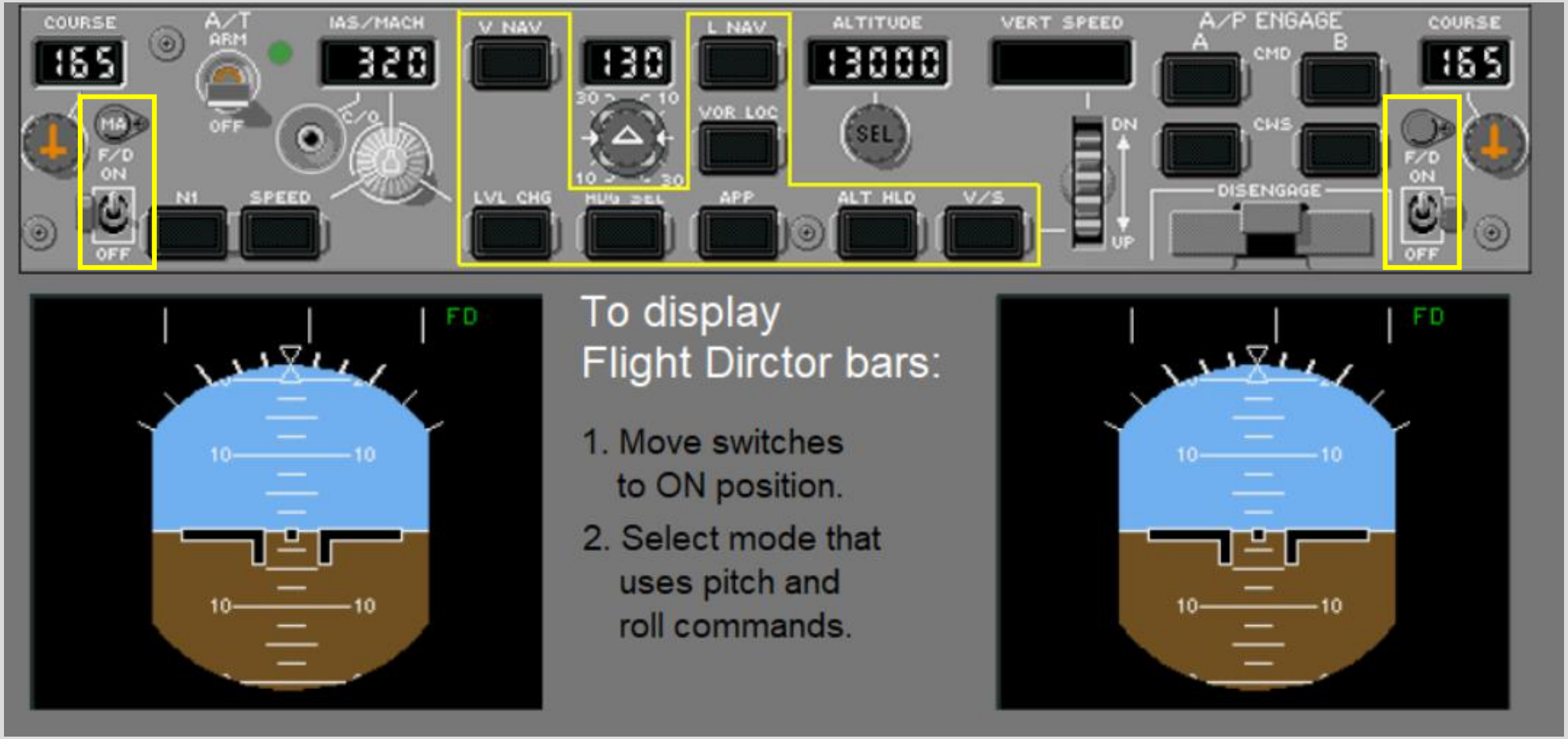
Provides Pitch/Roll command magenta bar cues for heading, climbing, maintaining a certain altitude, …

Left FD is controlled by FFC A
Right FD is controlled by FCC B



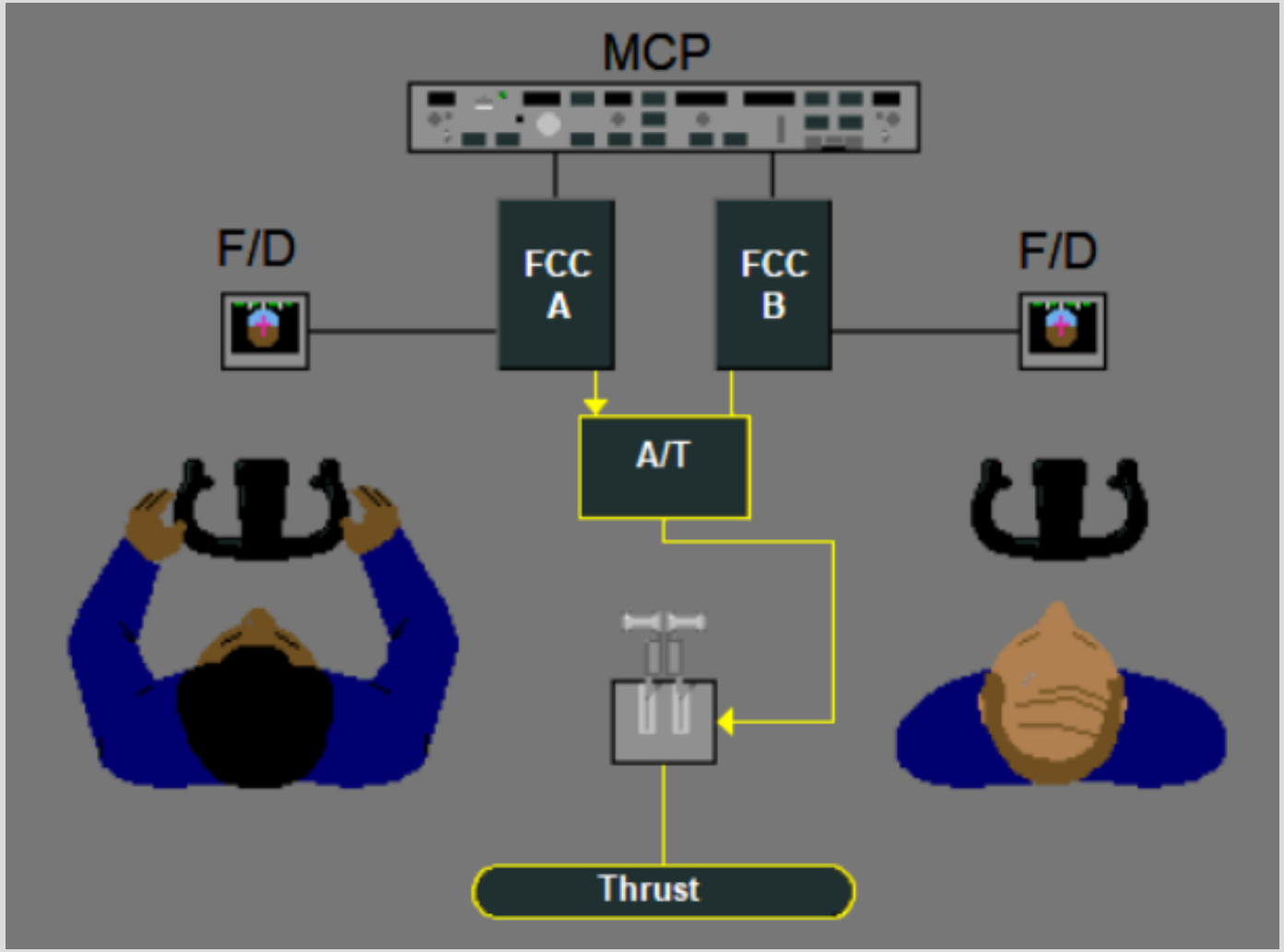


How to display Flight Director bars?

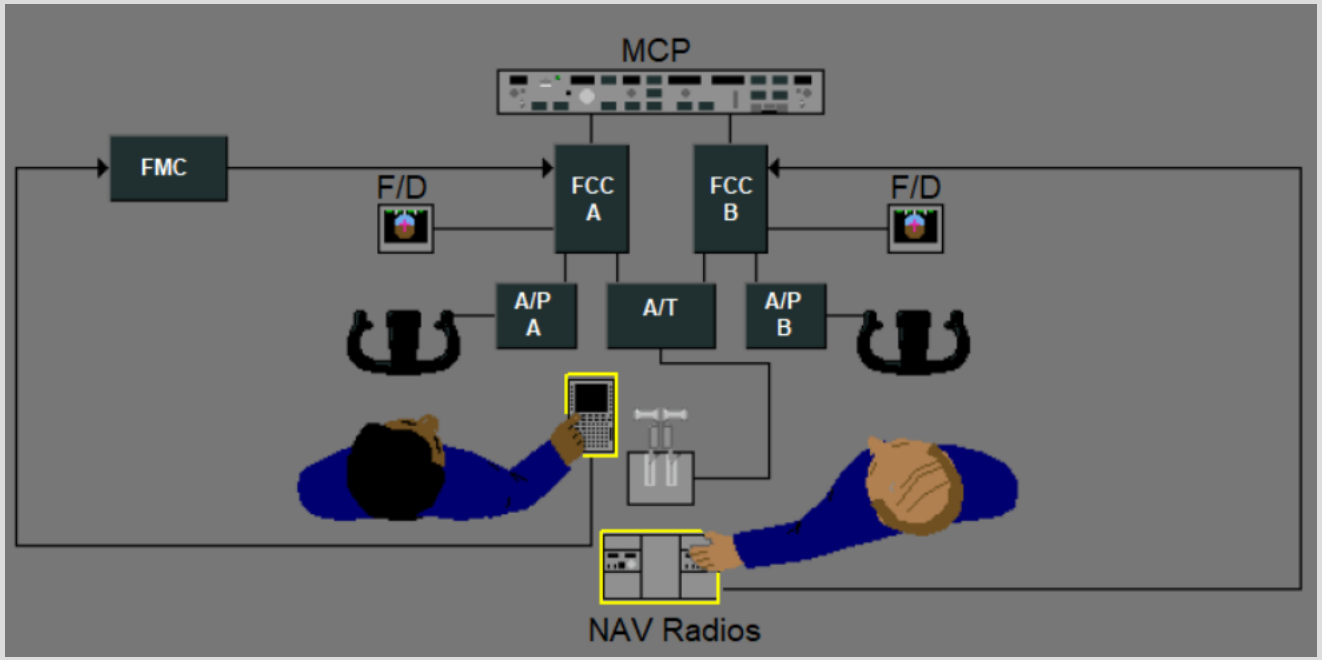


- The Autothrottle (AT)

The Autothrottle receives input commands from the FCCs to control thrust levers



➢ The Flight Management System (FMS)



FMS (through its computer FMC) allows the pilots to insert inputs for the autoflight system (AP, AT, FD, MCP) via the CDU

Page Display
displays data

Brightness Control
adjusts brightness of the Page Display

Alpha-Numeric Keys
to type data into FMC

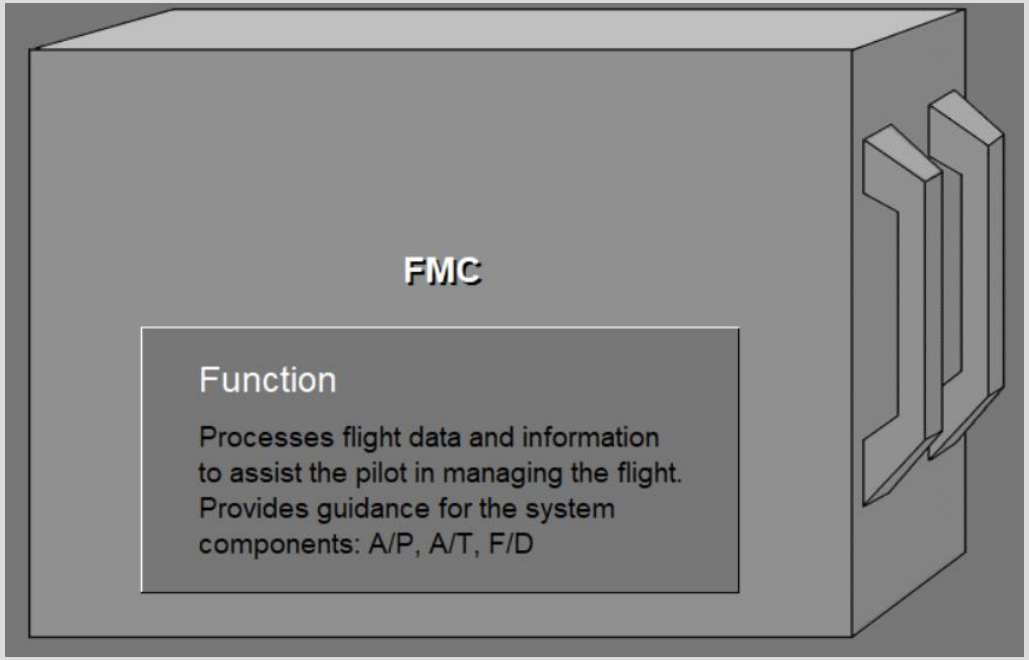
Line Select Keys
to move data in the Page Display

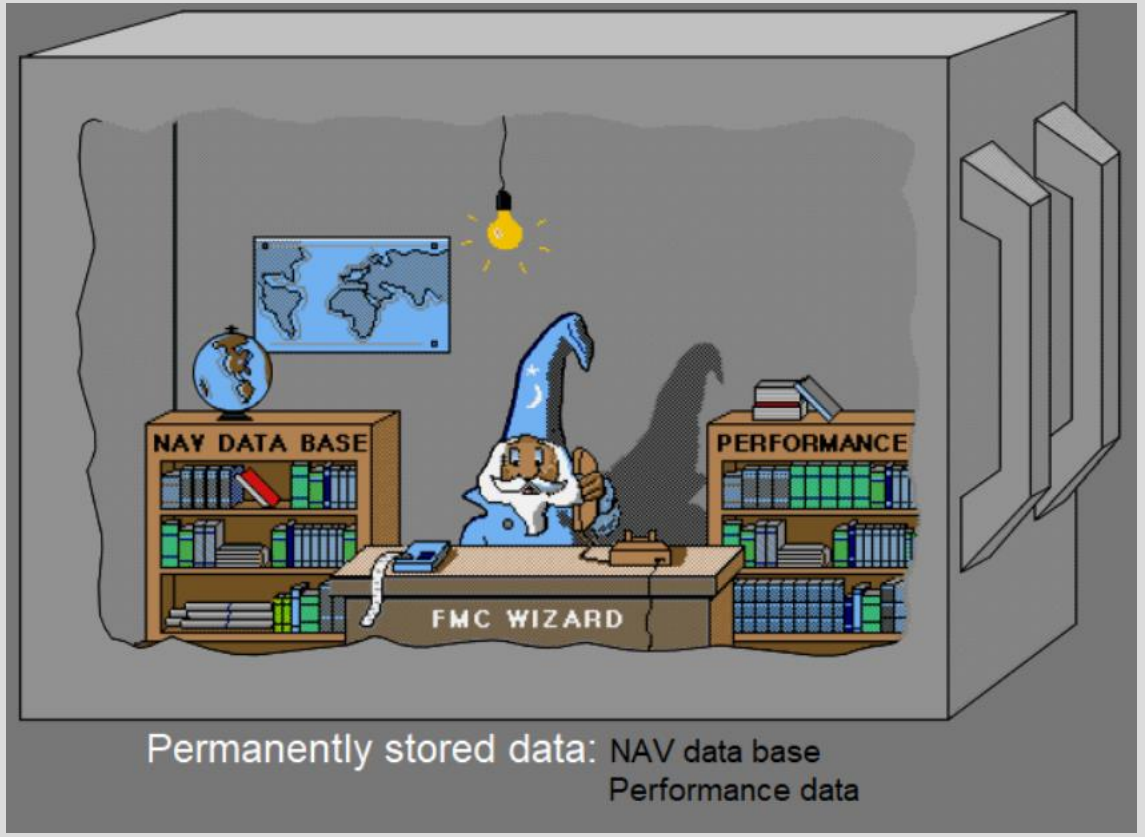
Execute Key
tells FMC modifications or entries are complete

Mode Keys
control the page displayed on the Page Display

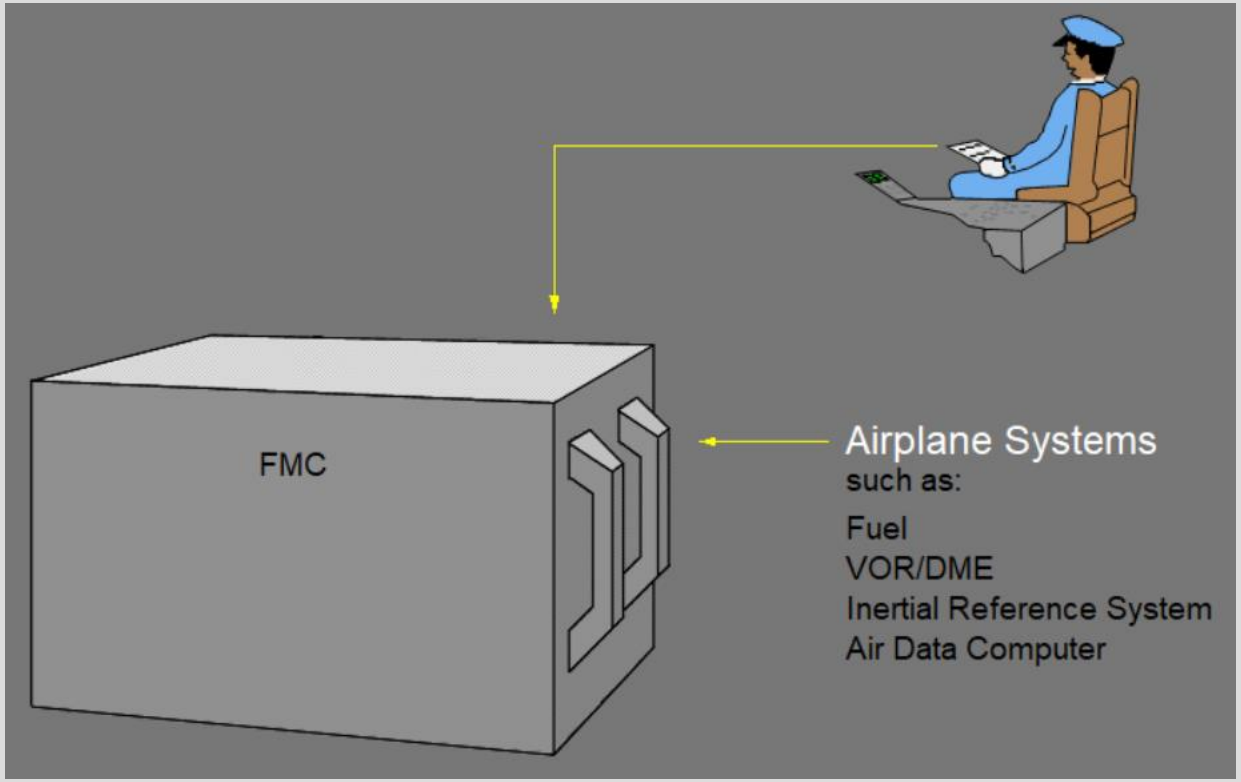
CDU (Control Display Unit)

Flight Management Computer (FMC)





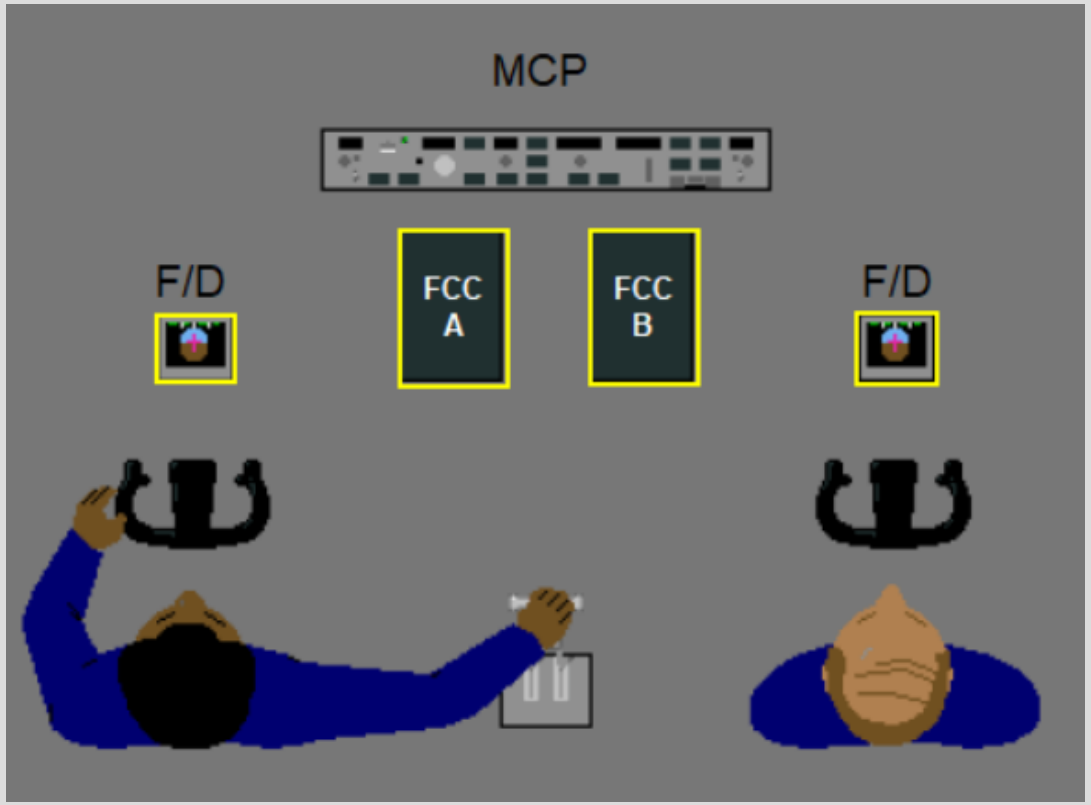
The FMC uses the navigation and performance database to calculate the optimum flight profile



The FMC receives information from you, the pilot, and also from other airplane systems

Three typical levels of Automation

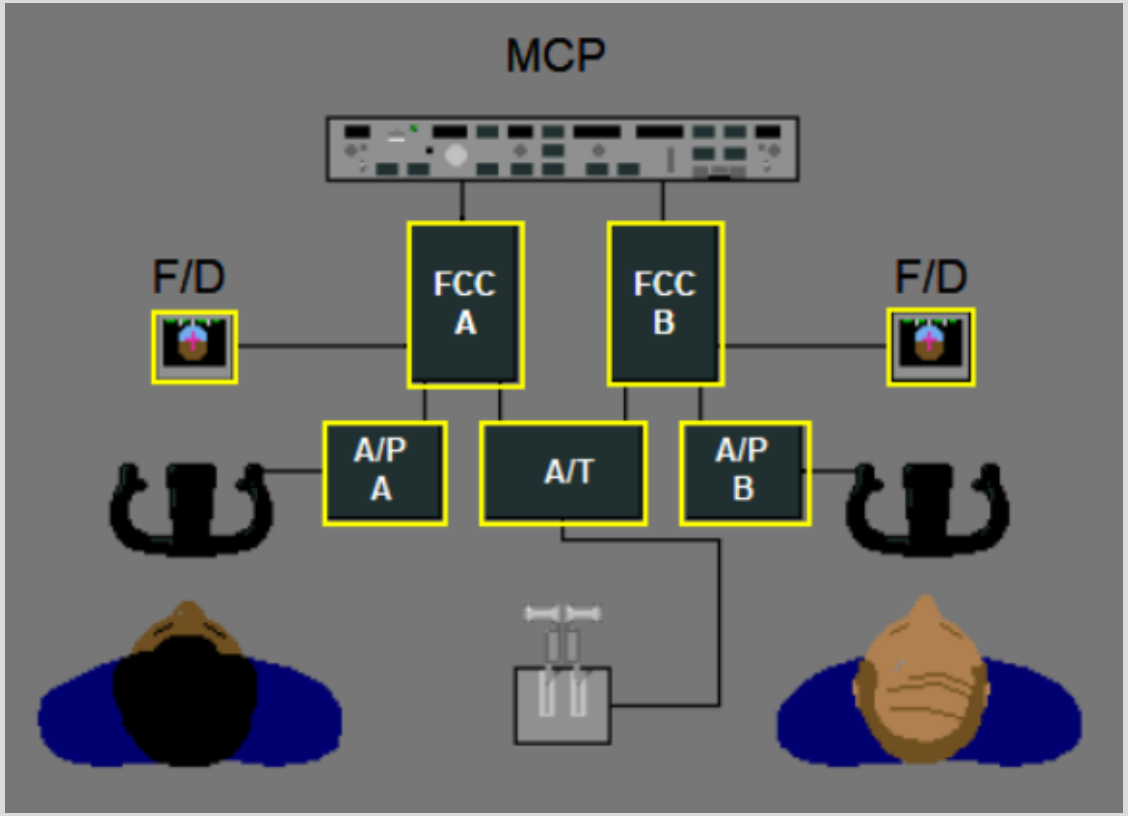
- **LEVEL 1: Manual flight**
  - Everything is done manually by the pilots (hand flying)
  - No autopilot nor autothrottle engaged
  - FDs can still be ON so that bars give you pitch and roll guidance



This adds to your workload since you must program the FD while actually flying the aircraft

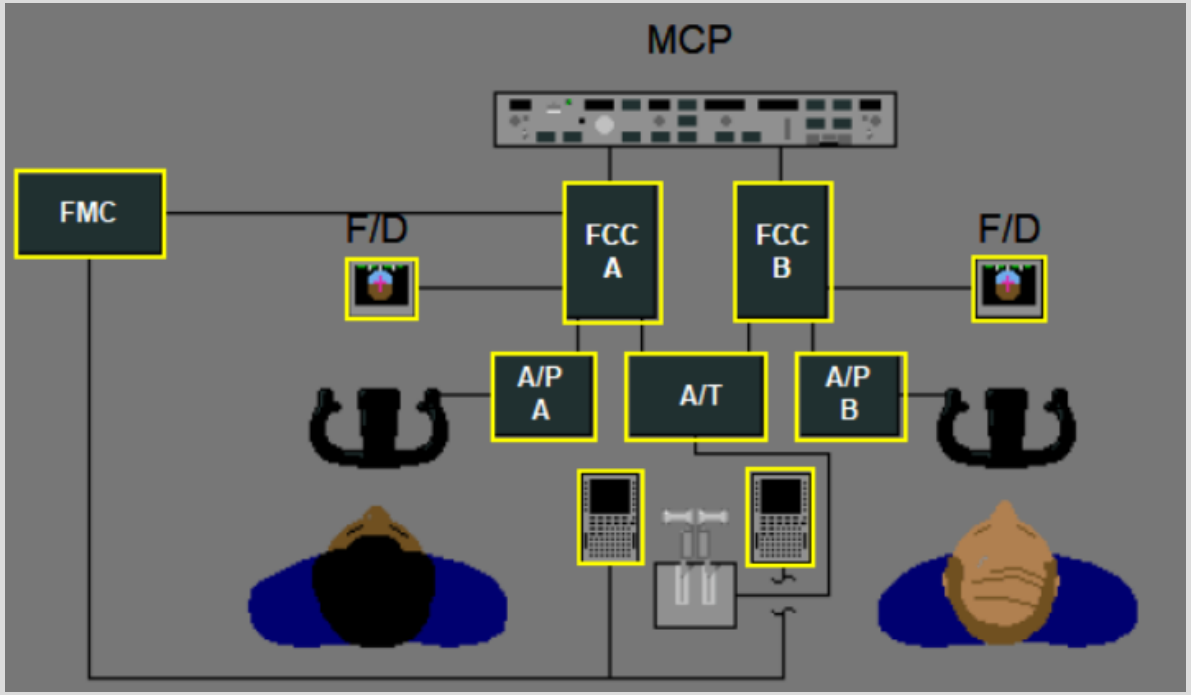
- **LEVEL 2: Autopilot + Autothrottle engaged**
  - You are using the guidance system to tell the autopilot what to do
  - You are now up to the MCP (Mode Control Panel) to select basic modes (heading, vertical speed, altitude, …)

The autopilot controls pitch and roll
The autothrottle controls the thrust



- **LEVEL 3: Autopilot + Autothrottle engaged + FMS**
  - Now the FMS tells the autopilot what to do (no longer the MCP)
  - To let the FMS do the work, you must first select LNAV and VNAV on the MCP
  - Everything (thrust management, speed control, vertical path, lateral navigation) are now controlled by the FMS
  - *"What you put in (the FMS), is what you get out"*

Your workload is now reduced
to monitoring the airplane status



Simple Autopilot modes

- Maintaining altitude, pitch angle (pitch)
- Maintaining heading or track (roll)

Advanced Autopilot modes

- **Vertical modes** such as:

Airbus	Boeing	Goal
V/S : vertical speed	V/S : vertical speed	Aircraft will change altitude at specified vertical speed in feet per minute or slope angle.
CLB/DES : Climb/descent	VNAV : vertical navigation	Aircraft will climb/descend in accordance with vertical flight path computed through (M)CDU including complying with altitude restrictions.
OP CLB/DES : open climb/descent	LVL CHG : level change	Aircraft will: - Climb using max power/thrust - Descend at idle power/thrust
APPR : approach	APP : approach	Related to vertical modes, approach mode will lead the aircraft to follow the vertical guidance available on 3D approaches (ILS, LPV, GLS).

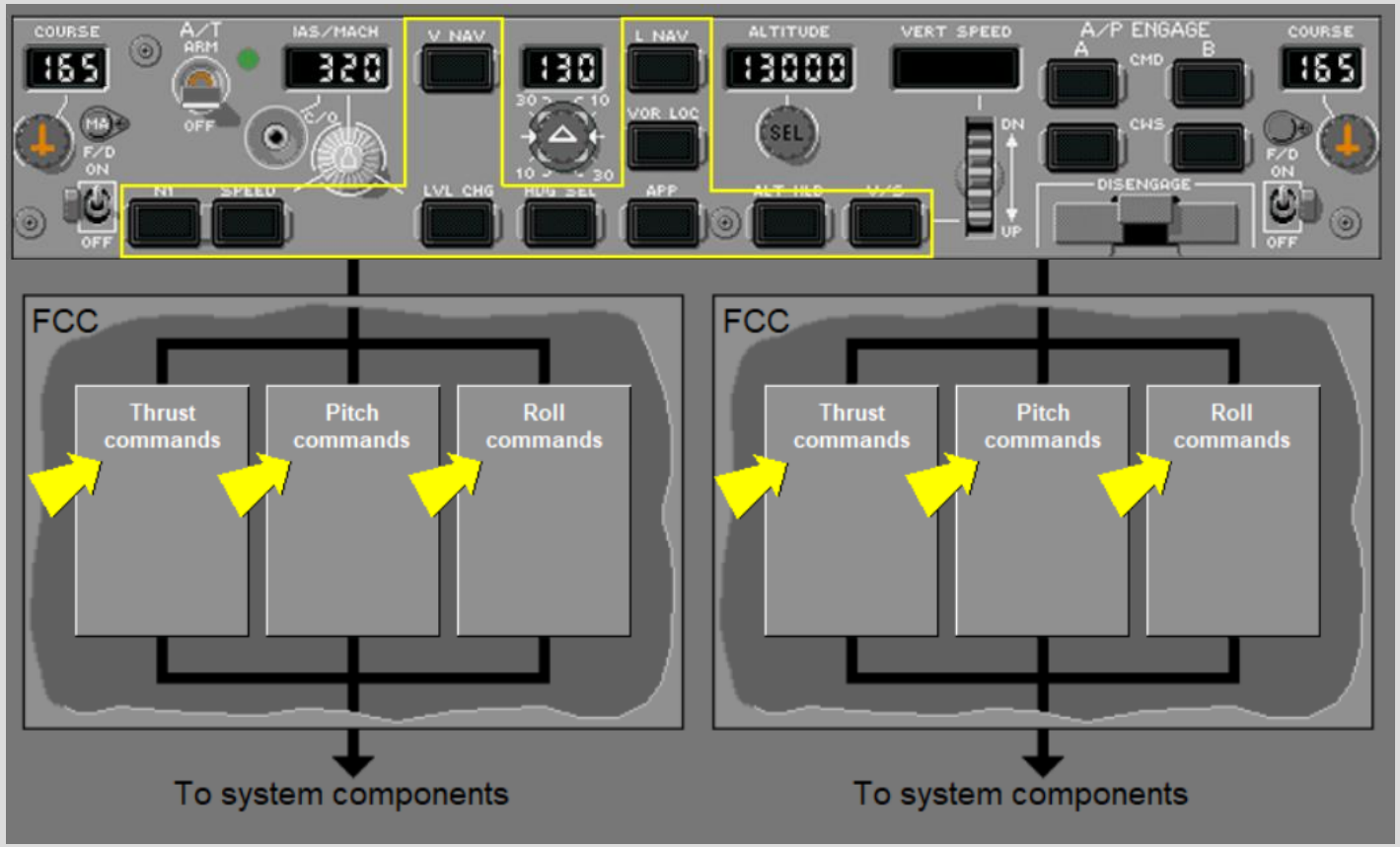
➢ **Lateral modes** such as:

Airbus	Boeing	Goal
NAV : lateral navigation	LNAV : lateral navigation	Aircraft will follow the legs entered by the pilots during the flight preparation into the (M)CDU.
LOC : Localizer	VOR LOC : VOR navigation Localizer	Aircraft will establish on the specified localizer frequency. Boeing allows also the possibility to establish on a specified VOR radial.
APPR : approach	APP : approach	Related to lateral modes, approach mode will lead the aircraft to follow the lateral guidance available on LOC and ILS conventional approaches.

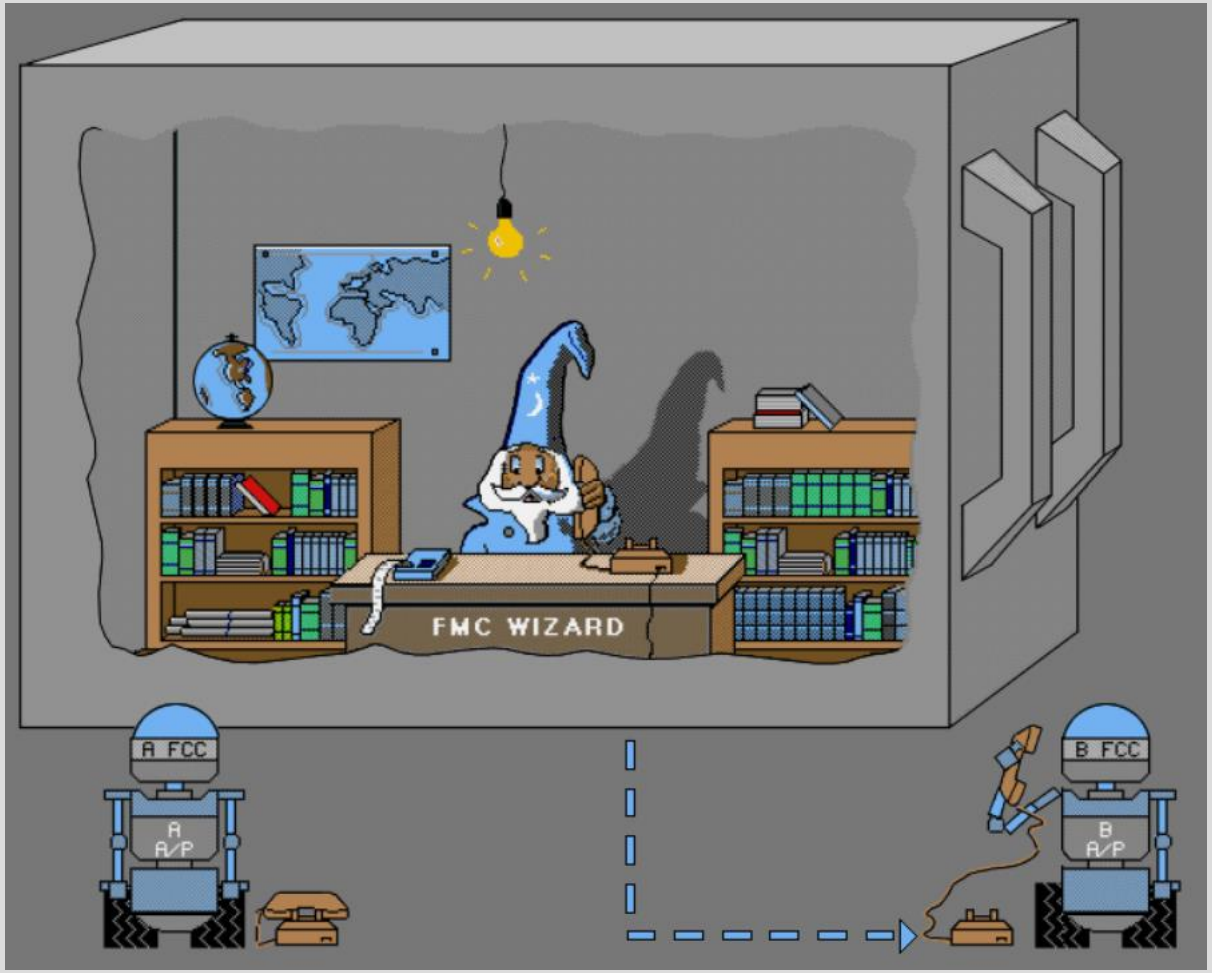
Change Autopilot modes

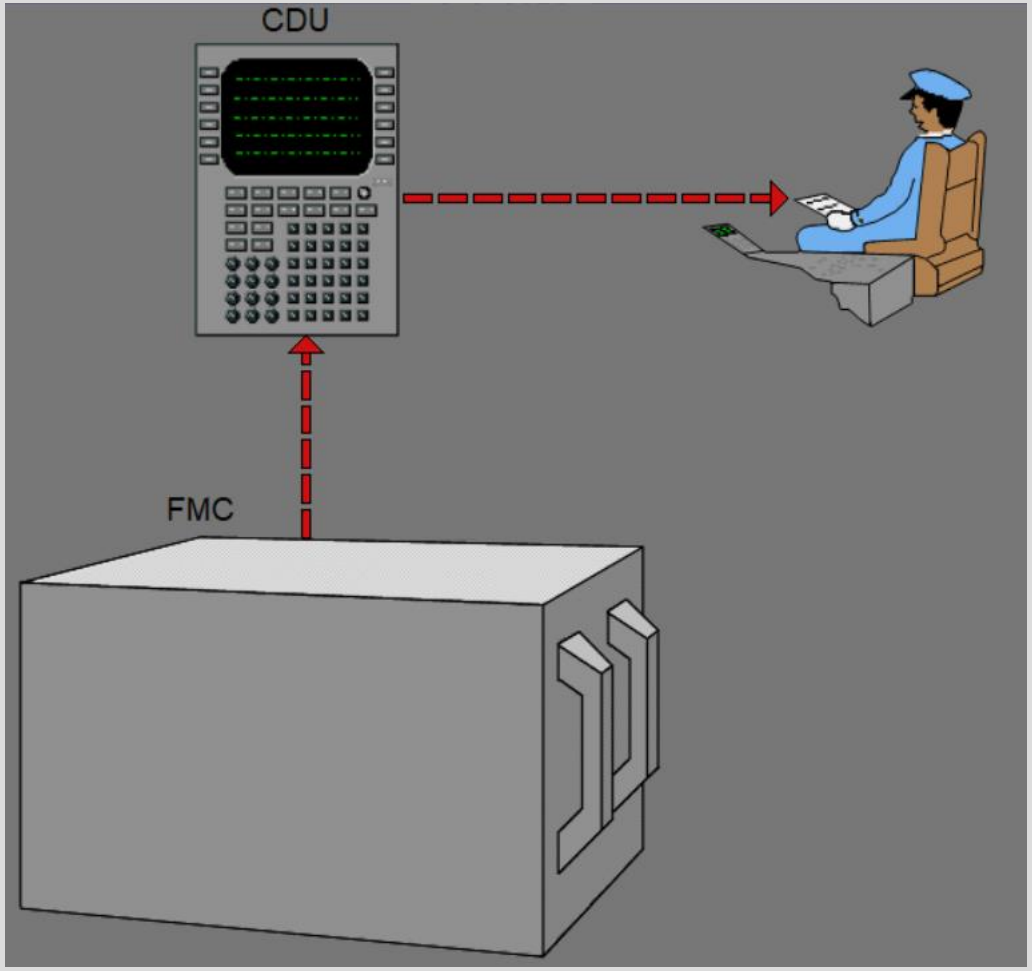
- Via the MCP

Pressing either buttons on the MCP causes FCC to calculate thrust commands, pitch commands, or any combinaison of thrust, pitch and roll commands



- Via the FMS





The CDU is like an interpreter to help you communicate with the FMC, … and to help FMC to communicate with you

Checking which mode is selected (autoflight status)?

- By reading the Flight Mode Annunciator (FMA)
- It is where to read which autopilot, autothrottle and flight director mode is engaged or armed

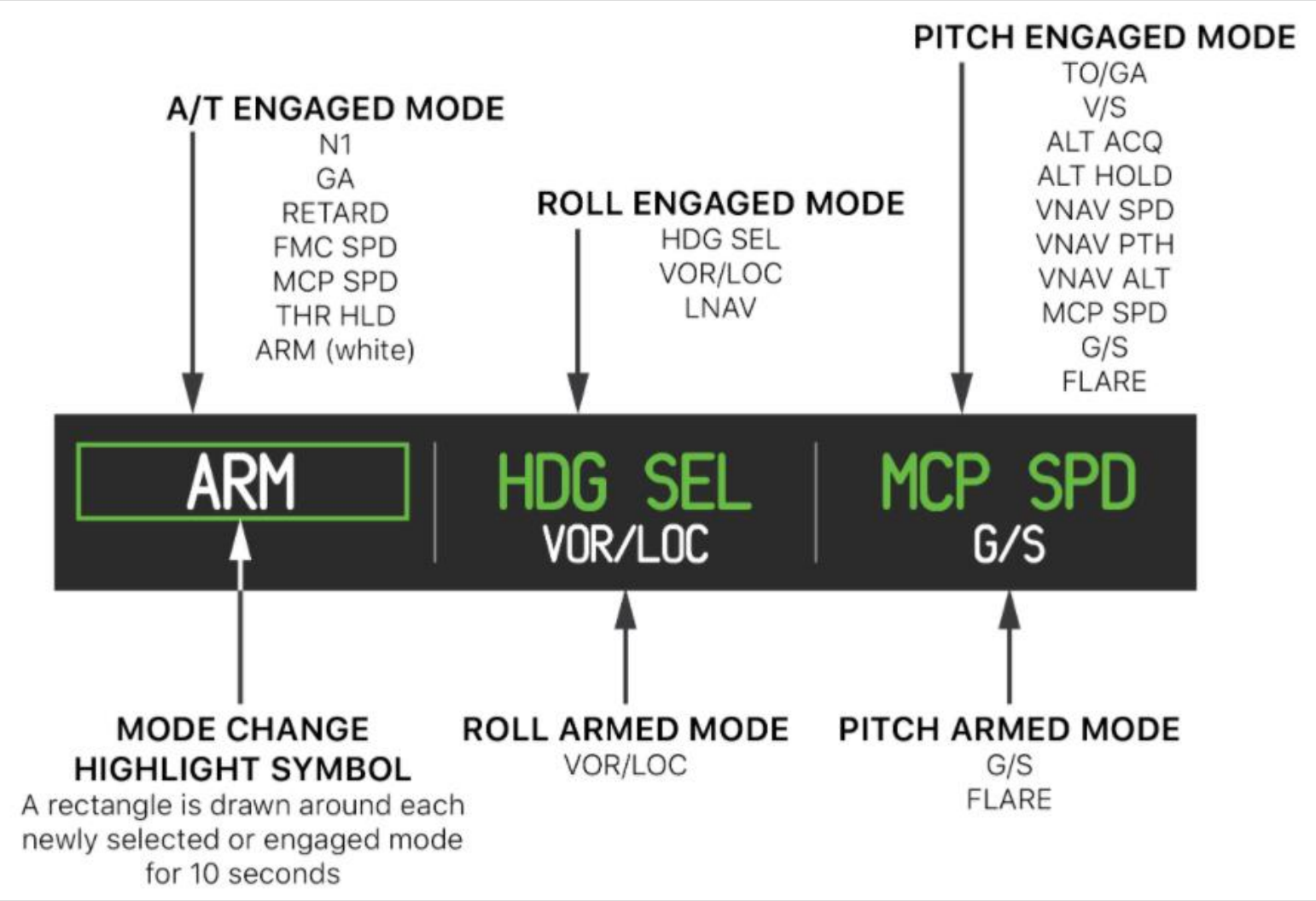
First field:
Autothrottle

Second field:
Roll mode

Third field:
Pitch mode

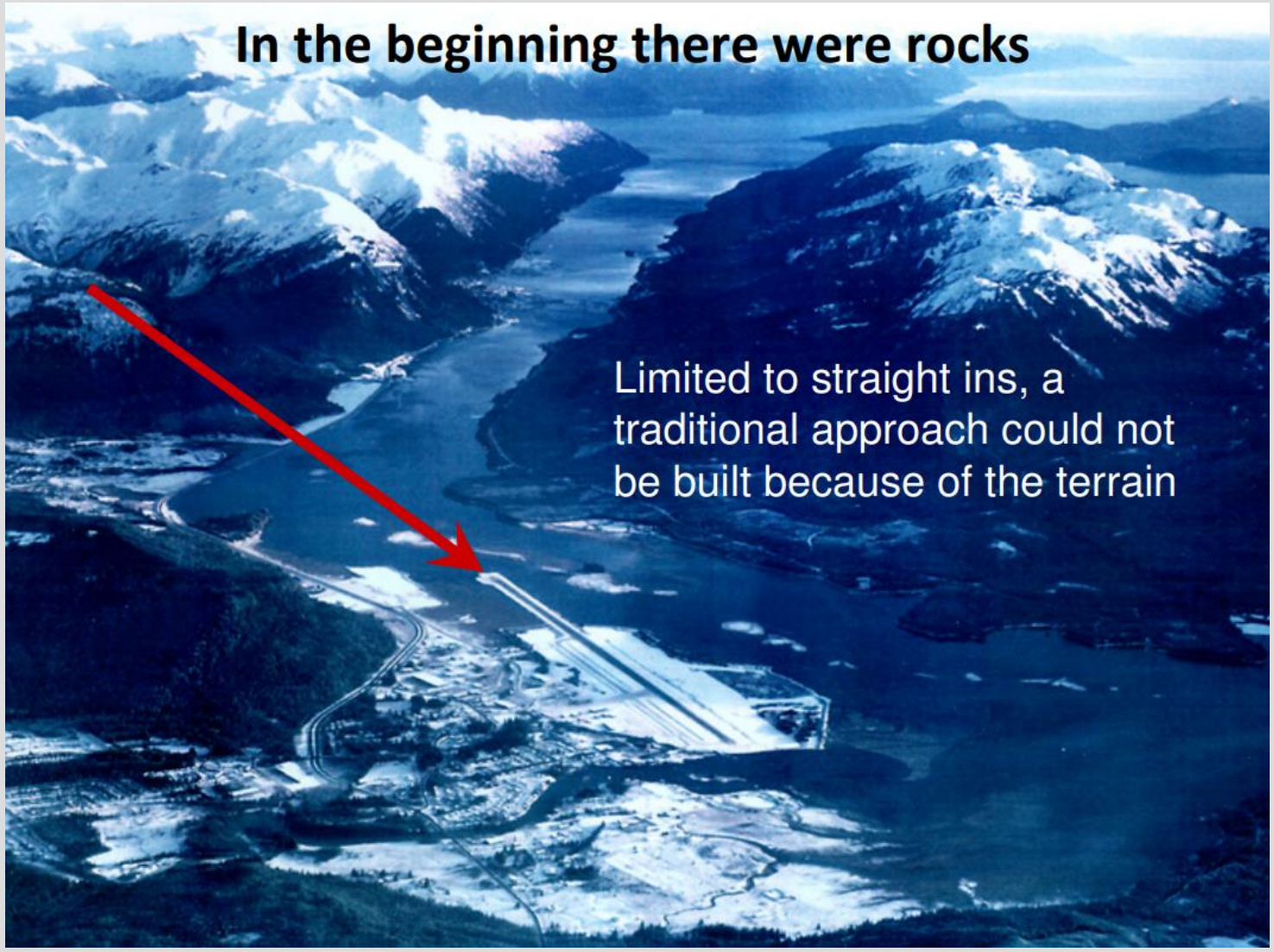
Fourth field:
AP status (CMD, FD or nothing)

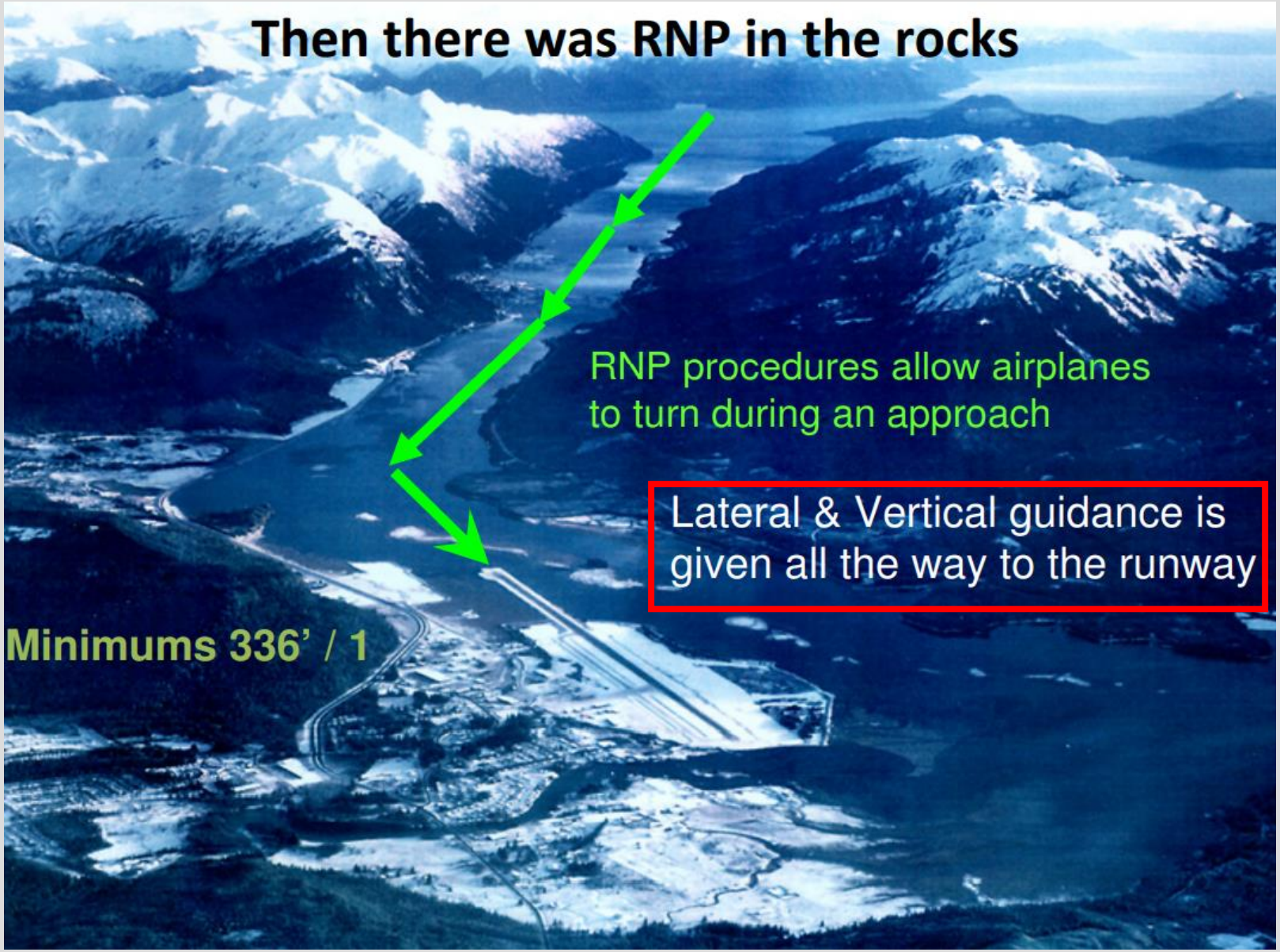
- Which different modes can be displayed?



Why LNAV/VNAV?

An example




Then there was RNP in the rocks
RNP procedures allow airplanes to turn during an approach
Lateral & Vertical guidance is given all the way to the runway
Minimums 336' / 1

Alaska Airlines
15 DEC 06 19-10-1
Special Aircrew Training Required

JUNEAU, ALASK
RNP RNAV Rwy 2

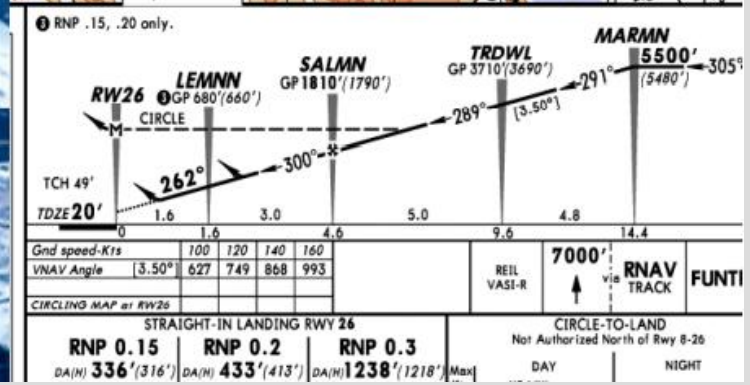
ATIS	ANCHORAGE Center	*JUNEAU Tower	*Ground	JUNEAU Radio (LAA)
135.2	133.9 132.17 133.2	118.7	121.9	CTAF 118.7 when Twr inop.

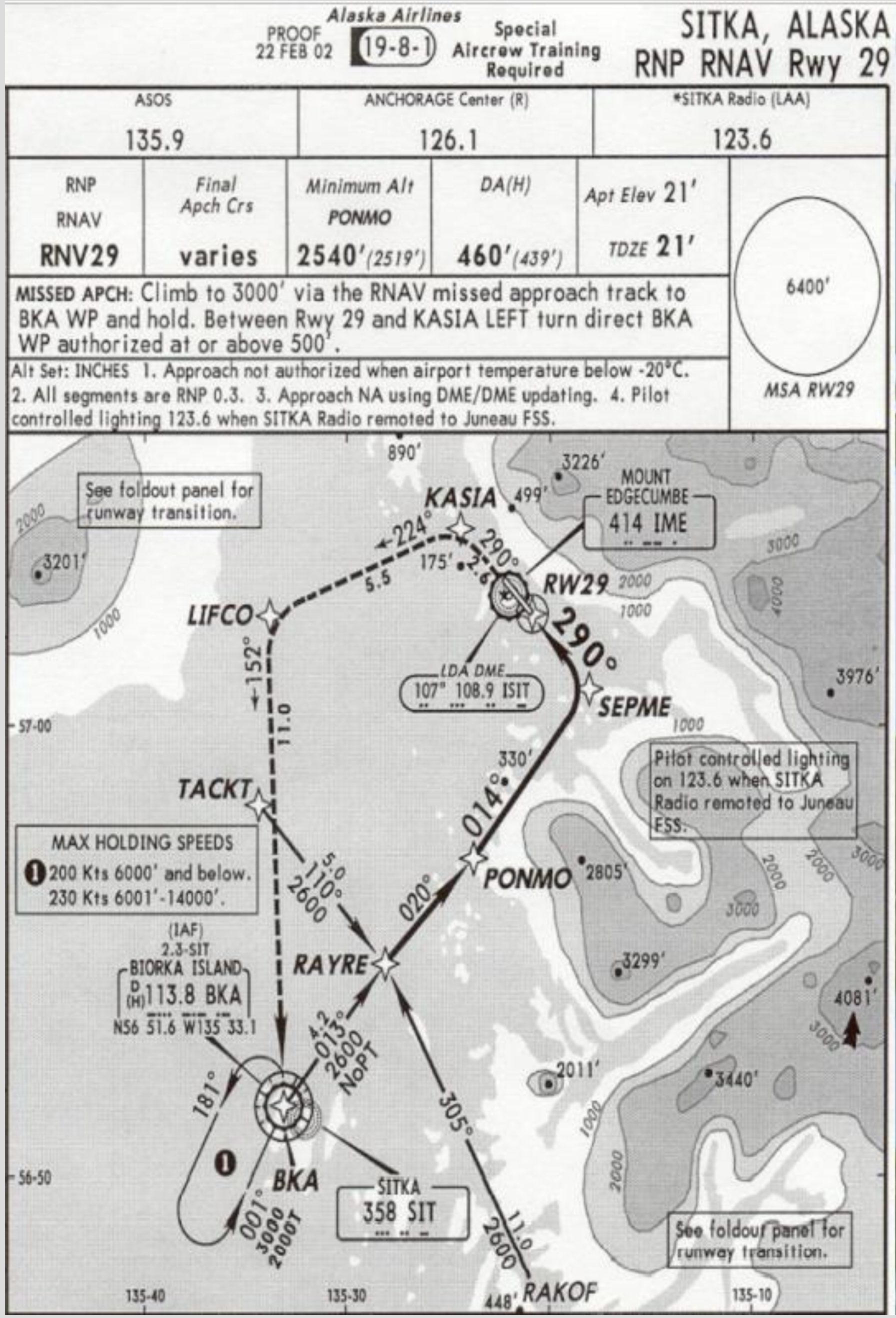
RNP RNAV	Final Apch Crs	Minimum Alt	DA(H)	Apt Elev 21'
RNV26	Varies	SALMN 1810'(1790')	Refer to Minimums	TDZE 20'

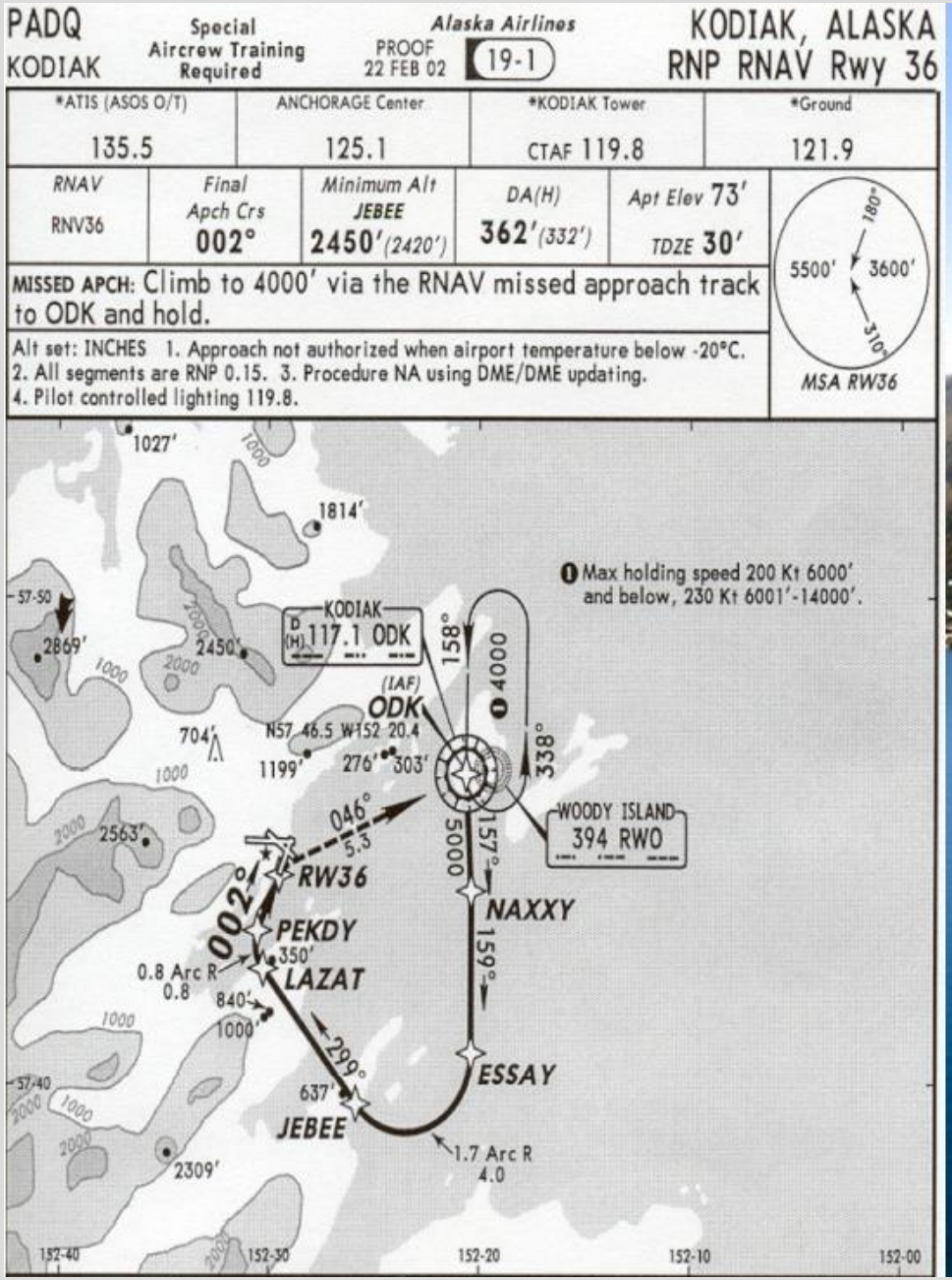
MISSED APCH: Climb to 7000' via the RNAV missed approach track to FUNTR and hold. Cross SAZYU at or above 680' and BARLO at or above 2200'.

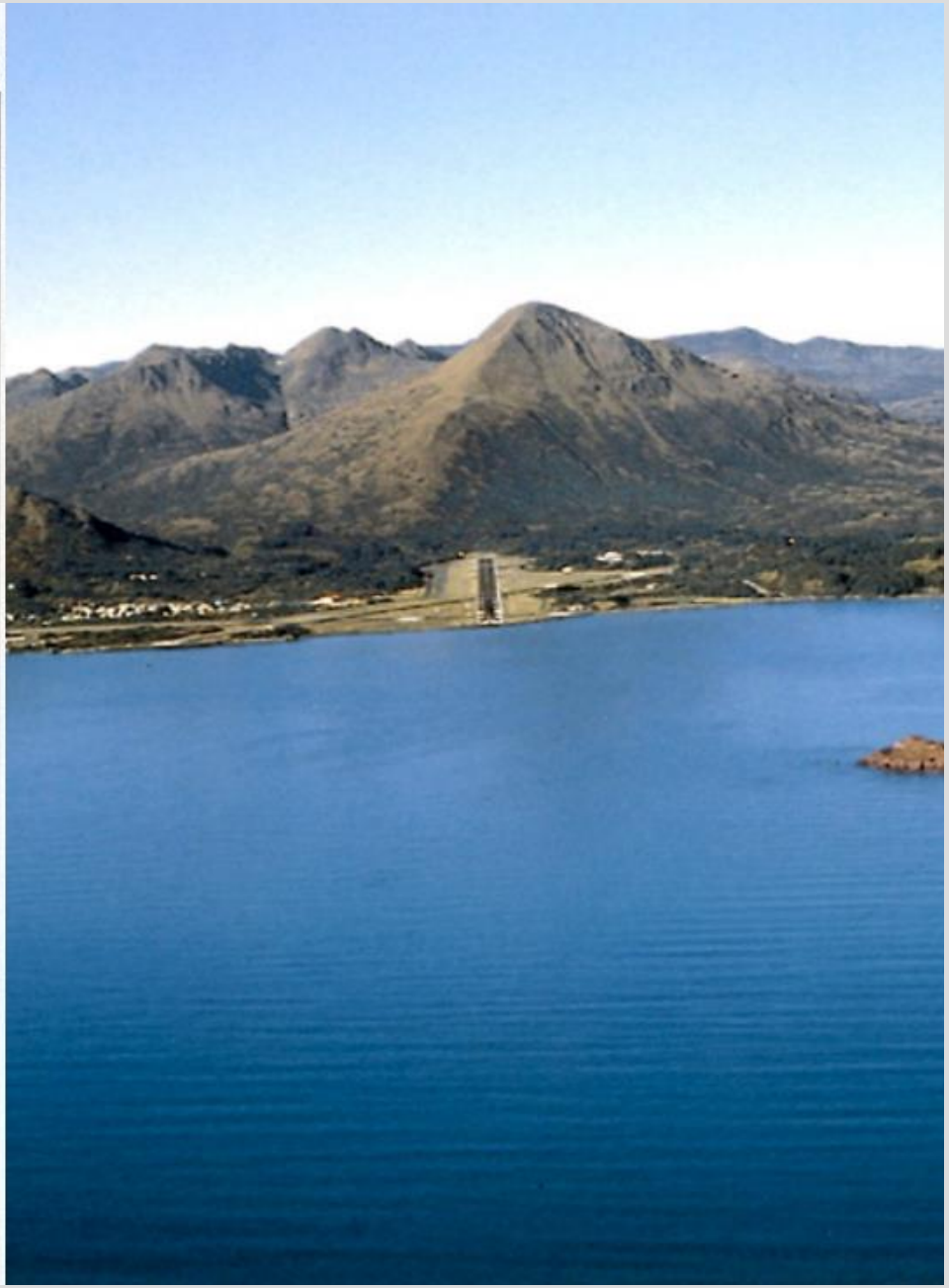
Alt Set: INCHES 1. Approach not authorized when airport temperature below -20°C.
2. Procedure not authorized using DME/DME updating.

MSA RW26




Alaska Airlines
PROOF
22 FEB 02
19-8-1
Special
Aircrew Training
Required
SITKA, ALASKA
RNP RNAV Rwy 29
ASOS
135.9
ANCHORAGE Center (R)
126.1
*SITKA Radio (LAA)
123.6
RNP
RNAV
RNV29
Final
Apch Crs
varies
Minimum Alt
PONMO
2540′(2519′)
DA(H)
460′(439′)
Apt Elev 21′
TDZE 21′
6400′
MSA RW29
MISSED APCH: Climb to 3000′ via the RNAV missed approach track to BKA WP and hold. Between Rwy 29 and KASIA LEFT turn direct BKA WP authorized at or above 500′.
Alt Set: INCHES 1. Approach not authorized when airport temperature below -20°C. 2. All segments are RNP 0.3. 3. Approach NA using DME/DME updating. 4. Pilot controlled lighting 123.6 when SITKA Radio remoted to Juneau FSS.
See foldout panel for runway transition.
KASIA
MOUNT
EDGECUMBE
414 IME
LIFCO
RW29
290°
LDA DME
107° 108.9 ISIT
SEPME
TACKT
Pilot controlled lighting on 123.6 when SITKA Radio remoted to Juneau FSS.
MAX HOLDING SPEEDS
200 Kts 6000′ and below.
230 Kts 6001′-14000′.
PONMO
RAYRE
(IAF)
2.3-SIT
BIORKA ISLAND
113.8 BKA
N56 51.6 W135 33.1
BKA
SITKA
358 SIT
See foldout panel for runway transition.
RAKOF


PADQ
KODIAK
Special Aircrew Training Required
Alaska Airlines
PROOF 22 FEB 02
19-1
KODIAK, ALASKA
RNP RNAV Rwy 36
*ATIS (ASOS O/T)
135.5
ANCHORAGE Center
125.1
*KODIAK Tower
CTAF 119.8
*Ground
121.9
RNAV
RNV36
Final Apch Crs
002°
Minimum Alt
JEBEE
2450′ (2420′)
DA(H)
362′ (332′)
Apt Elev 73′
TDZE 30′
MISSED APCH: Climb to 4000′ via the RNAV missed approach track to ODK and hold.
Alt set: INCHES 1. Approach not authorized when airport temperature below -20°C.
2. All segments are RNP 0.15. 3. Procedure NA using DME/DME updating.
4. Pilot controlled lighting 119.8.
180°
5500′
3600′
310°
MSA RW36
Max holding speed 200 Kt 6000′ and below, 230 Kt 6001′-14000′.
KODIAK
D (H) 117.1 ODK
158°
4000
(IAF)
ODK
N57 46.5 W152 20.4
338°
WOODY ISLAND
394 RWO
046°
5.3
RW36
002°
PEKDY
350′
0.8 Arc R
0.8
LAZAT
840′
1000′
299°
637′
JEBEE
5000
157°
NAXXY
159°
ESSAY
1.7 Arc R
4.0
1027′
1814′
2869′
2450′
704′
1199′
276′
303′
2563′
2309′
57-50
57-40
152-40
152-30
152-20
152-10
152-00



LNAV

- LNAV is the route you fly over the ground
- The aircraft may be using VORs, GPS, DME or any combination of the above
- Requirements for using LNAV: flight plan is entered into the FMS + “LNAV” is selected on the MCP
- Then the aircraft will then follow the magenta line that shows up on the navigation display

- **VNAV**
  - VNAV is a computed vertical path
  - Requirements for using VNAV: flight plan is entered into the FMS with altitude/speed constraints + “VNAV” on the
  - The computer will figure out where to bring the throttles and pitch angle to fly the aircraft at the desired inputs (in climb, cruise, descent and/or approach)

If the autopilot is OFF: *LNAV and VNAV still send their signals to the flight director (so you can hand fly the aircraft and follow the command bar cues)*

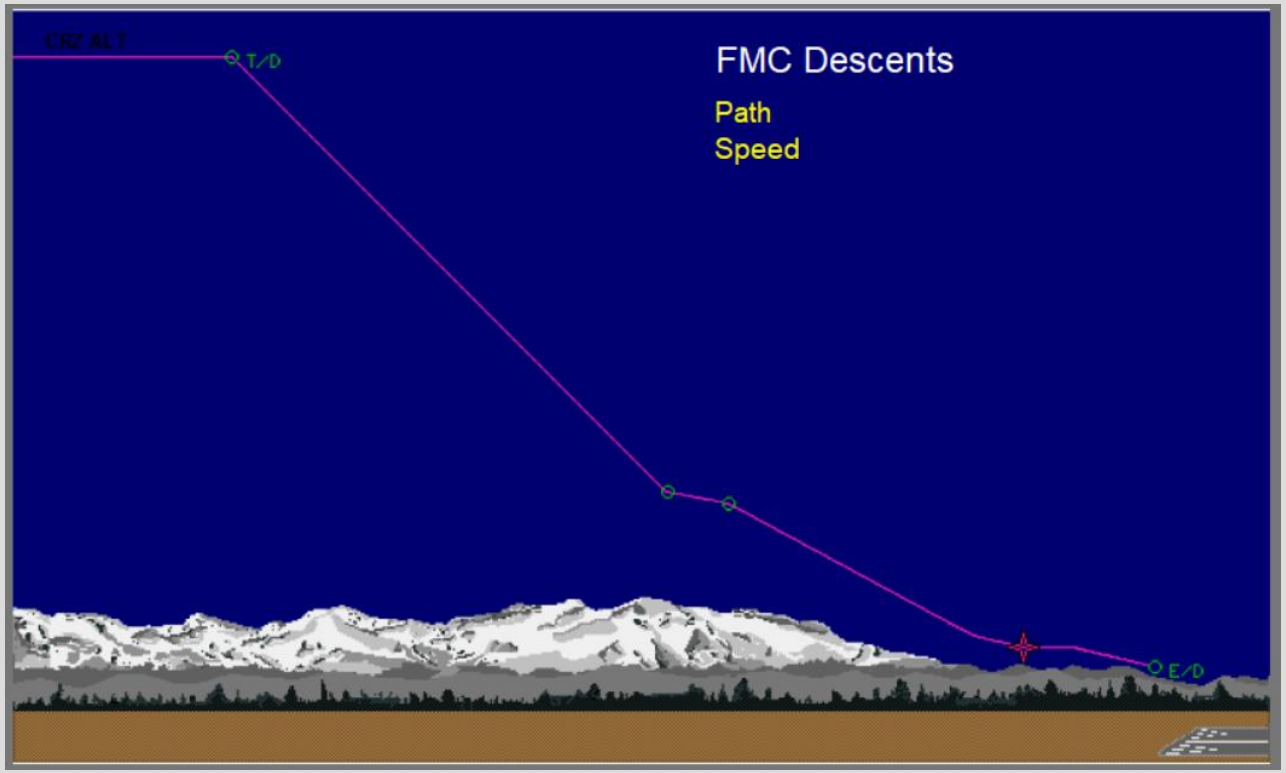
To sum up

- **LNAV**
  - Provides a precise lateral path defined by waypoints and legs (Flight Plan Route)
  - Computes guidance commands for the Autopilot or FD to follow the path
  - Uses information from IRS, GPS and/or VOR/DME

- **VNAV**
  - Is the vertical navigation flight profile which is the predicted flight trajectory of the airplane in the vertical plane as a function of distance along the horizontal flight path defined by the LNAV flight plan
  - The flight profile reflects all speed and altitude restrictions specified in the guidance flight plan while honoring airplane operating limits
  - Computes guidance commands for the Autopilot or FD and Autothrottle to follow the vertical path

The FMS and its relationship with LNAV/VNAV (focus on Descent modes)

- LNAV/VNAV may be used in climb, cruise, descent and approach
- But this section is only dealing with (Boeing) Descent modes
- Why? Because VNAV may seem extremely easy but **can lead you into troubles fast!**



Different ways to descent

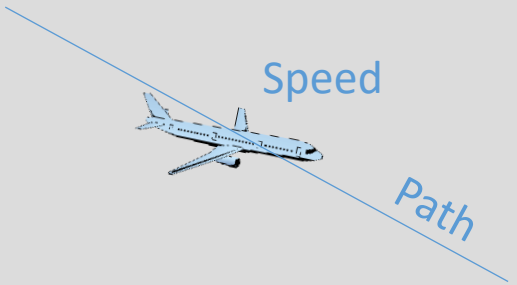
There are 3 parameters we would like to control during a descent:

- **Speed (kts),**
- **Rate of descent (ft/min), or**
- **Path (angle in °)**

Most of the time, the rate of descent is only required to follow for a short time when instructed to do so by the ATC (aircraft separation): V/S mode is then used.

Then, only SPEED or PATH have to be controlled in a decent.

This is done by using Thrust and Pitch attitude.

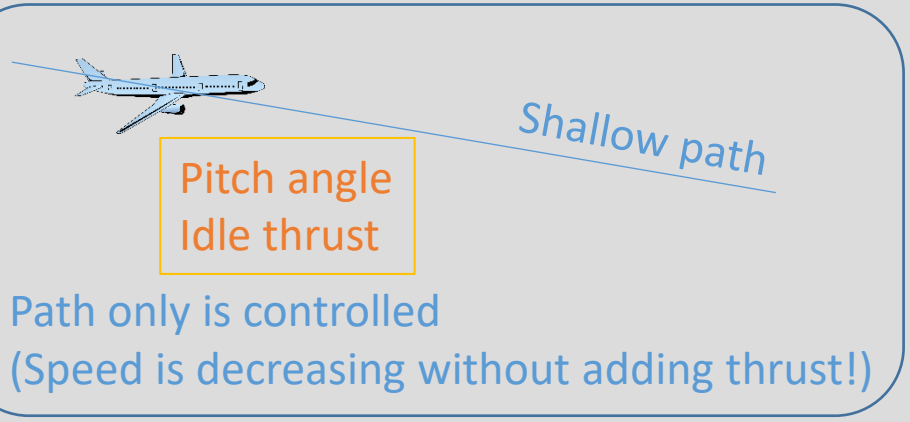


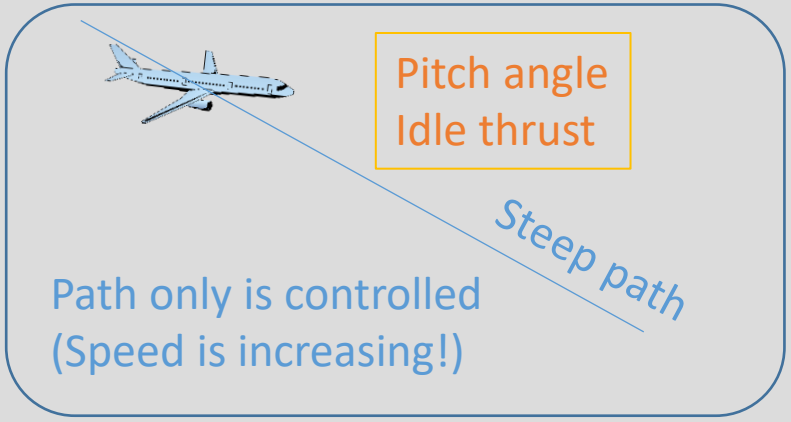
Only one way to make a best economical descent

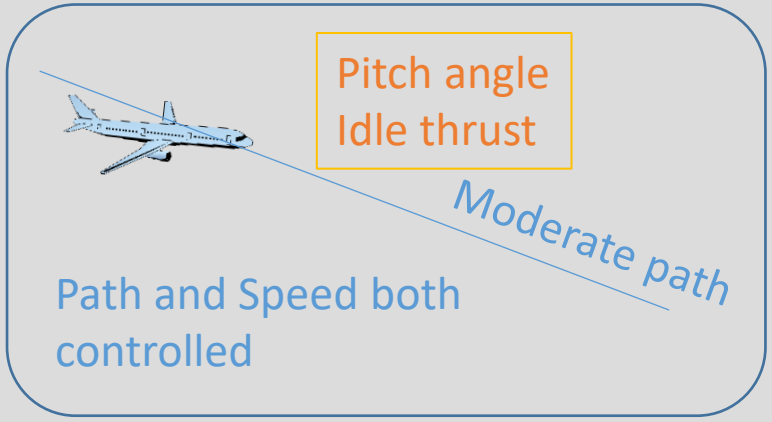
In order to keep the fuel consumption as less as possible during descent, thrust levers should be kept on idle

Economical descent = idle thrust descent

As a consequence, only PITCH attitude remains as a parameter to control the aircraft.







Boeing has decided to implement two different descent modes:

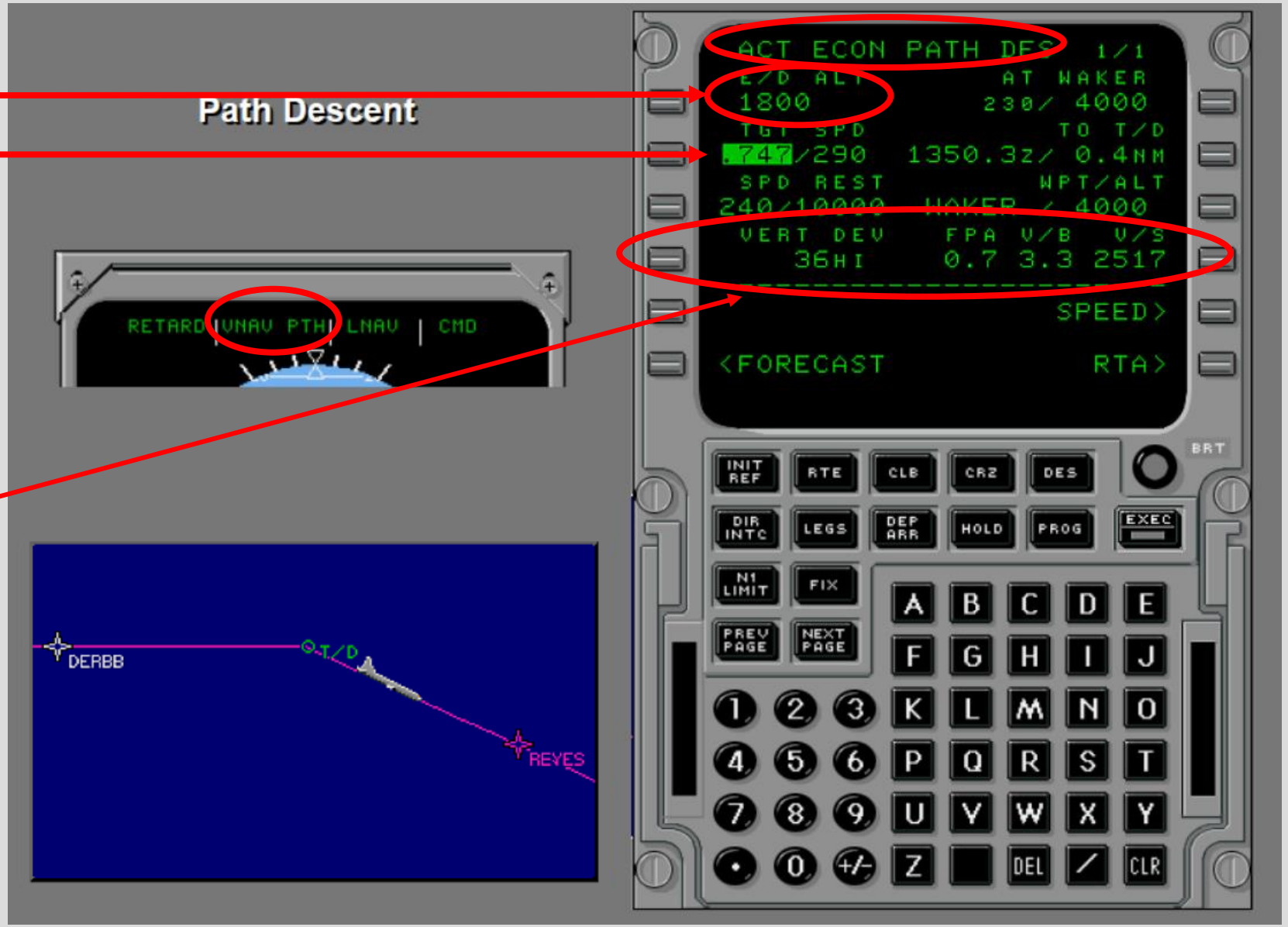
- **VNAV PATH**
  - The elevator controls the pitch attitude to follow a programmed descent path
  - Path has priority over speed during descent, no control of overspeeds!
  - If overspeed is detected a warning message appears in the scratchpad of the FMS (DRAG REQUIRED)
  - If actual aircraft speed is less than the target speed (in the FMS), the FMC will transition to FMC SPD as the thrust mode
  - The FCC will disengage VNAV and switch to LVL CHG if speed < minimum speed
  - It's up to you to manage the speed by using Speed brakes or even Thrust levers

- **VNAV SPD**
  - The elevator controls the pitch attitude of the aircraft to control speed
  - Speed has priority over the path during descent
  - Aircraft will descend at the FMC programmed speed with the thrust levers closed
  - Path is disregarded!
  - It's up to you to manage the path by using Speed brakes or Thrust

Most economical mode

End-Of-Descent point altitude

Target speed



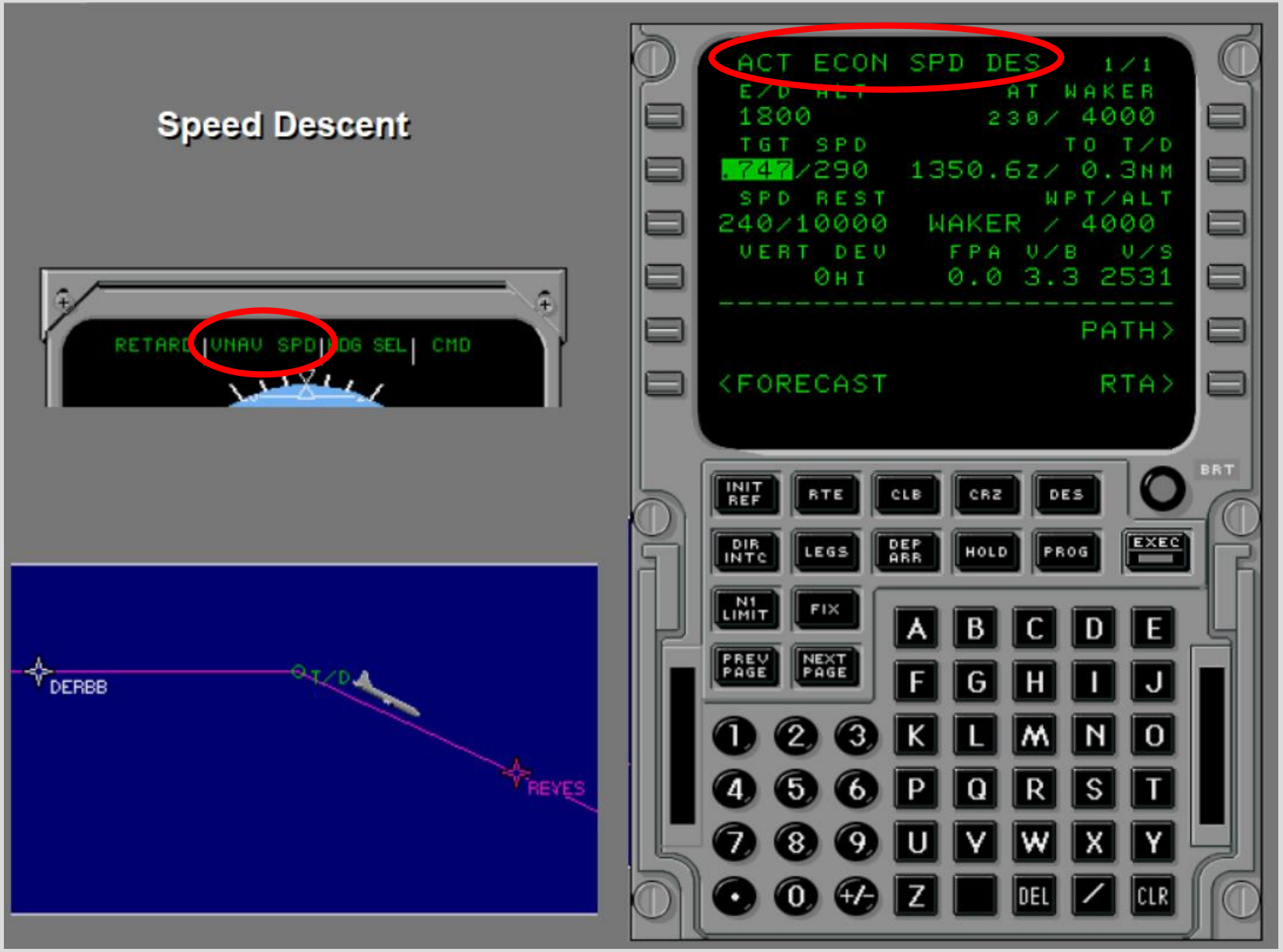
Vertical path deviation

FPA = Flight Path Angle

V/B = Vertical Bearing

V/S = Vertical speed

Flexible mode



How to select PATH and SPD descent modes?

- **VNAV is available if and only if:**
  - The last waypoint (E/D, end of descent) exhibits an altitude restriction (entries made manually by the pilot or when inserting an arrival)
  - LNAV mode is engaged

- **VNAV SPD is always available, and in particular when:**
  - The pilot pushes the "Speed Intervention" switch on the MCP, or
  - Any roll mode is engaged (LNAV or HDG), or
  - Passing TOD and using high target speed (6 kts to Vmo/Mmo), VNAV may revert to VNAV SPD to prevent overspeed

Path Descent

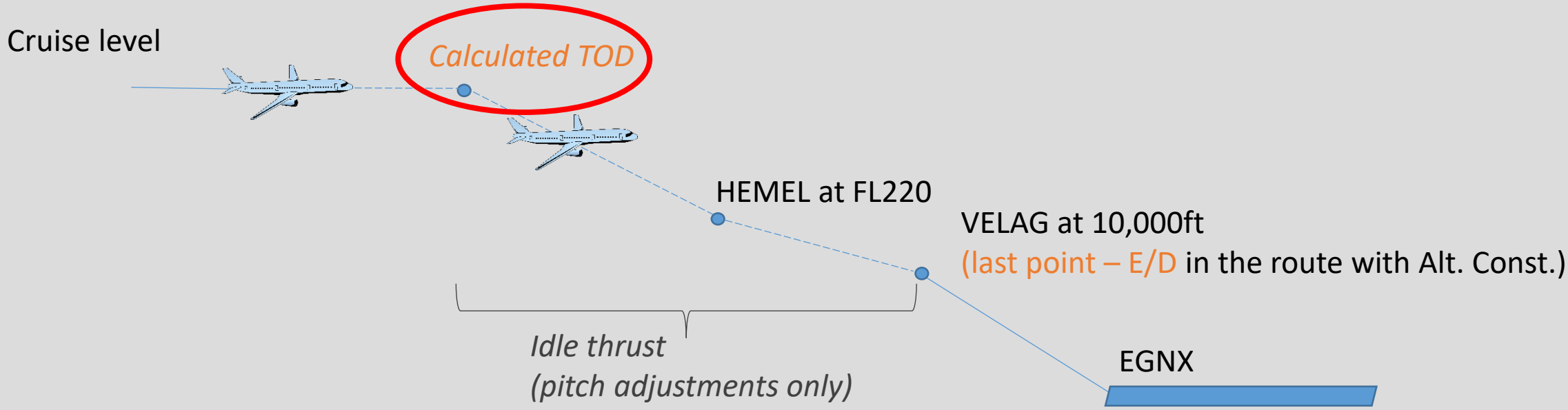
Economical
FMC maintains path
Pilot maintains airspeed
VNAV engaged
LNAV engaged

SPD Descent

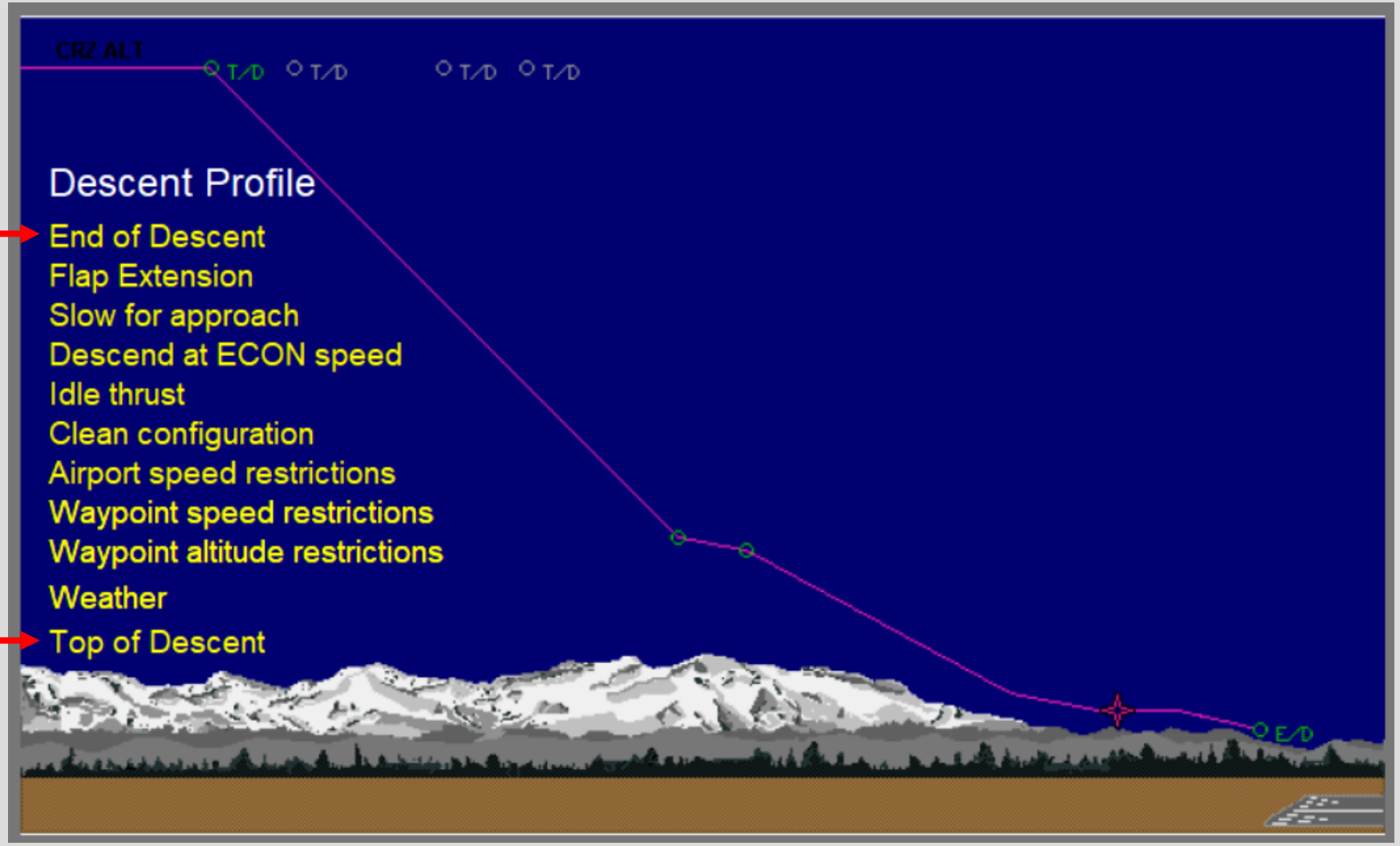
Flexible
FMC maintains airspeed
Pilot maintains path
VNAV engaged
Any roll mode engaged

How the FMS computes the most economical descent path?

- The FMS generates what is called a FMS path descent
- To do this, the FMS attempts to build an **idle thrust path (at ECON speed)** from the last point in the route that is assigned an altitude constraint up to the current cruise altitude
- The Top-Of-Descent (TOD) is then calculated



What parameters are taken into account for the computed descent profile?



Improve the accuracy of the descent profile by inserting descent winds

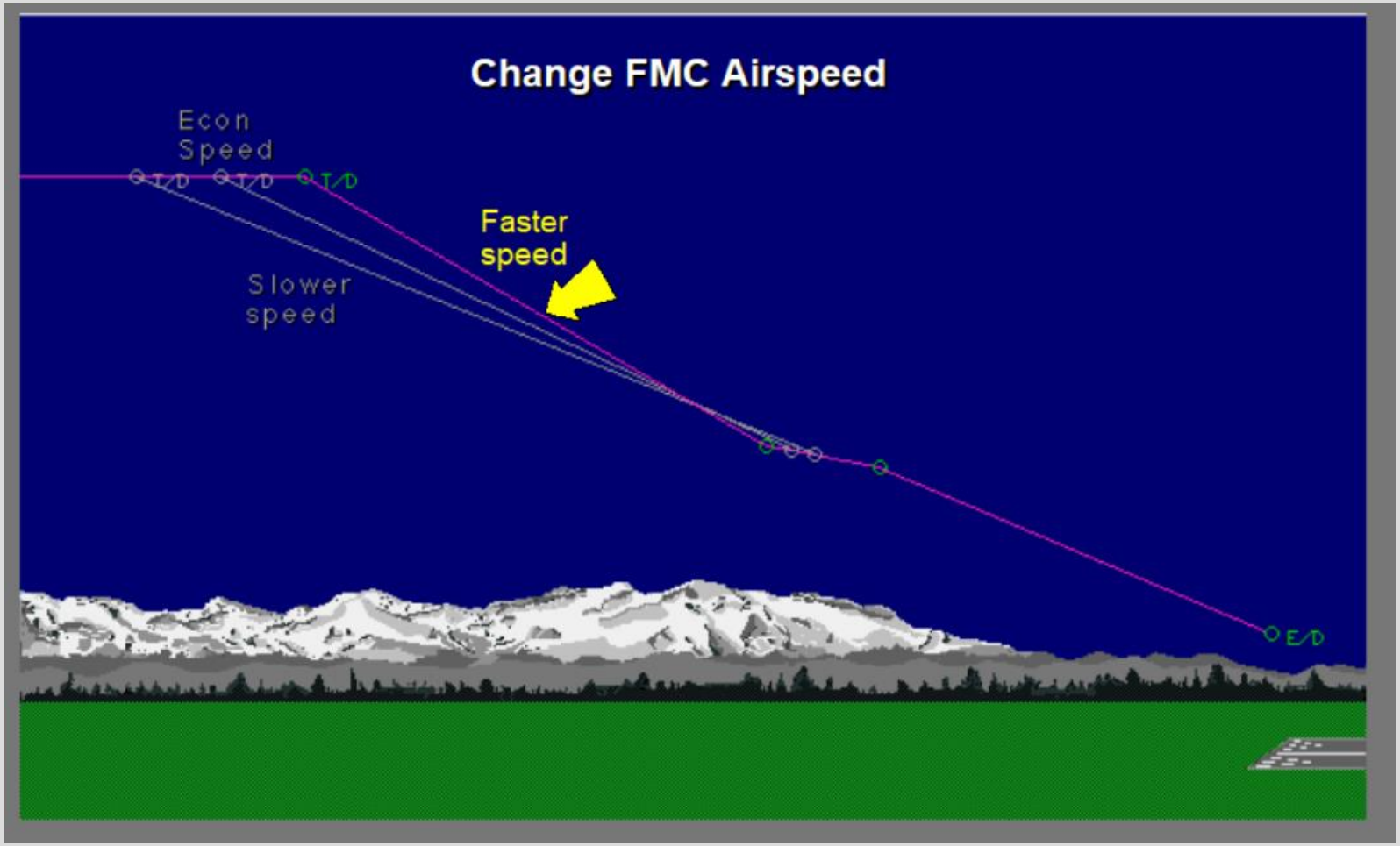
While on Descent page (either SPD or PATH):

1. Select FORECAST prompt
2. Enter Data
3. Press EXEC

How the descent profile is reshaped if the FMC speed is changed before TOD?

A new TOD is then recalculated.

If a slower speed than ECON speed
is entered the TOD moves further back
(the opposite for a faster speed)



Let us see how the path descent (VNAV PATH) is then practically managed

Approaching the TOD, the FMC reminds you to reset the MCP.

The aircraft is cruising at FL350, approaching the TOD:

Pilot: « SUPAERO 1, standing by for descent »

ATC: « SUPAERO 1, Cleared MOORE 3 arrival, descent 3000 ft QNH 1020 »

Pilot: « Cleared MOORE 3 arrival and descent 3000 ft QNH 1020, SUPAERO 1 »

The airplane is now **ready to descent** when it crosses TOD point

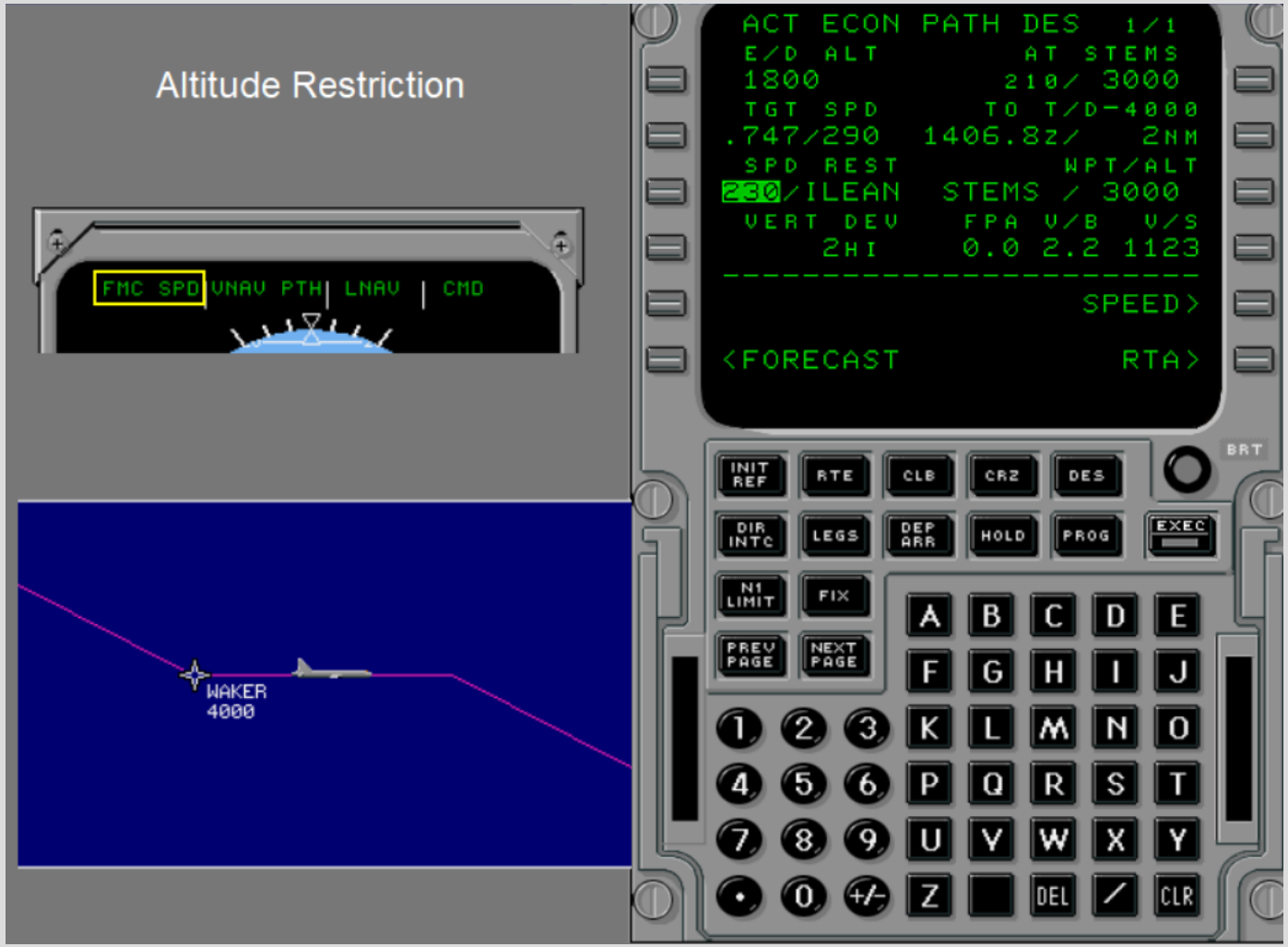
The current **flightpath angle required to maintain the path descent** is displayed.

It is similar to the glideslope angle on an ILS approach

If there is a level off to perform somewhere along the descent path, the FMC increases thrust to maintain the airspeed.

The FMC thus temporarily controls thrust anytime you level off during a path descent (FMC SPD mode appears on the FMA)

This control is maintained until the idle-thrust descent segment is intercepted.



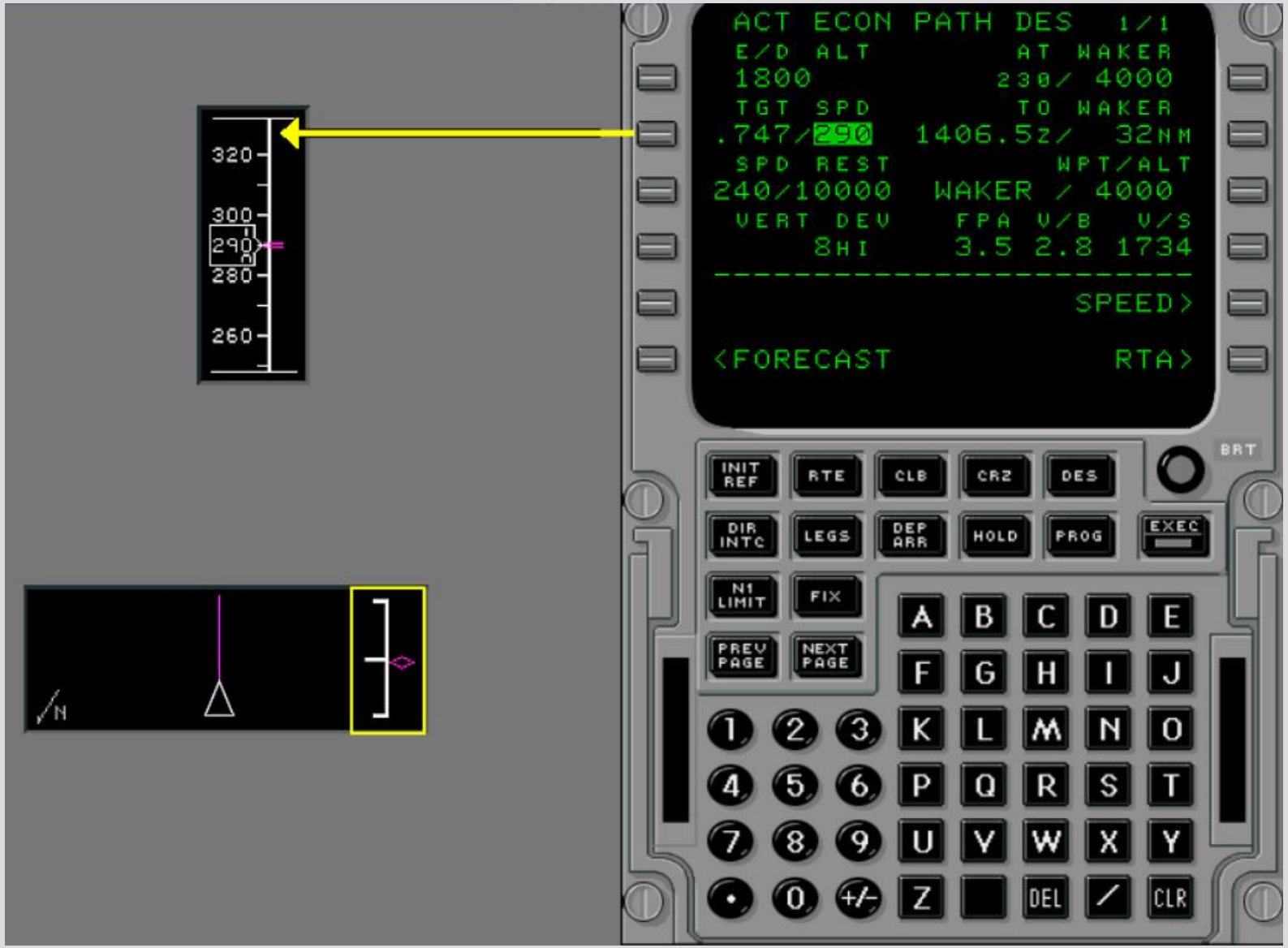
DESCENT PATH (normal indications)

Vertical path deviation near 0

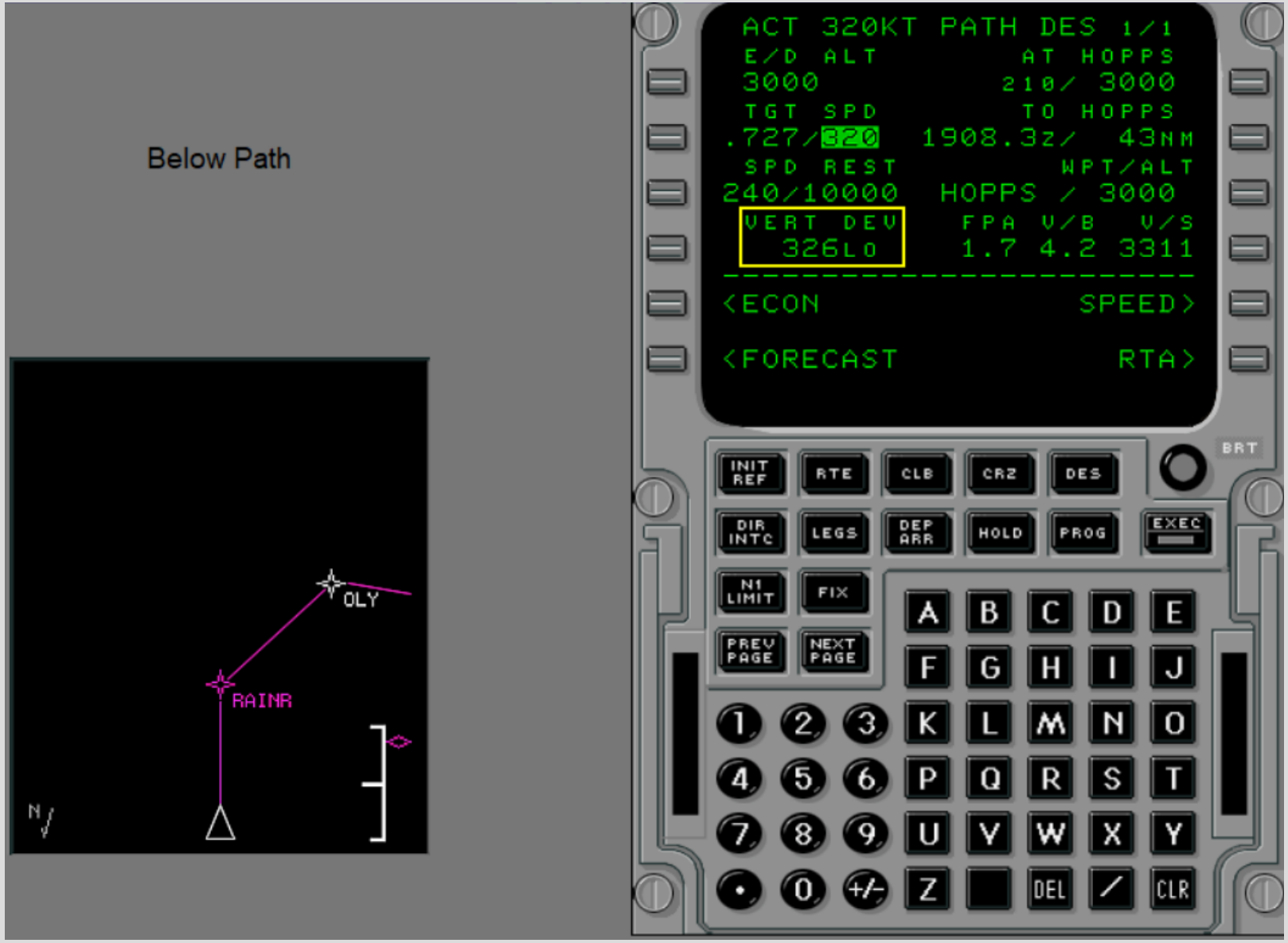
Target speed is maintained (here 290 kts)

The magenta diamond shows you are on path

If path predictions were wrong, the airspeed would vary



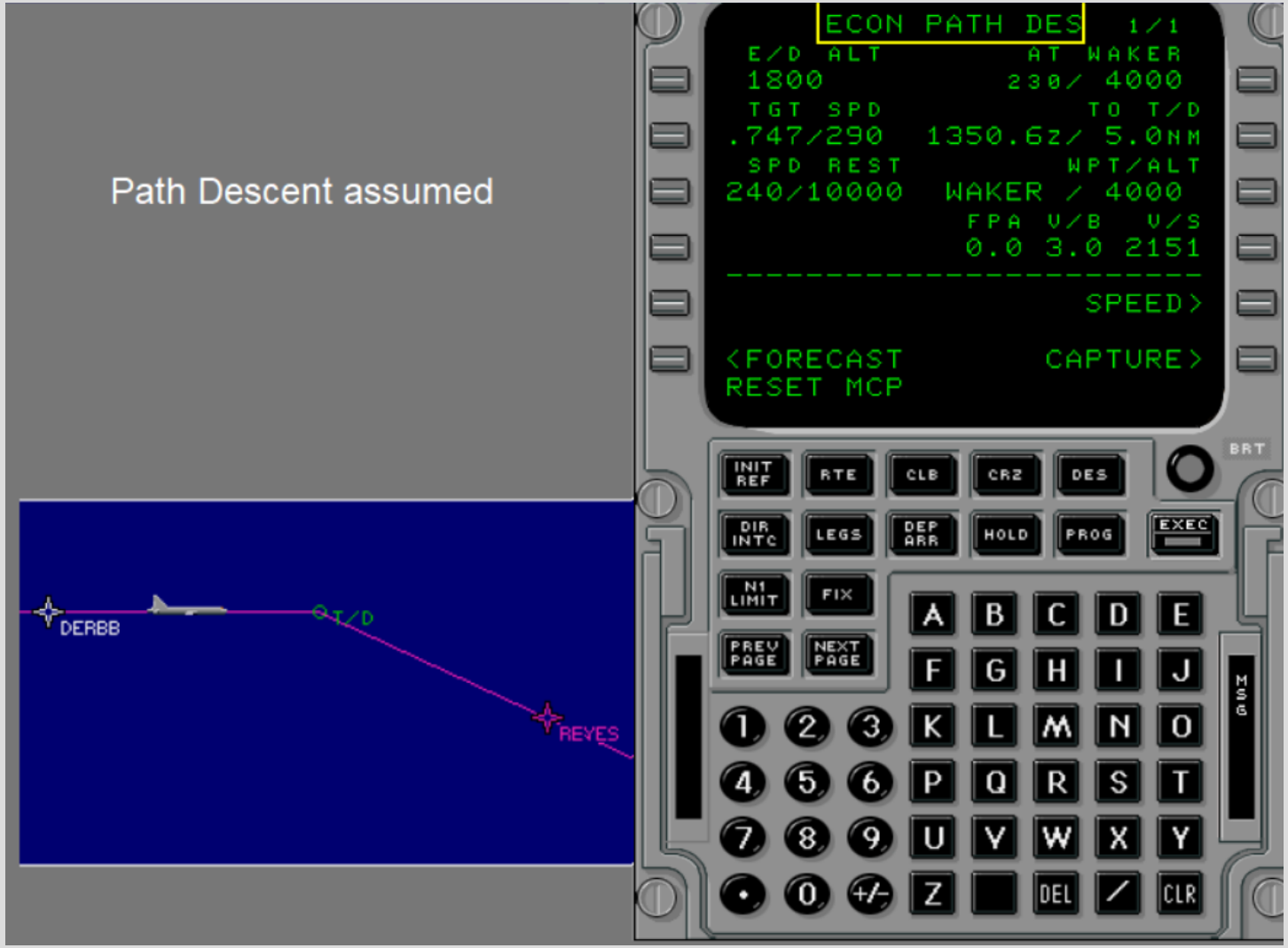
DESCENT PATH (below path)



… and how could we force speed descent (VNAV SPD) to become active?

The FMC assumes you want
a path descent.

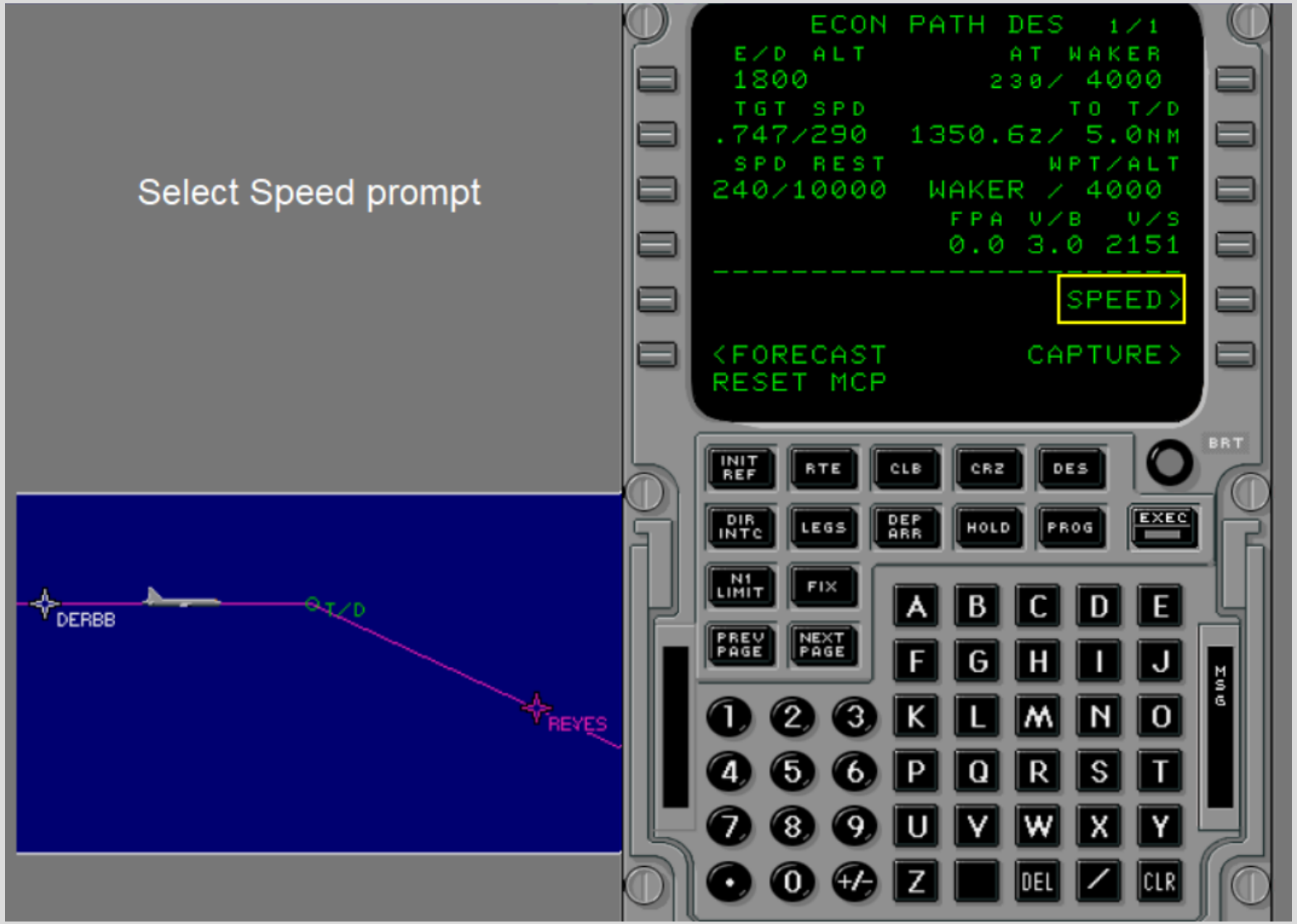
You have to tell the FMC you want
a speed descent.



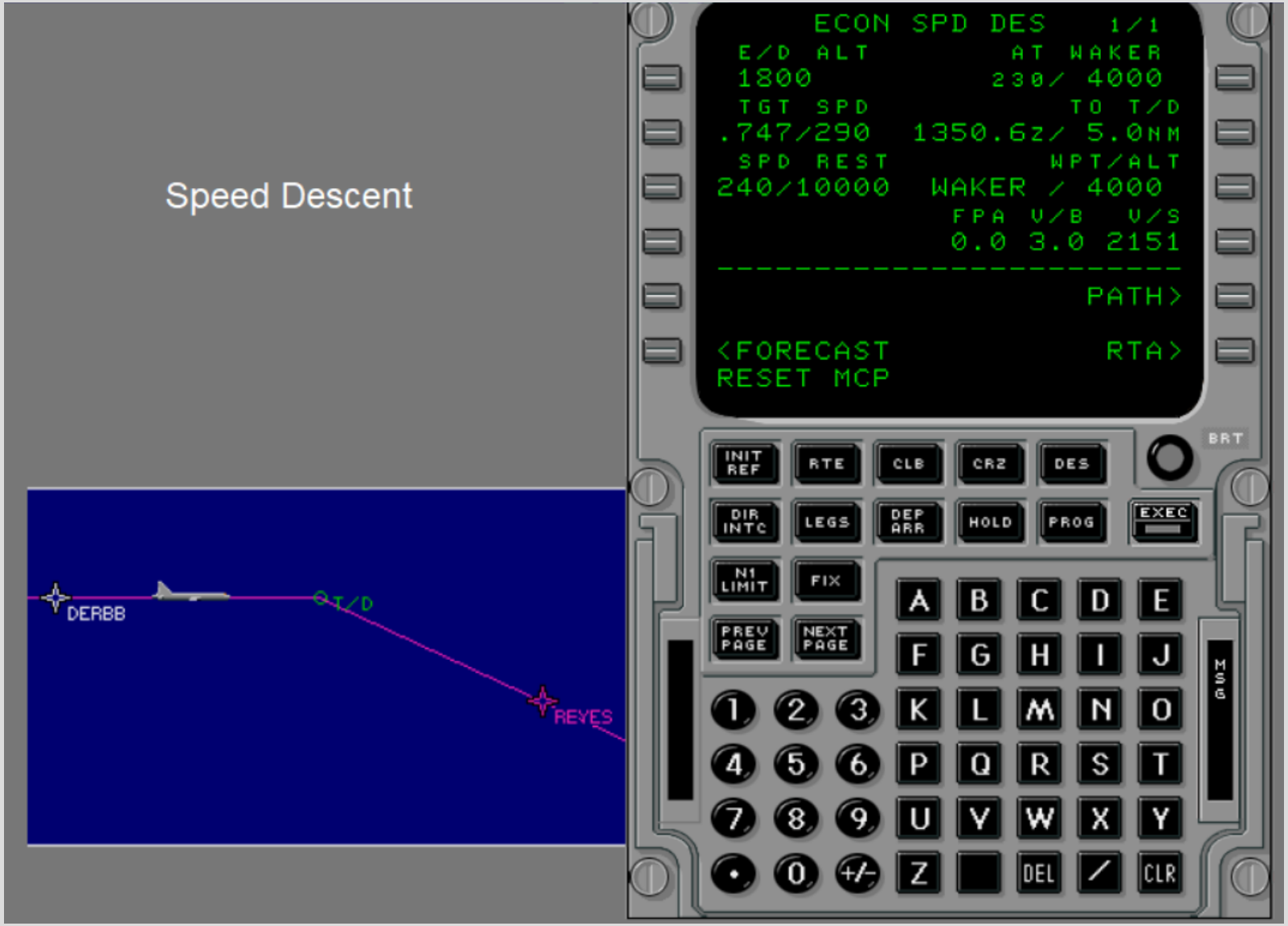
In cruise and before reaching TOD

Select the Speed prompt

and EXEC



The Speed descent becomes active when you cross TOD



Approaching TOD

Pilot: « SUPAERO 1, standing by for descent »

ATC: « SUPAERO 1, descent 4000 ft QNH 1020 »

Pilot: « Descent 4000 ft QNH 1020, SUPAERO 1 »

In case we need path descent this mode is still available

At TOD

The thrust levers retard (RETARD)

The airplaine pitches down to maintain the FMC target speed (VNAV SPD)

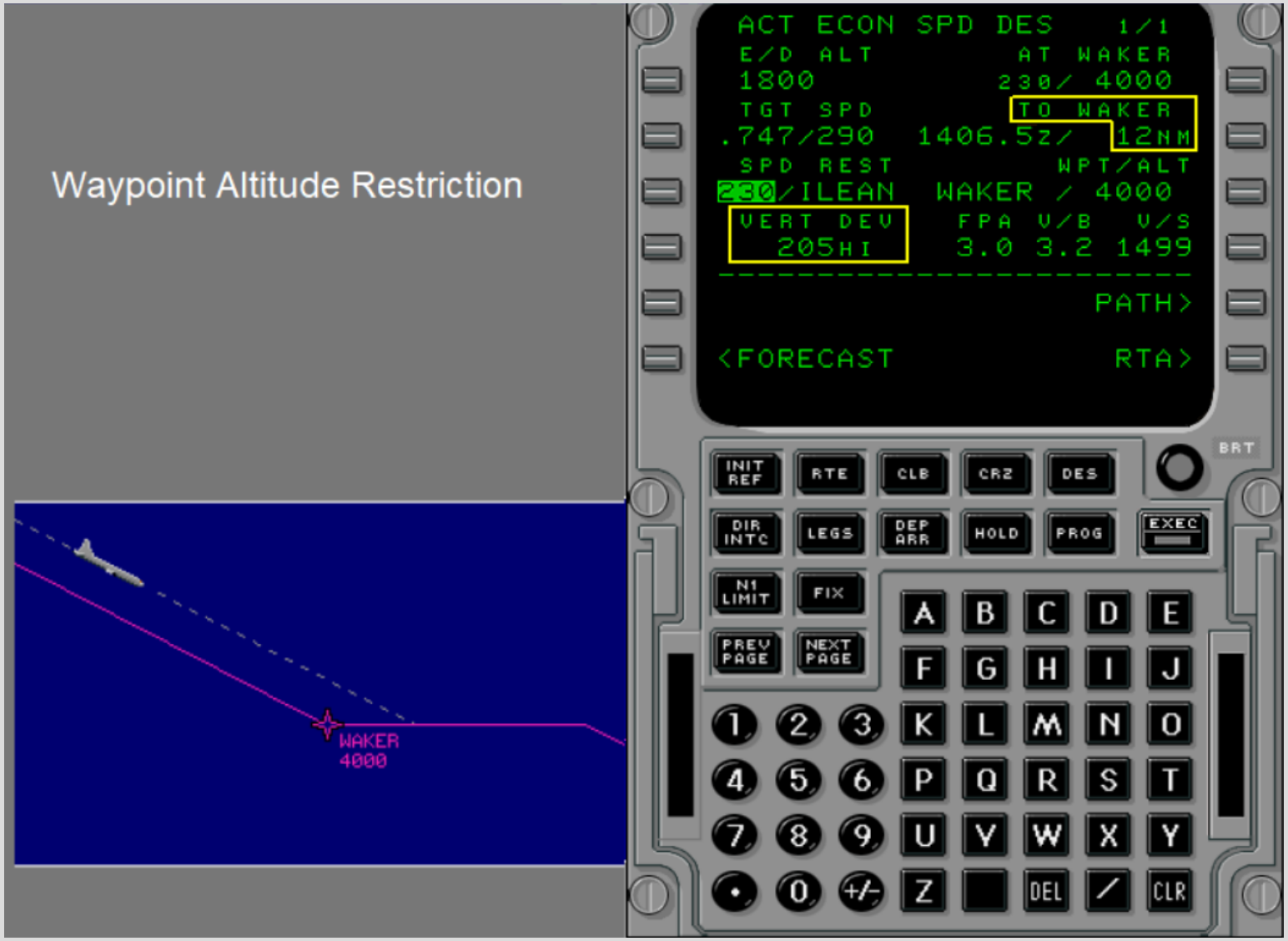
Recall that you are responsible for maintaining the path!

During a speed descent

The FMC still monitors the descent progress.

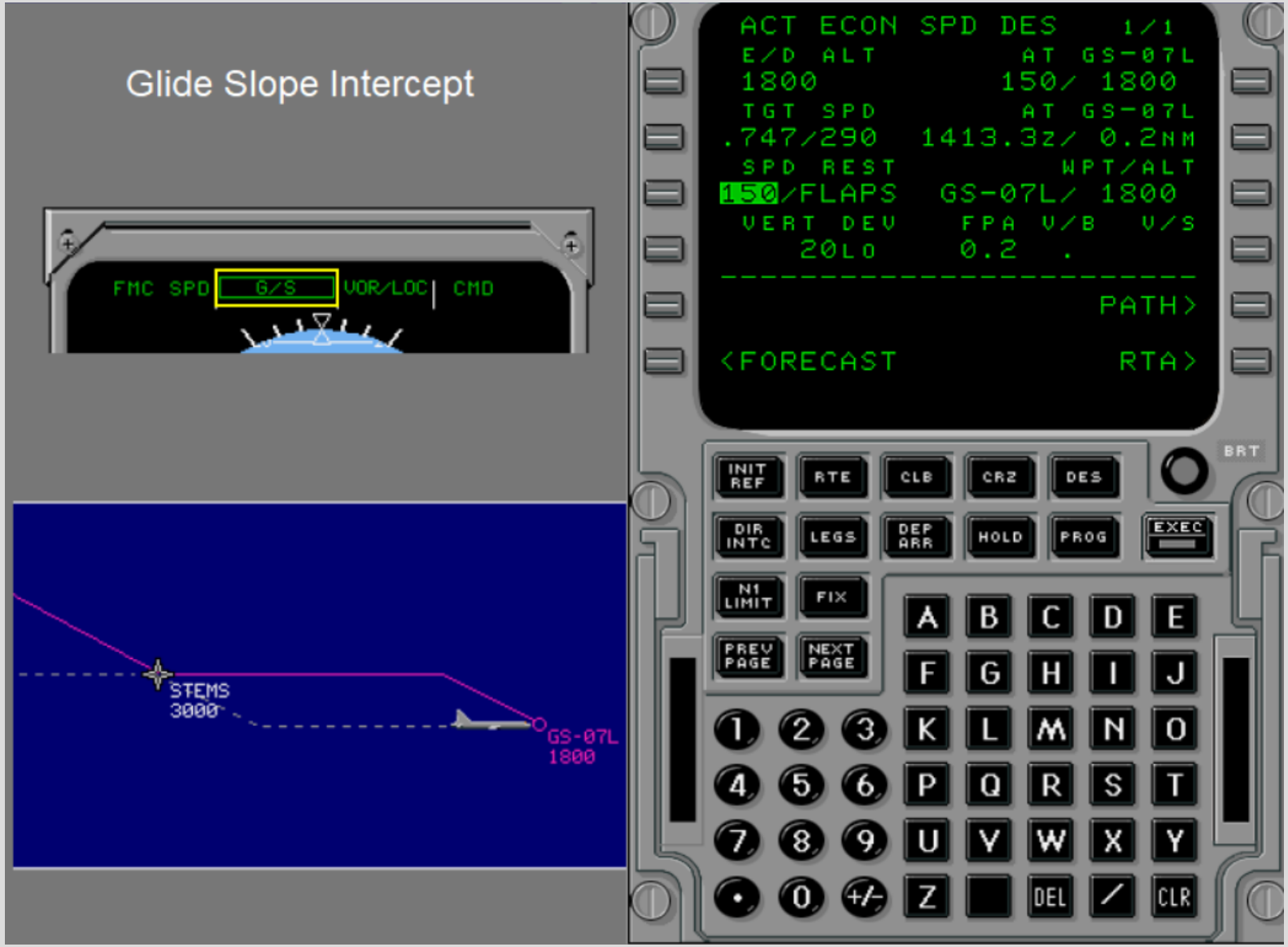
Here, you are about 200ft high and only 12 miles from WAKER

It appears you will not make this altitude restriction…



Intercepting the glide slope

The Speed descent is terminated



Changing FMC speed during the defined descent (in VNAV SPD mode)

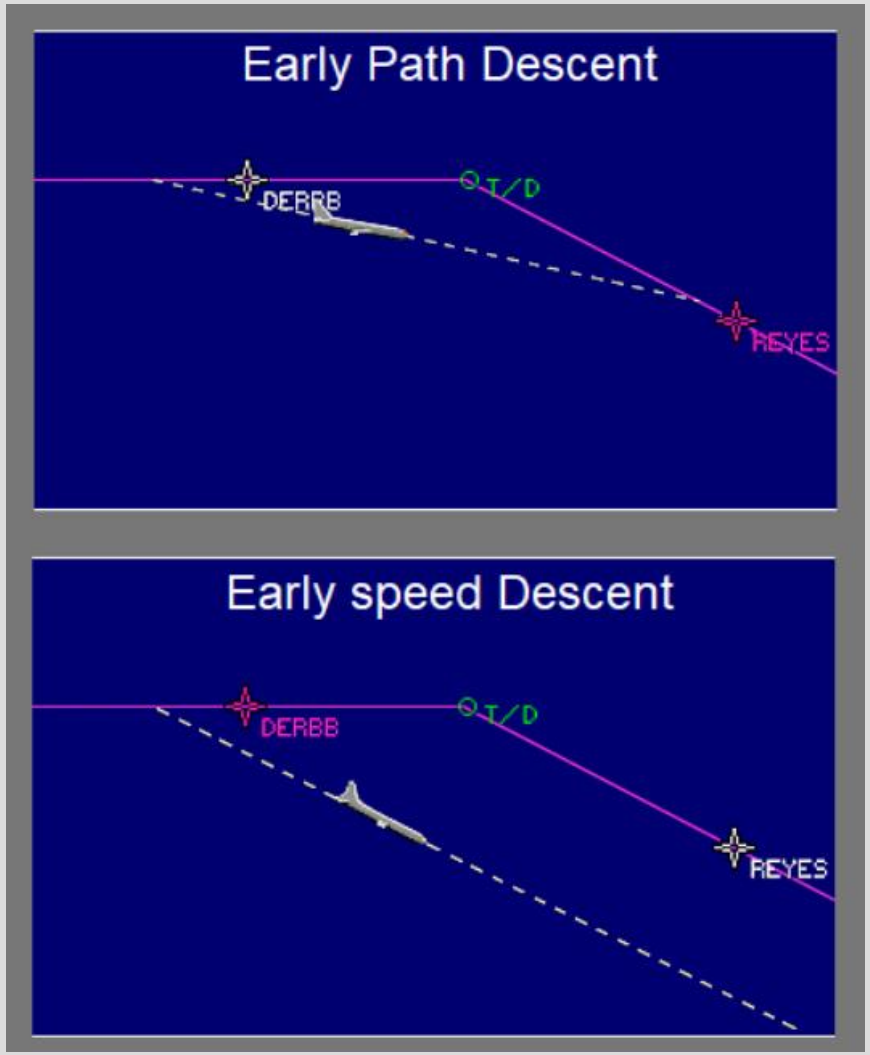
- If a lower speed is selected during the defined descent:
  - The gradient will be shallower and the aircraft will not meet the altitude restriction without some added drag (speed brakes) as the slower speed has less drag

- If a higher speed is selected during the defined descent:
  - The aircraft will descend at a steeper gradient
  - If the altitude is reached prior to the waypoint, the aircraft will level off

What does happen in case of an early descent?

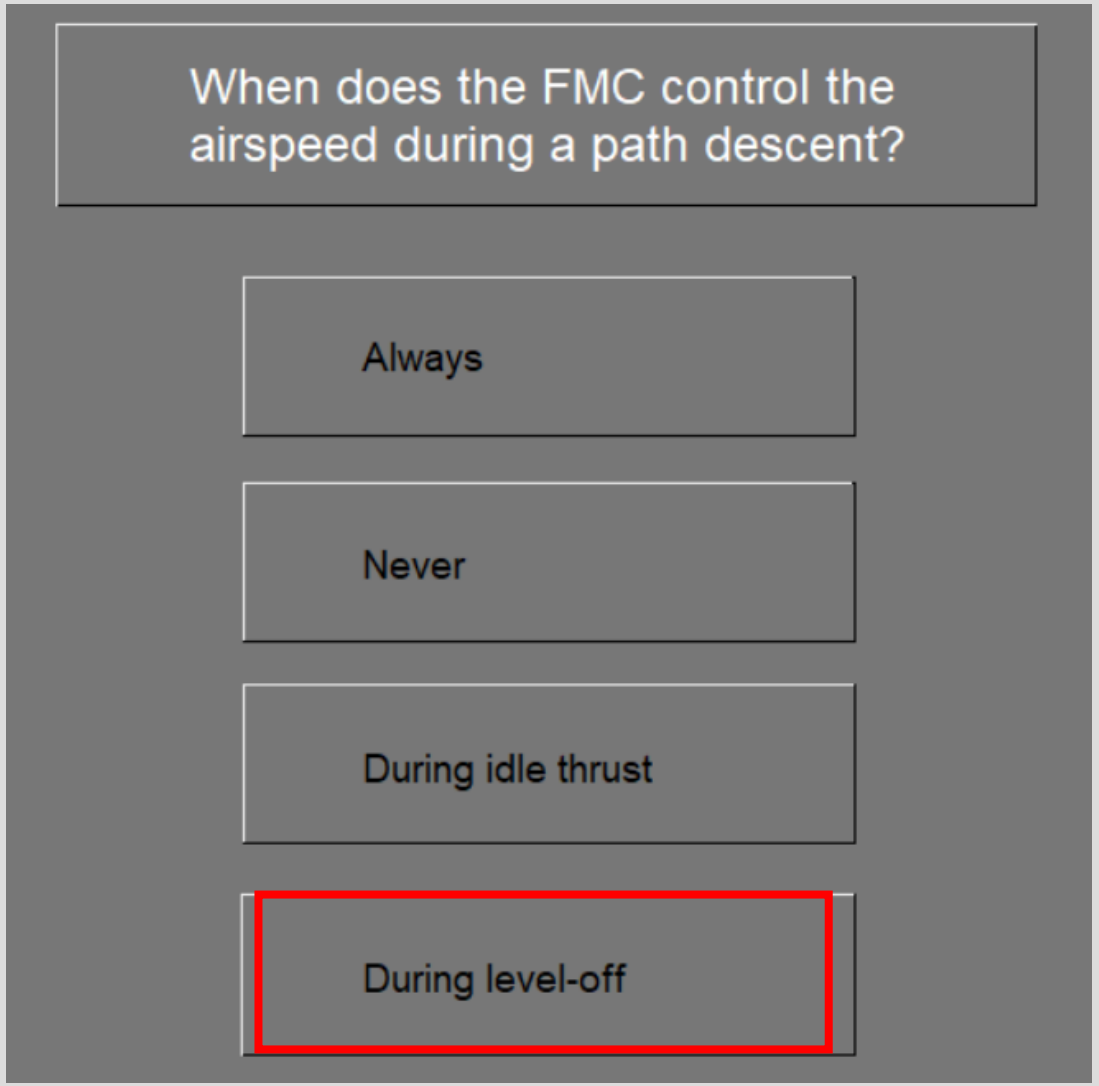
Path descent
Press on « DES NOW» prompt
- 1000 ft/min
- Thrust levers retard

Speed descent
The FMC makes no attempt
to intercept the available path



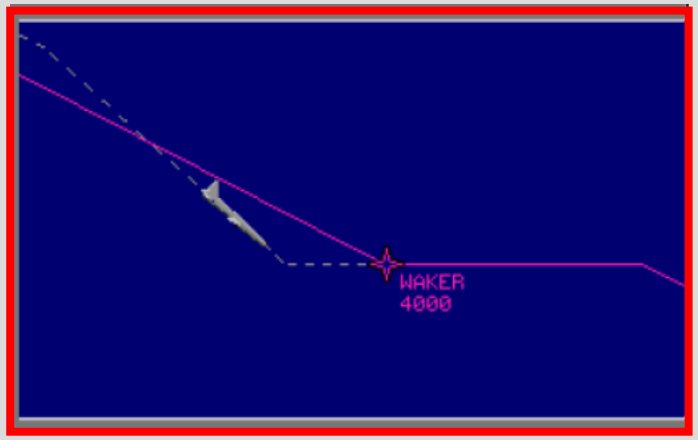
Review questions

Question 1

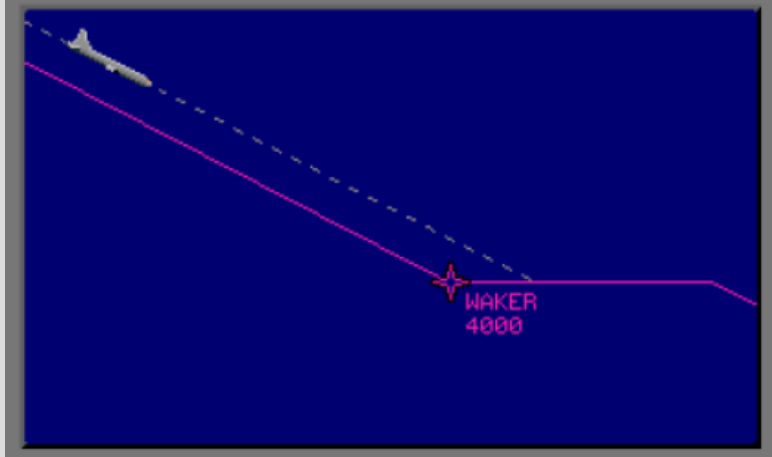


p. 51:
If there is a level off to perform somewhere along the descent path, the FMC increases thrust to maintain the airspeed (FMC SPD)

Question 2



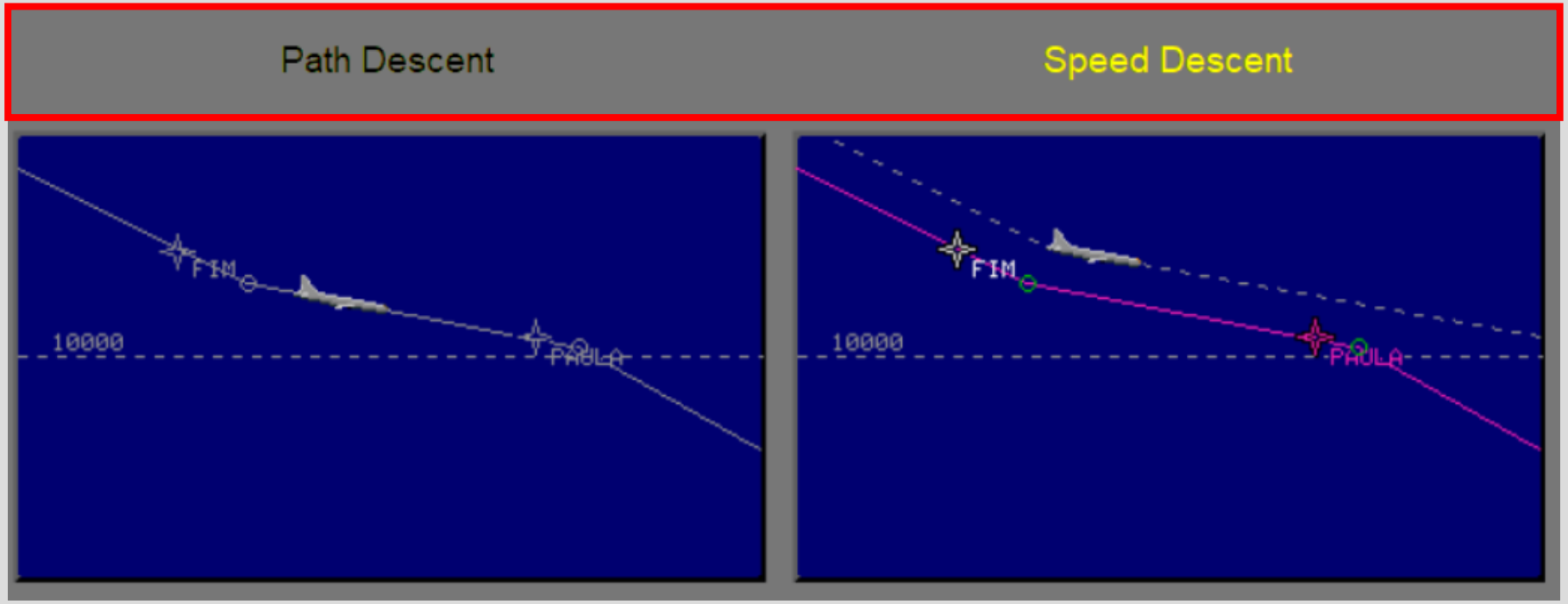
To comply with the altitude restriction at WAKER in a Speed Descent, you should



- Do nothing, the FMC controls the Path in a Speed descent.
- Extend the speed brakes
- Lower the gear, shutdown one engine and extend flaps.
- Delete the altitude restriction at WAKER.

Question 3

Which picture is showing a path descent and a speed descent?

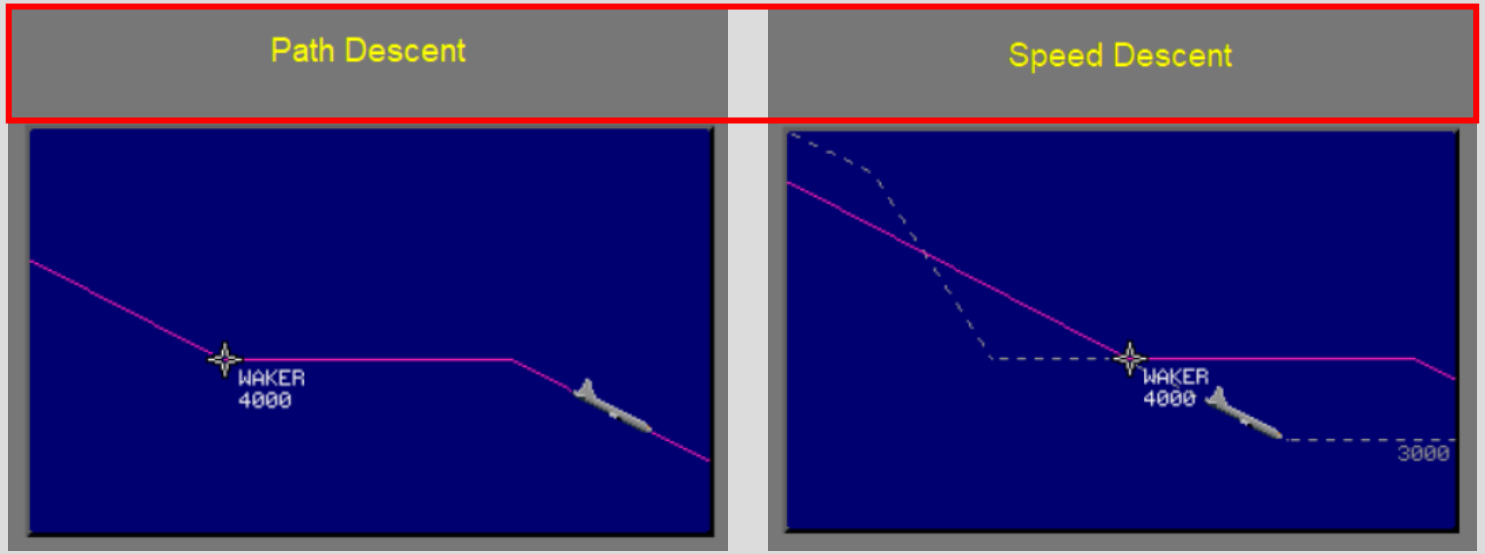


Question 4

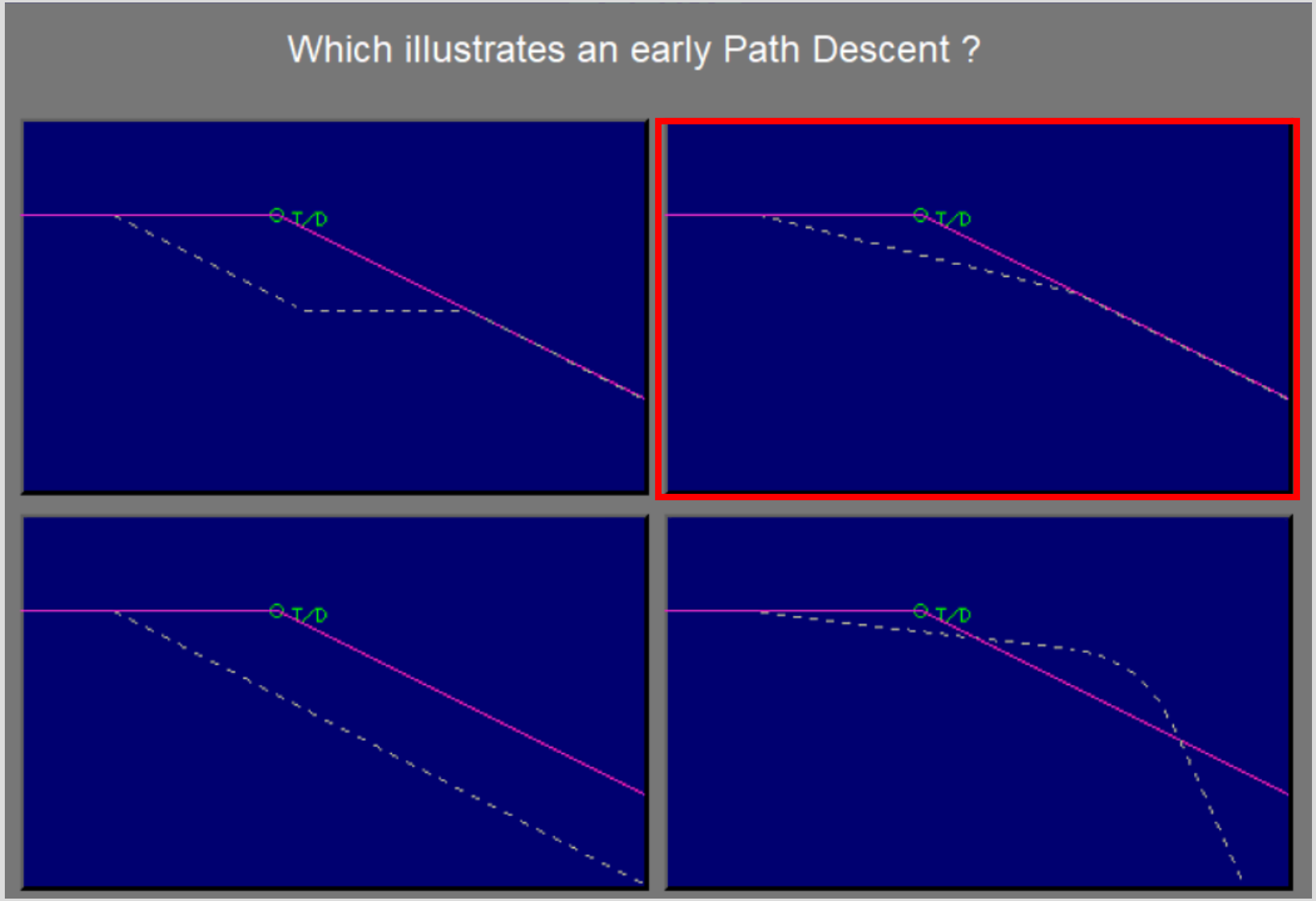
Which picture is showing a path descent and a speed descent?

In path descent, *the airplane does not descent immediately after passing an altitude restriction.*
The FMC waits until the idle-thrust descent profile is intercepted.

In speed descent, *the airplane descends immediately after the altitude restriction is crossed*



Question 5



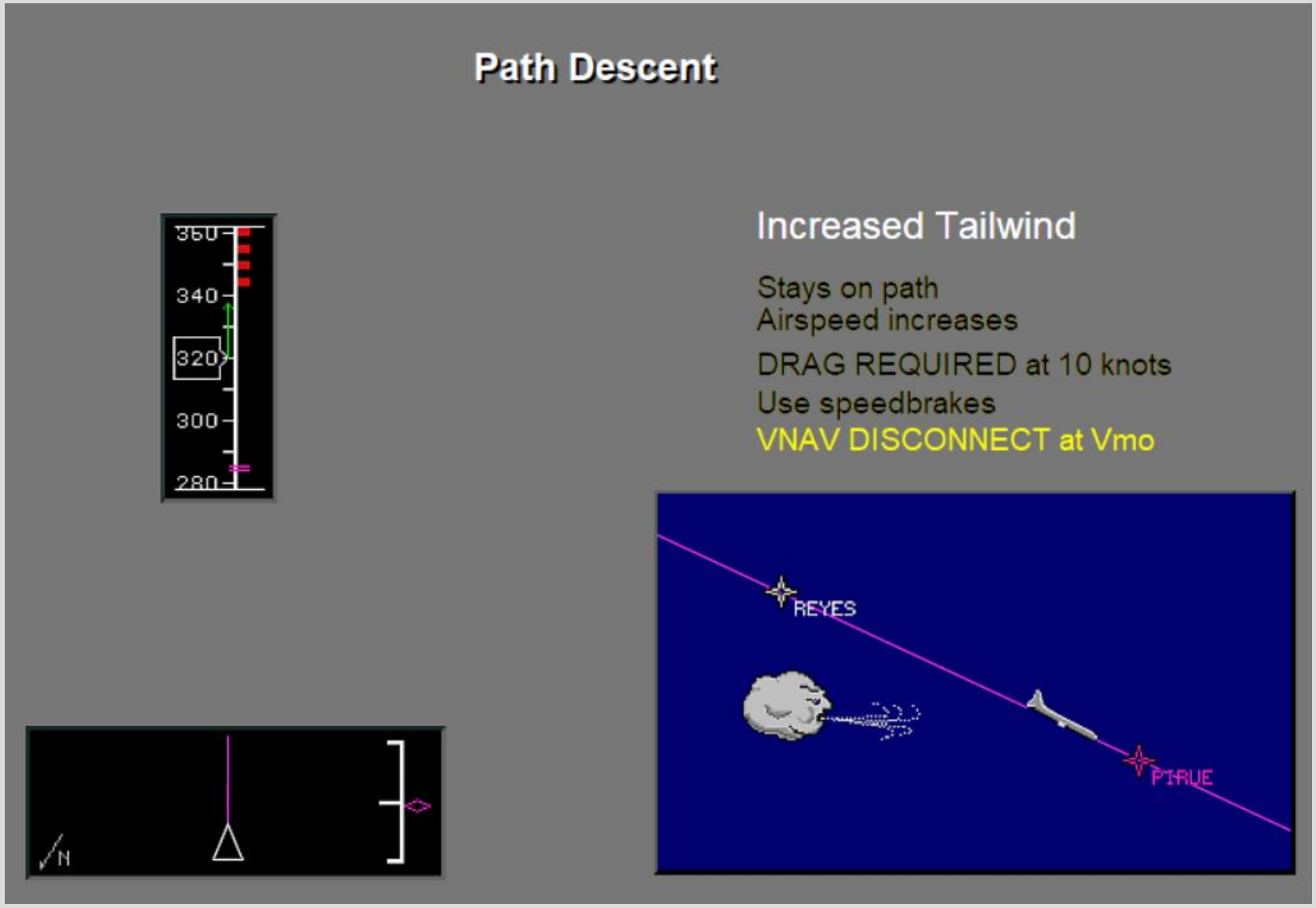
Question 6

The number
3976 represents

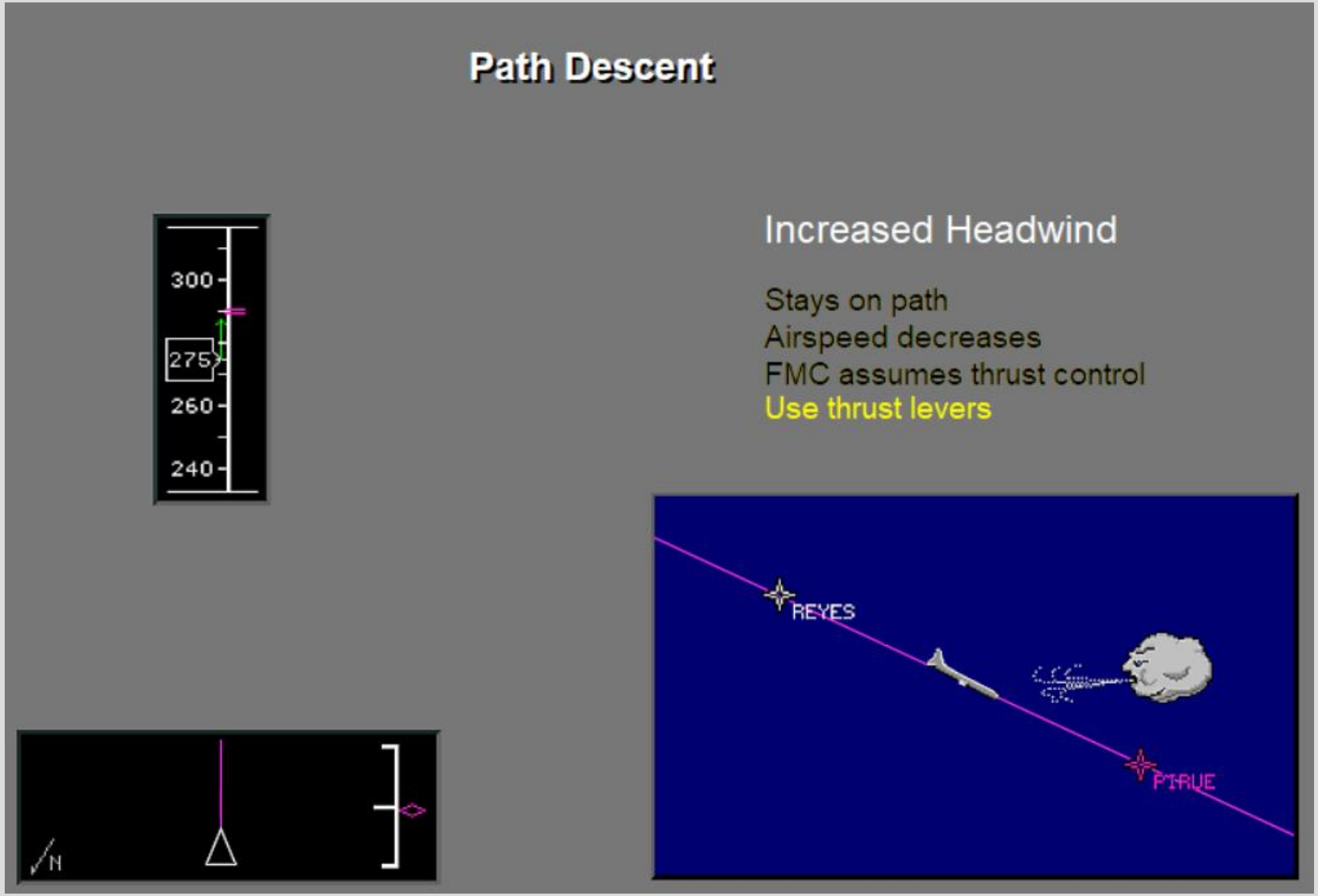
- The angle between the horizon and the actual descent path.
- The angle between the horizon and the proposed descent path.
- The vertical speed required to fly the vertical bearing.
- **The vertical speed required to fly the flight path angle.**

Impact of tail or headwinds when using Path descent?

Increased tailwind

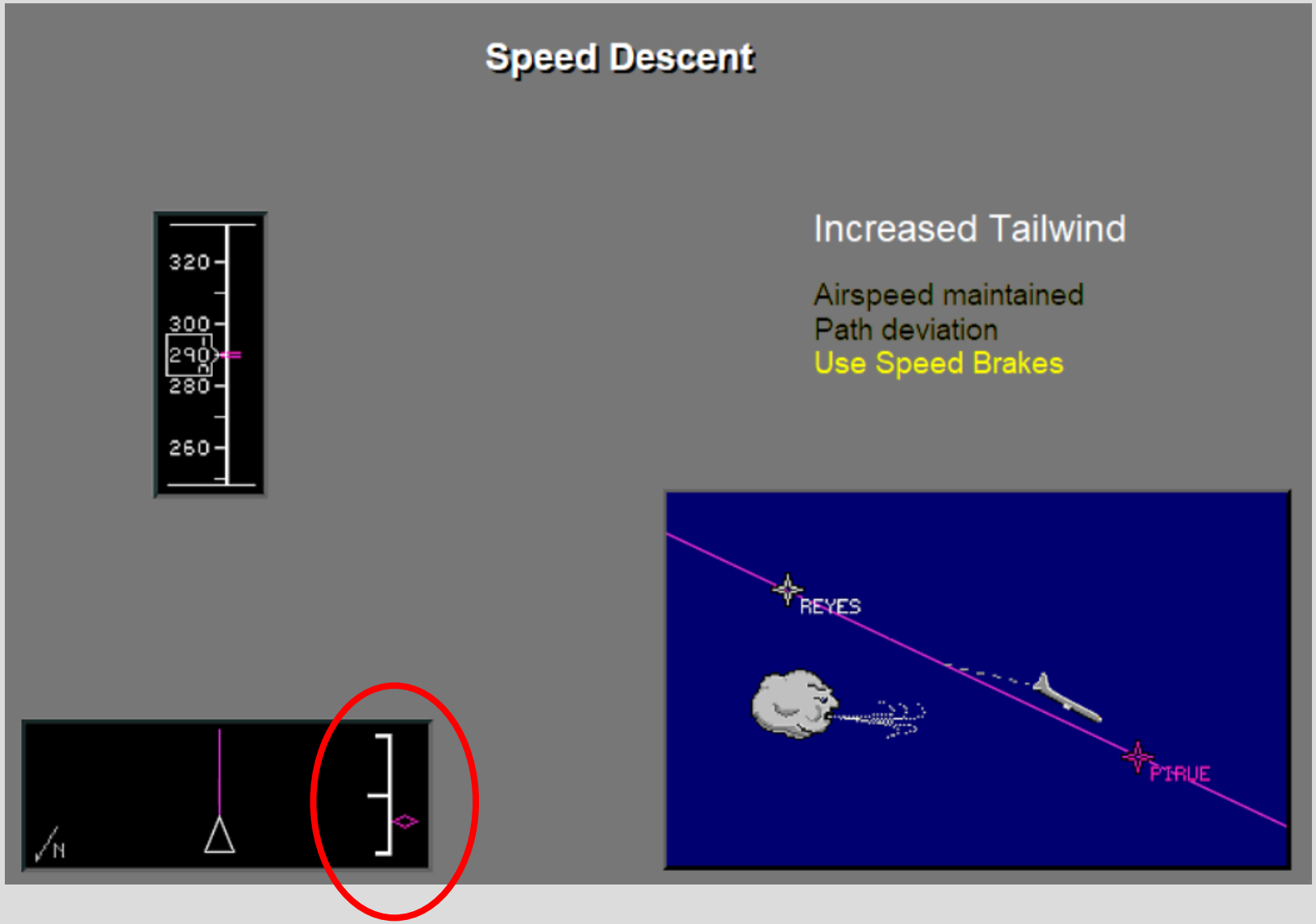


Increased headwind

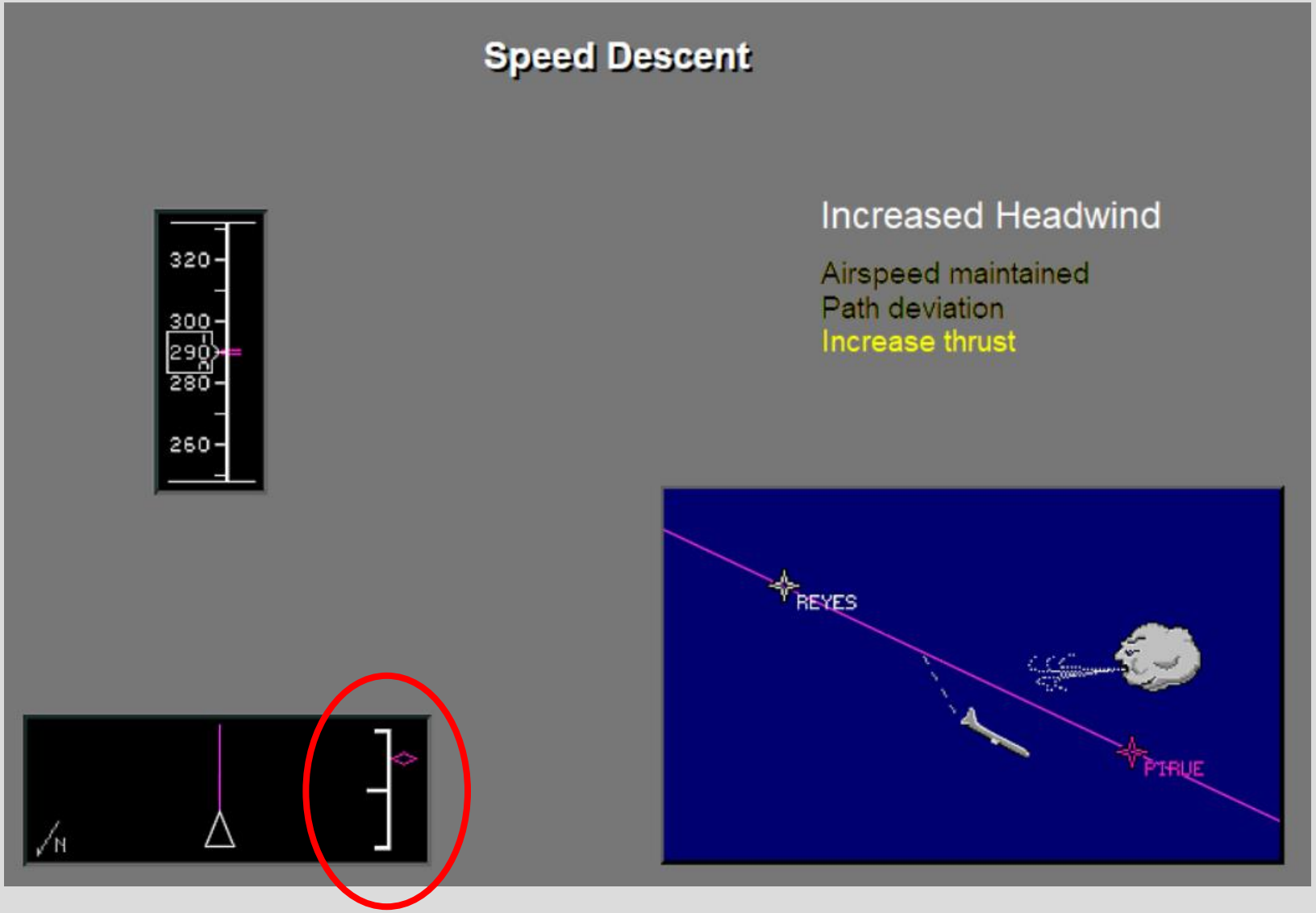


Impact of tail or headwinds when using Speed descent?

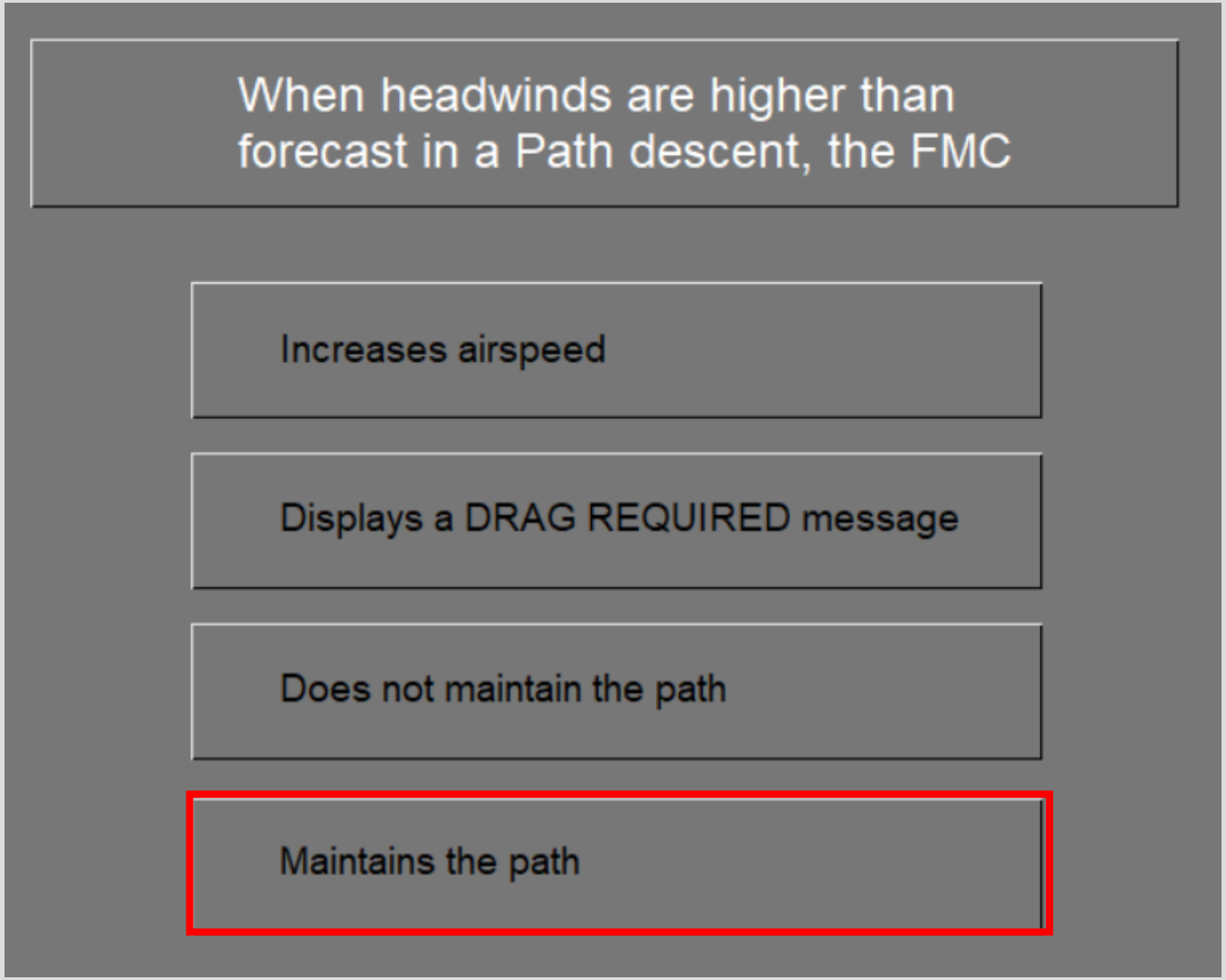
Increased tailwind



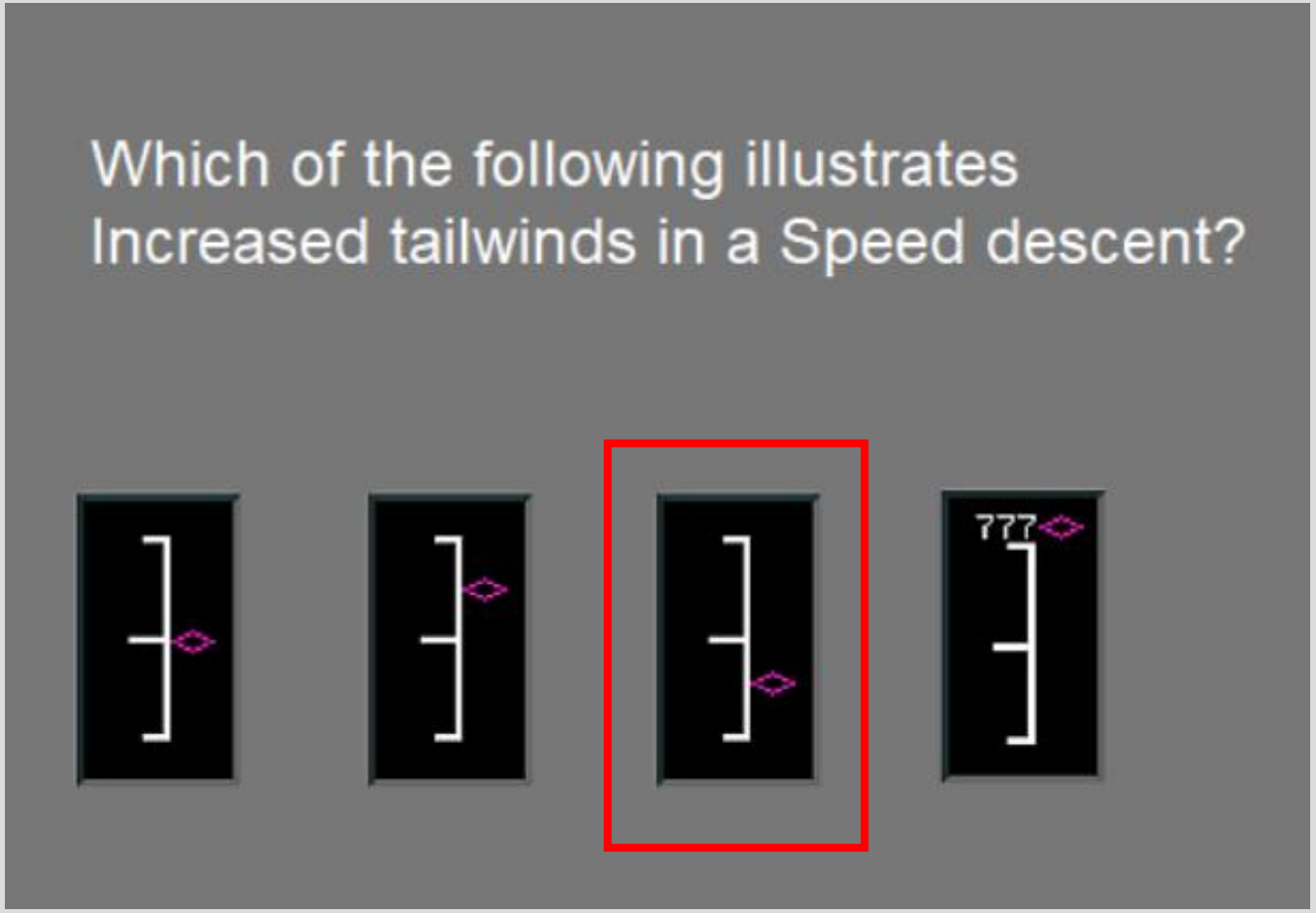
Increased headwind



Question 7


When headwinds are higher than forecast in a Path descent, the FMC
Increases airspeed
Displays a DRAG REQUIRED message
Does not maintain the path
Maintains the path

Question 8


Which of the following illustrates
Increased tailwinds in a Speed descent?
777

Question 9

Yor see these indications in a Path descent.
What should you do as the FMC corrects back to path?

- **Extend speedbrakes to control airspeed**
- Increase thrust
- Pitch the nose up
- Do nothing

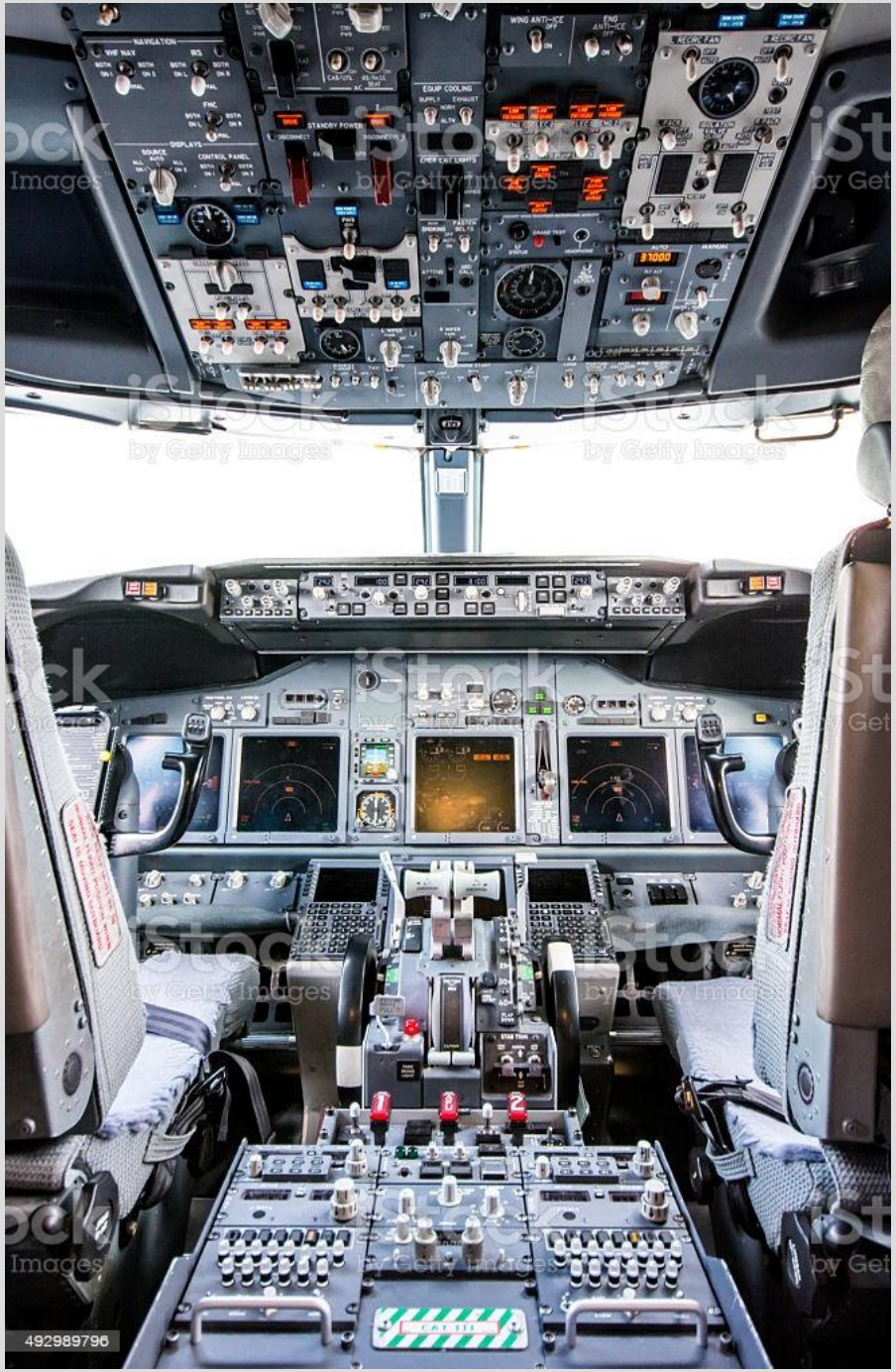
Question 10

Yor see these indications in a Path descent.
What should you do as the FMC corrects back to path?

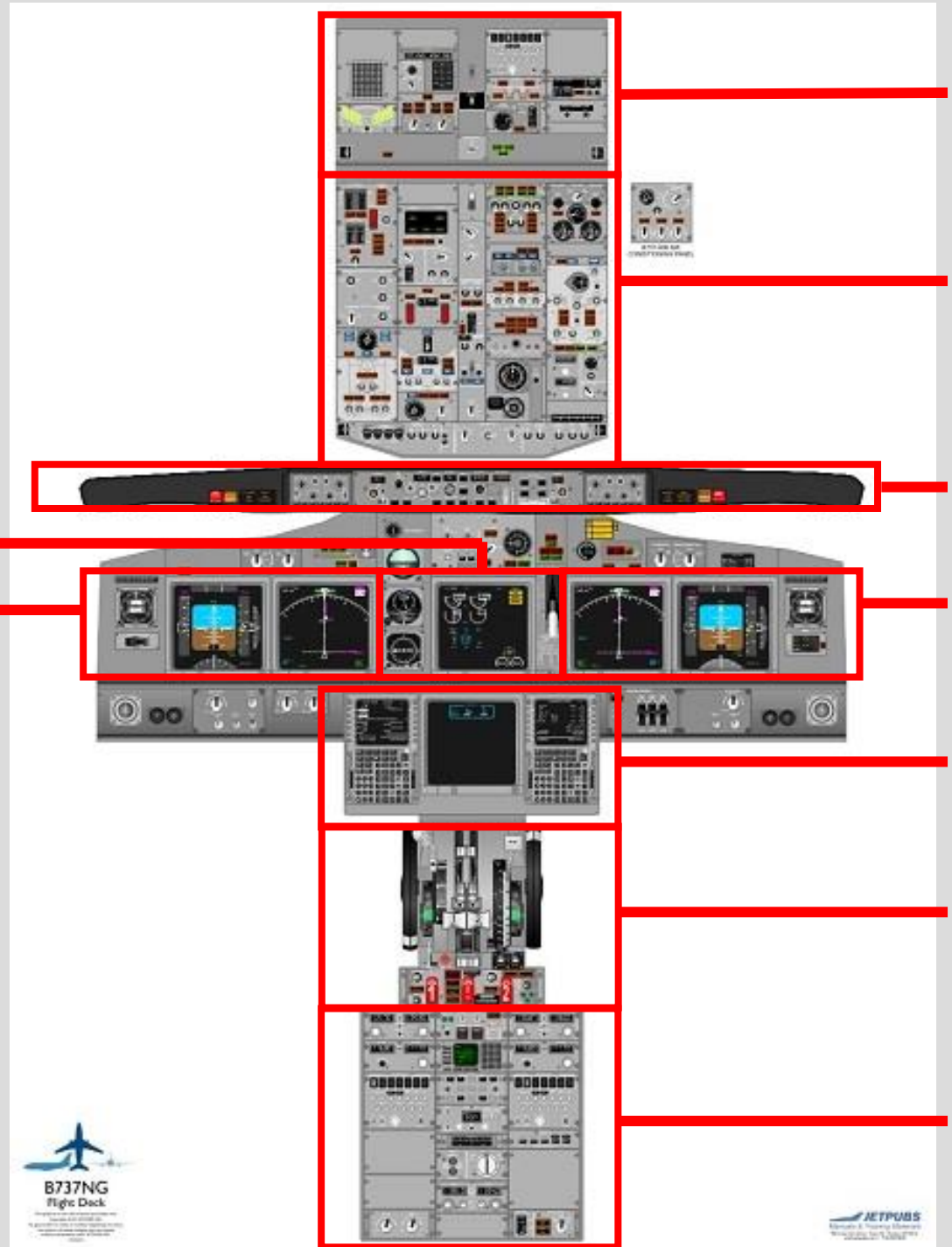
- Extend speedbrakes to control airspeed
- Increase thrust
- Pitch the nose up
- Do nothing

Chap2: The 737NG

B737NG Cockpit view



B737NG Cockpit layout



Aft overhead panel

Forward overhead panel

Glareshield panel

Center forward panel
(upper DU)

Left forward panel
(left inboard/ outboard DUs)

Right forward panel
(right inboard/ outboard DUs)

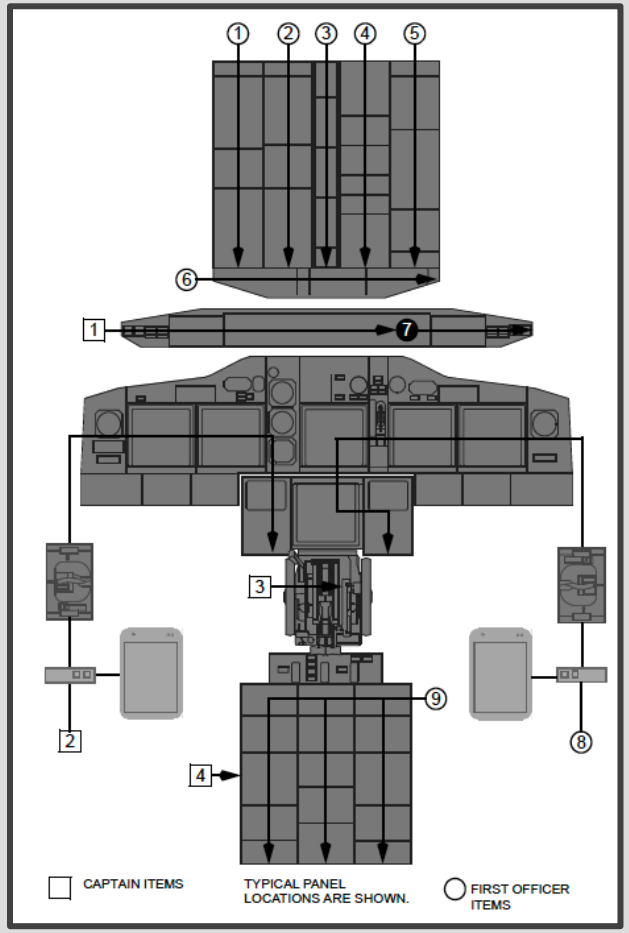
Forward Aisle stand
(lower DU + FMCs)

Control Stand

Aft electronic panel

Normal Procedures – Scan Flow

- Each crewmember is responsible for moving the controls and switches in their area of responsibility
  - Preflight and postflight areas of responsibility (**CPT – FO**) are defined by a Scan Flow



Preflight and Postflight Scan Flow for B737NG

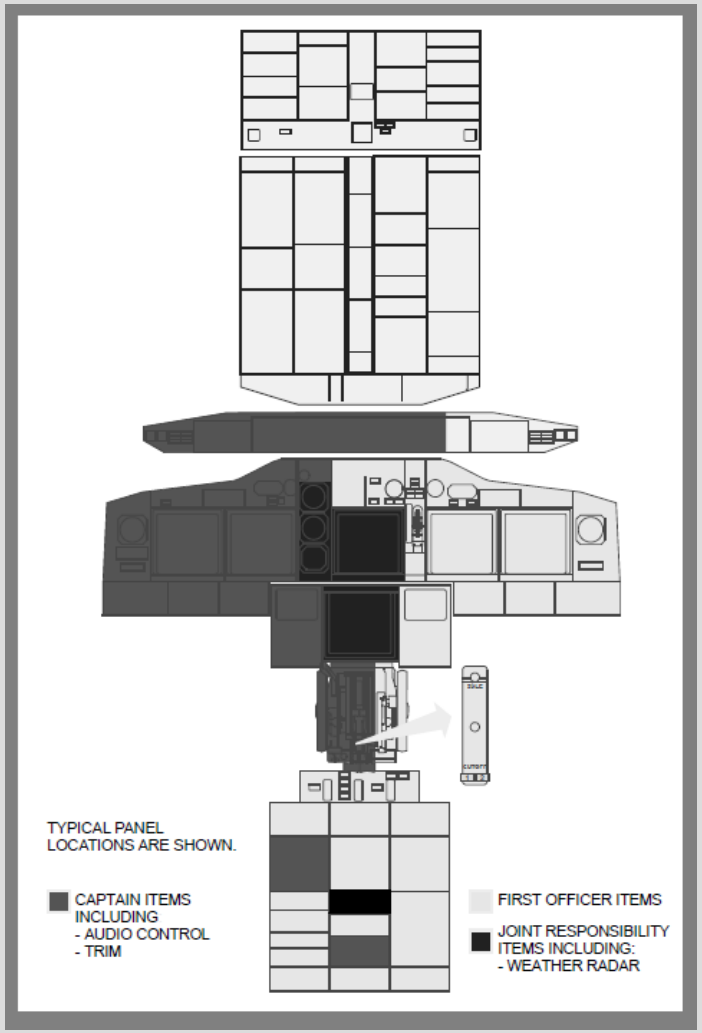
- 4 scan flow sectors for **CPT**
- 9 scan flow sectors for **FO**
- The scan flow diagram provides general guidance on the order each flight crew member should follow when doing the preflight and postflight procedures

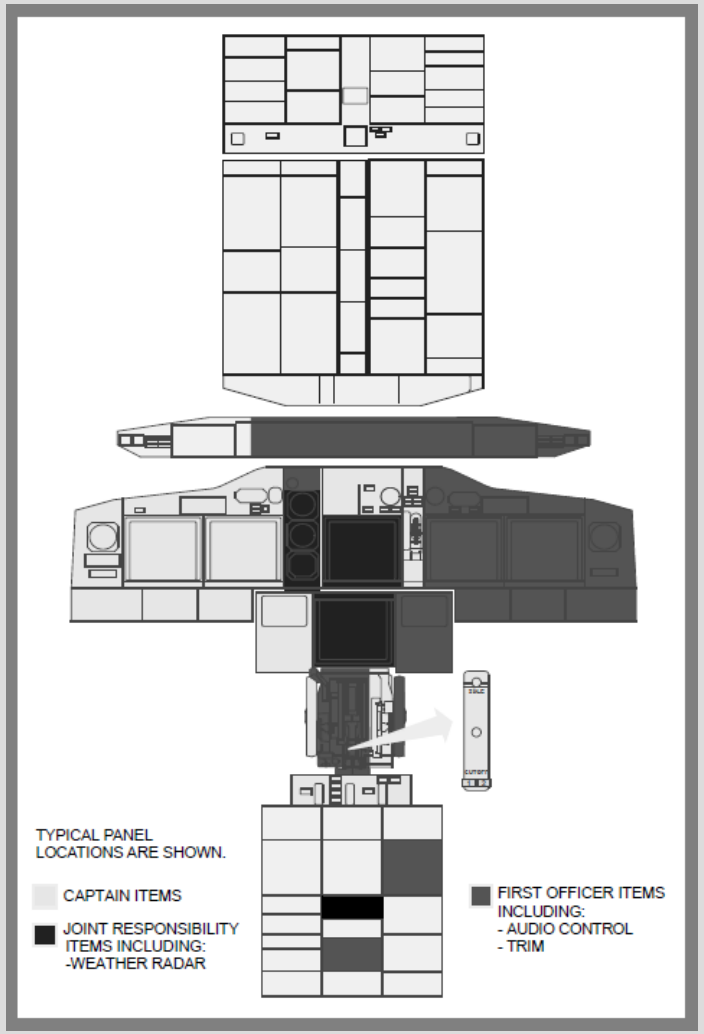
➔ *The scan flow sequence may be changed as needed*

Normal Procedures – Crew Duties 1/2

- The duties are divided between the two pilots according to their **role** in each phase of flight **(PF - PM)**

*Captain as **Pilot Flying** (or Taxiing)*





*First Officer as **Pilot Flying** (or Taxiing)*

Normal Procedures – Crew Duties 2/2

- **PF phase of flight responsibilities are:**
  - Taxiing
  - Flight path and airspeed control
  - Airplane configuration
  - Navigation
- **PM phases of flight responsibilities are:**
  - Checklist reading
  - Communications
  - Tasks asked for by the PF
  - Monitoring taxiing, flight path, airspeed, airplane configuration and navigation

➔ *MCP is the PF's responsibility. When flying manually, the PF directs the PM to make the changes on the mode control panel*

Use of Checklists – Overview

Checklist	Call	Read	Verify	Respond
PREFLIGHT	Captain	First Officer	Both	Area of responsibility
BEFORE START	Captain	First Officer	Both	Area of responsibility
BEFORE TAXI	Captain	First Officer	Both	Area of responsibility
BEFORE TAKEOFF	PF	PM	Both	PF
AFTER TAKEOFF	PF	PM	Both	PM
DESCENT	PF	PM	Both	Area of responsibility
APPROACH	PF	PM	Both	Area of responsibility
LANDING	PF	PM	Both	PF
SHUTDOWN	Captain	First Officer	Both	Area of responsibility
SECURE	Captain	First Officer	Both	Area of responsibility

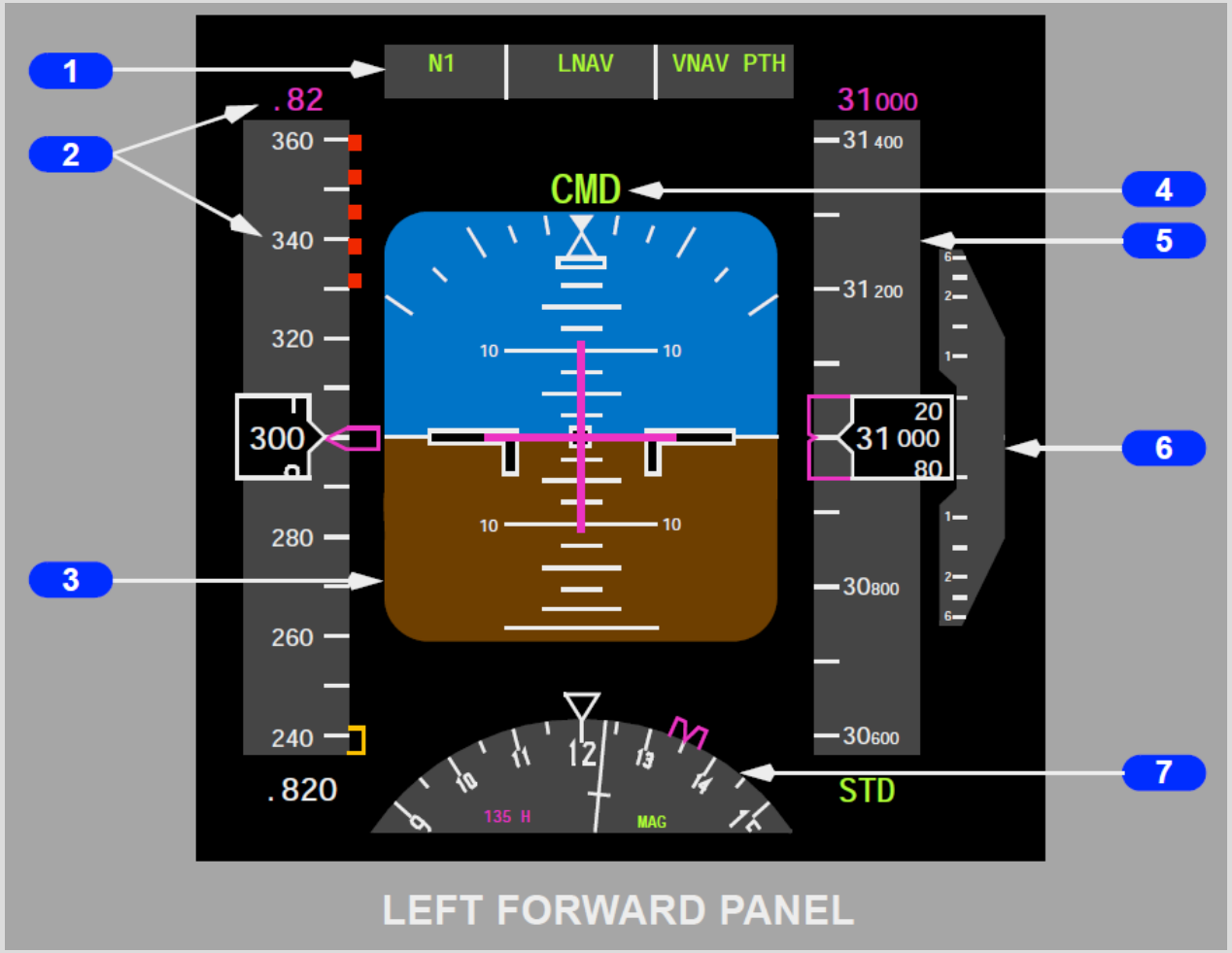
- Once a checklist is completed, the PM must advise the PF and announce: ***"Checklist complete"***

Aircraft Systems

Primary Flight Display (PFD)

(Captain Outboard Display)

1. Flight Mode Annunciator (FMA)
2. Airspeed/Mach indications
3. Attitude indications
4. A/P and F/D system status
5. Altitude indications
6. Vertical speed indications
7. Heading/Track indications

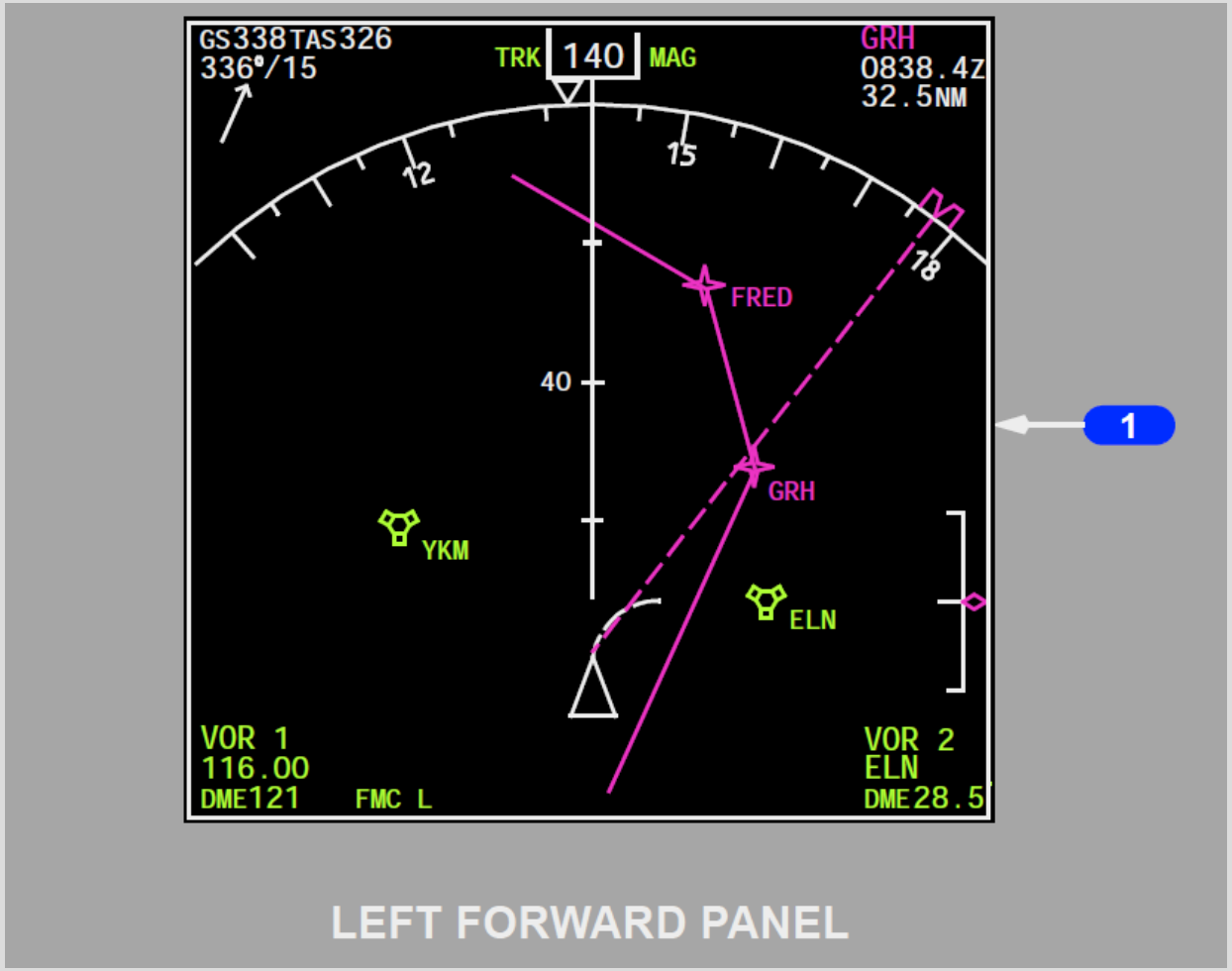


PFD displays very important parameters for conducting the flight
(speed, altitude, attitude, heading, active and armed autopilot modes, …)

Navigation Display (ND)

(Captain Inboard Display)

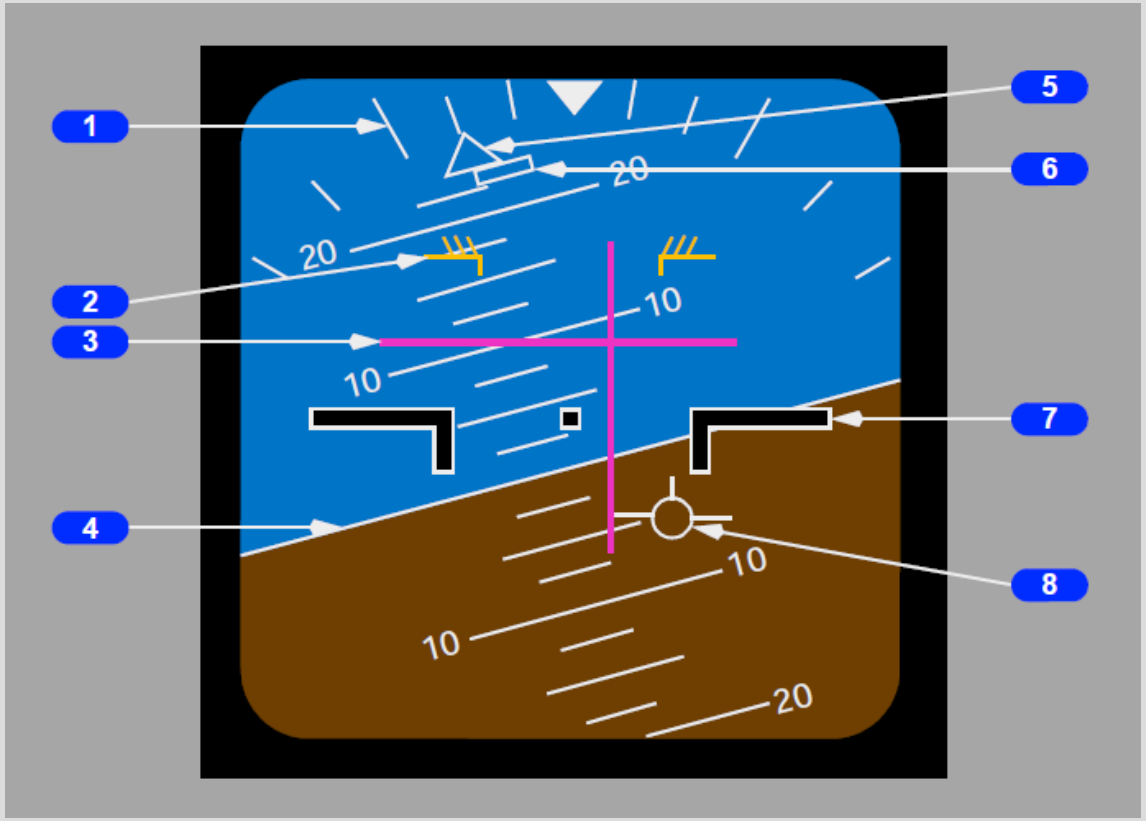
1. Displays Map, Approach, VOR, or Plan modes as selected on the EFIS panel



ND displays important features for navigation
(waypoints, wind direction and intensity, ground speed, navaids frequencies, …)

Attitude Indications

1. Bank scale (0, 10, 20, 30, 45 and 60°)
2. Pitch Limit indication (amber)
3. F/D bar (magenta)
4. Horizon line and pitch scale 2.5° increments
5. Bank pointer (filled amber when > 35°)
6. Slip/Skid indication
7. Airplane symbol
8. Flight Path Vector (FPV)
   - Displays flight path angle + Drift

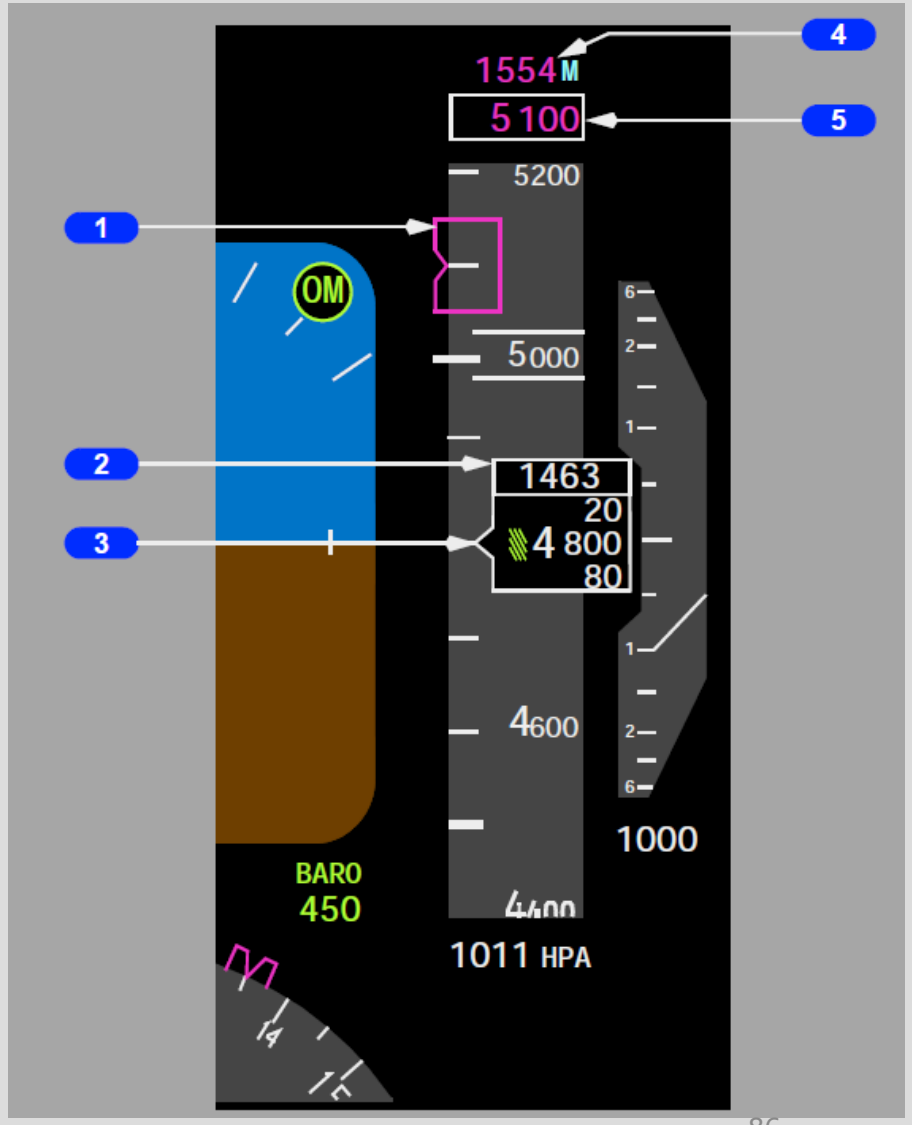


Displays important information about the aircraft attitude (bank and pitch angles, FD bars, symetry of the flight, …)

Altitude Indications

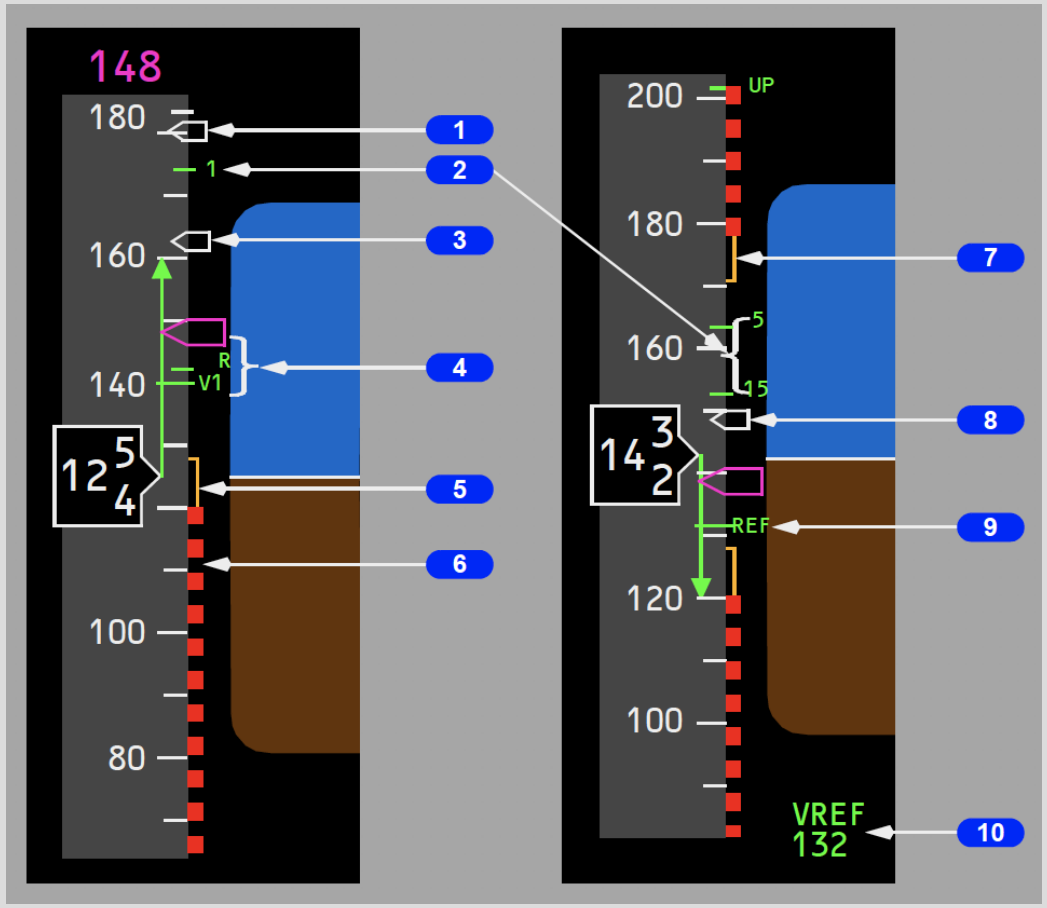
1. Selected altitude Bug (magenta) – set in the MCP
2. Current altitude in meters when MTRS is selected
3. Current altitude in feet
4. Current MCP altitude in meters when MTRS is selected
5. Current MCP altitude set in the MCP

Displays important information about the aircraft altitude (altitude or flight level, vertical speed, altimeter setting, …)



Displays important information about the aircraft speeds (actual, for flaps retraction/extension, VMO, …)

PFD Airspeed Indications



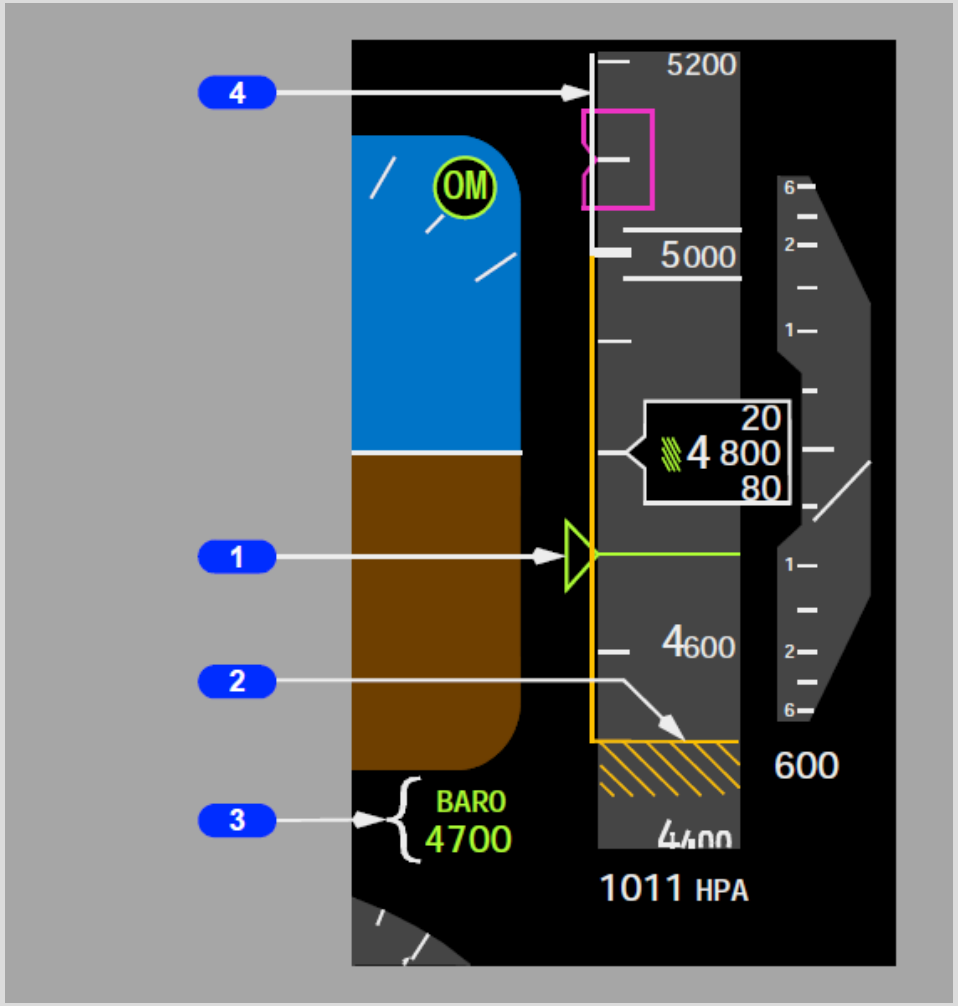
1. Bug 5 (white)
2. Flaps maneuvering speeds (green)
3. V2 + 15
4. V1 and VR
5. Minimum maneuver speed
6. Minimum speed (stick shaker)
7. Maximum maneuver speed
8. VREF + 20
9. Landing Reference Speed
   Indicates REF (reference speed) as selected on the CDU APPROACH REF page
10. REF speed is displayed at the bottom of airspeed indication when selected and value is off scale.

Landing Altitude/Minimums Indications

1. BARO minimums pointers (green)
   Indicates the barometric minimums selected on the EFIS control panel: pointer and line turn amber when airplane descends below selected minimum altitude
2. Landing altitude indication (amber)
3. Minimums reference (green)
4. Landing altitude reference bar:

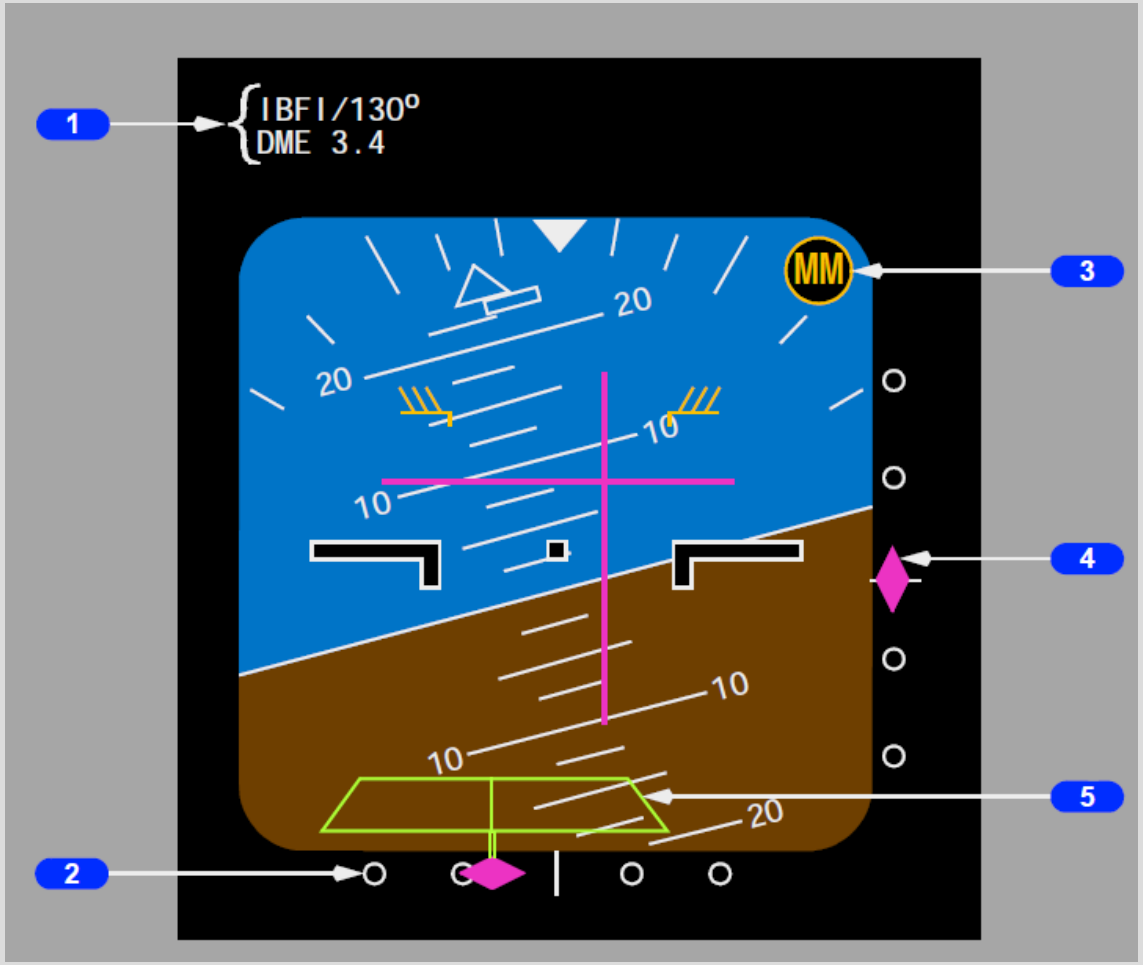
   - 500 to 1,000 feet above Land Alt (white)

   - 0 to 500 feet above Land Alt (amber)



ILS Indications

1. Selected ILS frequency/Approach course
   DME distance
2. LOC pointer and deviation scale
3. Outer (OM)/Middle (MM)/Inner (IN) Markers
4. GLIDESLOPE Pointer
5. Rising Runway



Displays important information for performing an ILS (LOC and GLIDE pointers, FDs, ILS frequency, …)

Automatic flight
Takeoff profile (without the FMS)

Verify engine bleeds and PACKS operating
Engine start switches as needed
AUTO BRAKE OFF
Landing Gear lever OFF
Then Read the After TO C/L

3000 ft HAA

"FLAPS UP, NO LIGHTS"

1500 ft HAA

400 ft AGL

"FLAPS UP"

"AFTER T/O C/L"

"FLAPS 1"

"Set VNAV"

PM

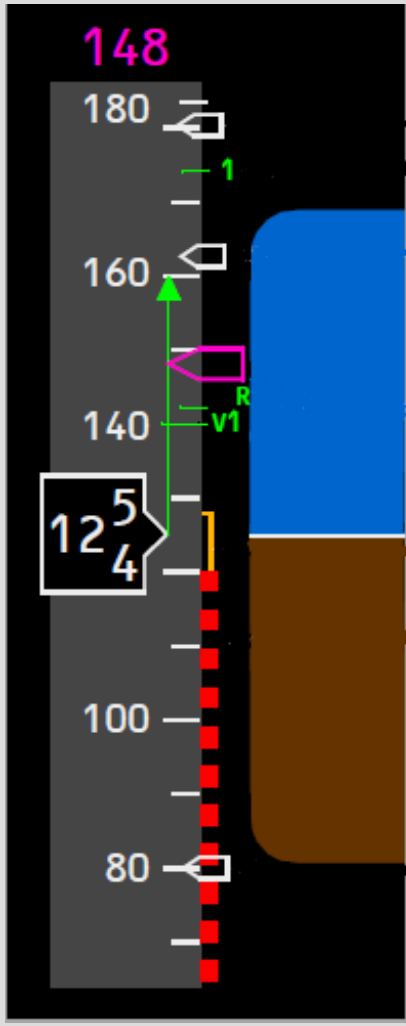
"Positive Rate"

"80 kts, V1, Rotate"

Verify LNAV or select roll mode

"Gear Up"

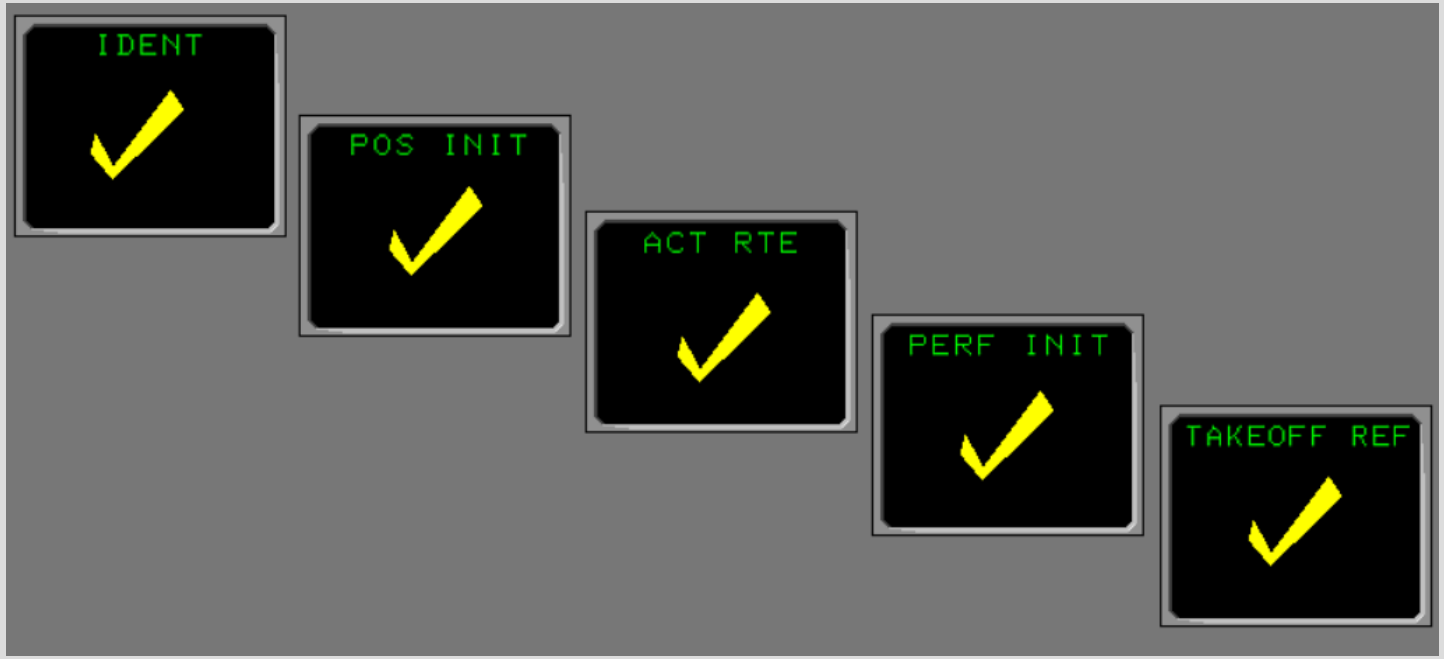
PF



Engage the A/P when above minimum Altitude for A/P engagement (400 ft AGL)

FMS programmation and MCP setup for an automatic LNAV/VNAV Takeoff and Climb

- **FMS programmation prior to Automatic Takeoff and Climb**
  - Preflight of the CDU is complete when you have entered all required information on 5 preflight pages



- **MCP setup prior to Automatic Takeoff and Climb**
  - Both FDs must be ON
  - Arm Autothrottle (confirm ARM on FMA and verify TO on TMD)

- Both LNAV and VNAV switches ON

This will allow LNAV and VNAV to engage automatically when passing 50 and 400ft RA (Radio Altitude) respectively

Automatic control systems are ready to go!

LNAV/VNAV Takeoff profile

Watch videos!

- Takeoff in basic modes (2’24’’)
- Takeoff in LNAV/VNAV (4’20’’)

FMS Takeoff page

Standard PF in-flight Takeoff page 1

Speeds and assumed temperature must be entered manually from performance tables.

TO SHIFT should be entered if departing from an intersection as this is used to update the FMC position when TOGA is pressed at the start of the takeoff roll.

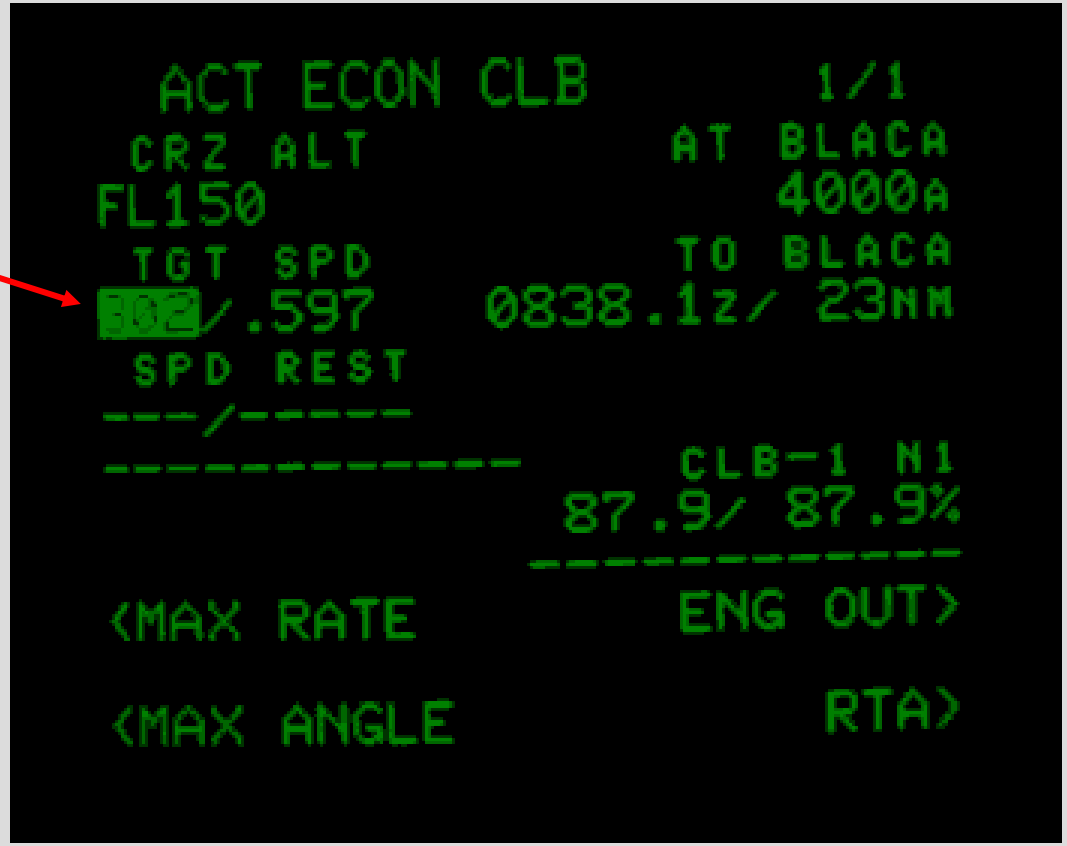
FMS ECON Climb page

Standard PF in-flight ECON climb page

302 kts is highlighted indicating that this is the Target Speed.

This will automatically change over to Mach (0.597 in this case) during the climb (when passing approximatively 26,000ft).

Other climb modes are available with keys 5 & 6, L & R.



Examples of Climb in Level Change and V/S

Watch videos!

- Climb in Level Change (1’31’’)
- Climb in V/S (2’23’’)

FMS Cruise page

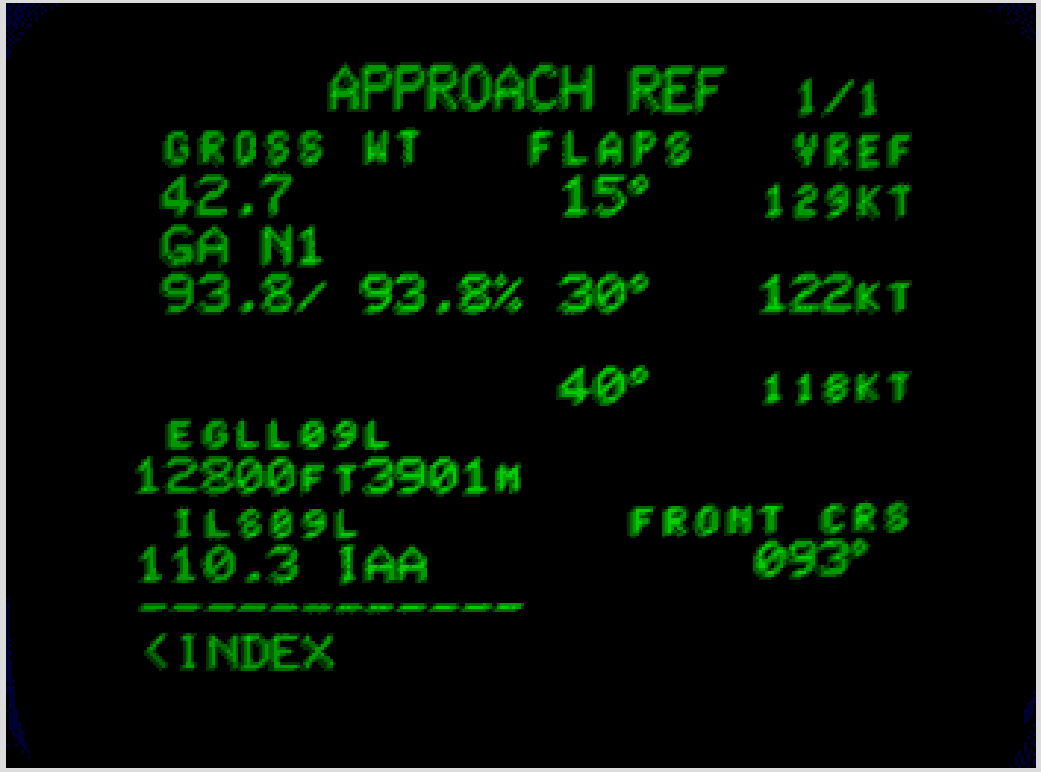
Standard PF in-flight cruise page

The target speed (here a Mach number) is the ECON speed which is derived from the cost index and winds

FMS Approach page

Standard in-flight approach page

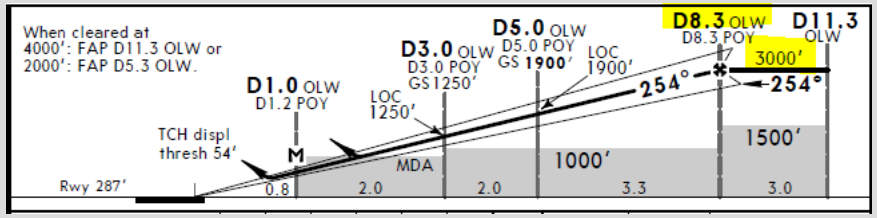
VREF is calculated from the *current* gross weight, pedants my wish to overwrite the GROSS WT with the predicted GW for landing.

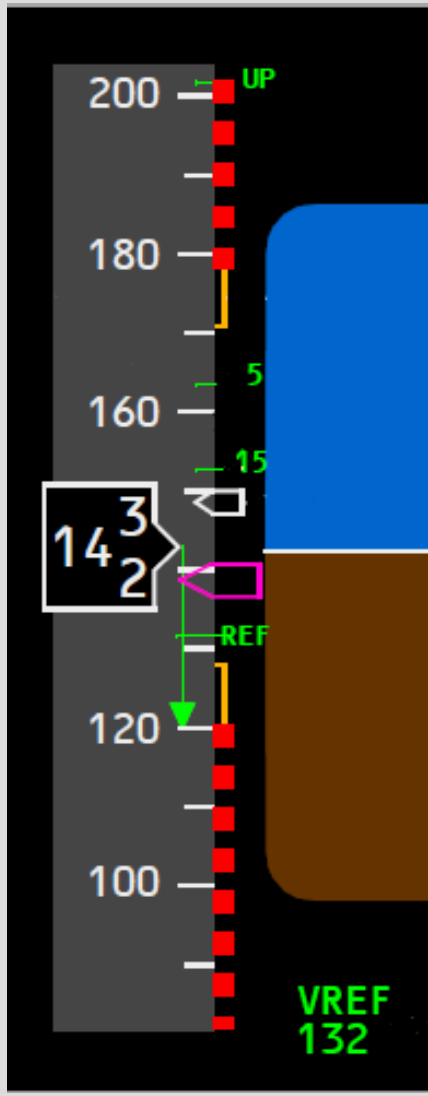


ILS Approach profile

PM

PF





"SET SPEED UP"

"FLAPS 1"

"FLAPS 5"

"LOCALIZER ALIVE"
"GLIDE ALIVE"

"FIX, ….feet"

"STABILIZED / GO AROUND"

"CLEARED"
"STANDBY FOR CLEARANCE"

"GEAR DOWN"
"FLAPS 15"

"FLAPS 30"

"LANDING C/L"

1000 ft RA

500 ft RA

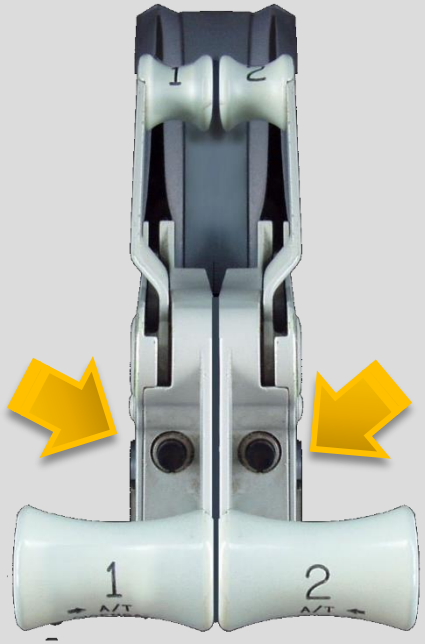
MINIMUM

"CONTINUE"
"GO AROUND"

"LANDING"

"SPEED BRAKE UP"
"REVERSERS NORMAL"
"60kts"

Go-around profile



PM

PF

MAA

"SET SPEED UP"

"Flaps 1"

"Flaps UP"

"After TO C/L"

Above 400 ft RA

Verify LNAV or select roll mode

"Positive Rate"

"Gear Up"

"GO AROUND, FLAPS 15"
Push TOGA (one time)
Verify Go Around Attitude
Verify Go Around Thrust

The End

Questions?