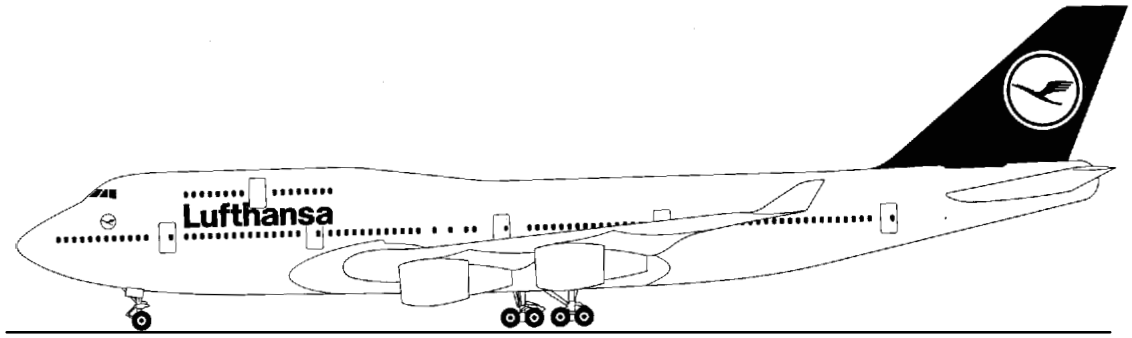
Lufthansa Technical Training

Training Manual B 747-400



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AFDS Operation

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Lufthansa Technical Training

Lufthansa Technical Training GmbH

Lufthansa Base Frankfurt

D-60546 Frankfurt/Main

Tel. +49 69 / 696 41 78

Fax +49 69 / 696 63 84

Lufthansa Base Hamburg

Weg beim Jäger 193

D-22335 Hamburg

Tel. +49 40 / 5070 24 13

Fax +49 40 / 5070 47 46

ATA 22-10 AFDS OPERATION

AFDS OPERATION

This Autopilot flight director system (AFDS) operation section provides a description of the flight director and autopilot operation. This description is to help the maintenance personnel understand the AFDS operation and is not an airplane operational guide.

The AFDS provides control command for the following modes:

- Takeoff
- Climb
- Cruise
- Descent
- Approach
- Autoland
- Go around
- Rollout

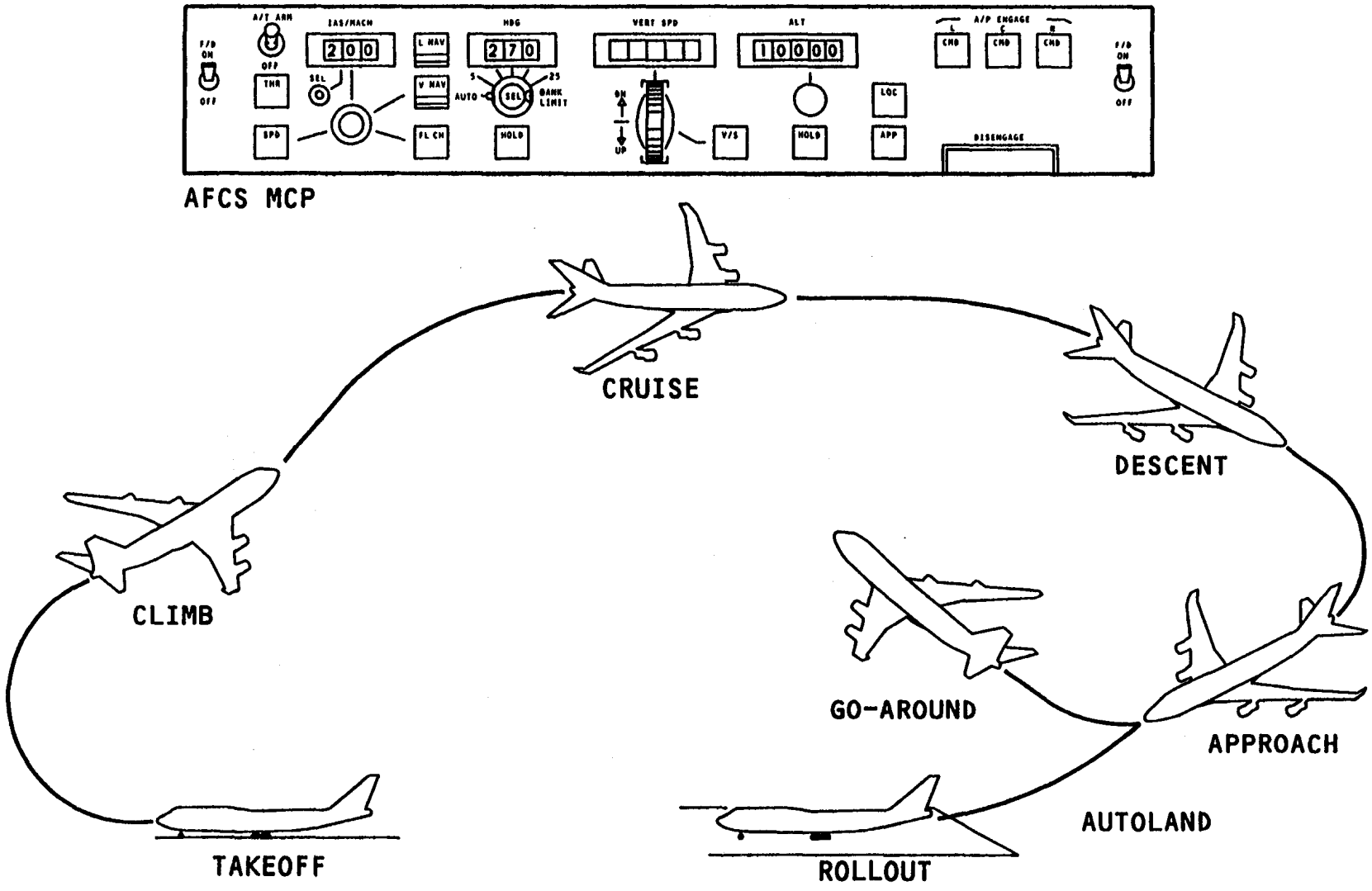


Figure 1 AFDS Operation

TAKEOFF MODE

General

The flight director provides command information for takeoff. Flight director commands are not for use during the takeoff roll. The pilots use the flight director commands after the airplane is in the air.

Takeoff Mode Operation

Before takeoff, enter V2 on the MCP IAS display. The flight director roll command is wings level and the pitch command is a pitch up attitude of eight degrees. The FMAs show TO/GA for both pitch and roll.

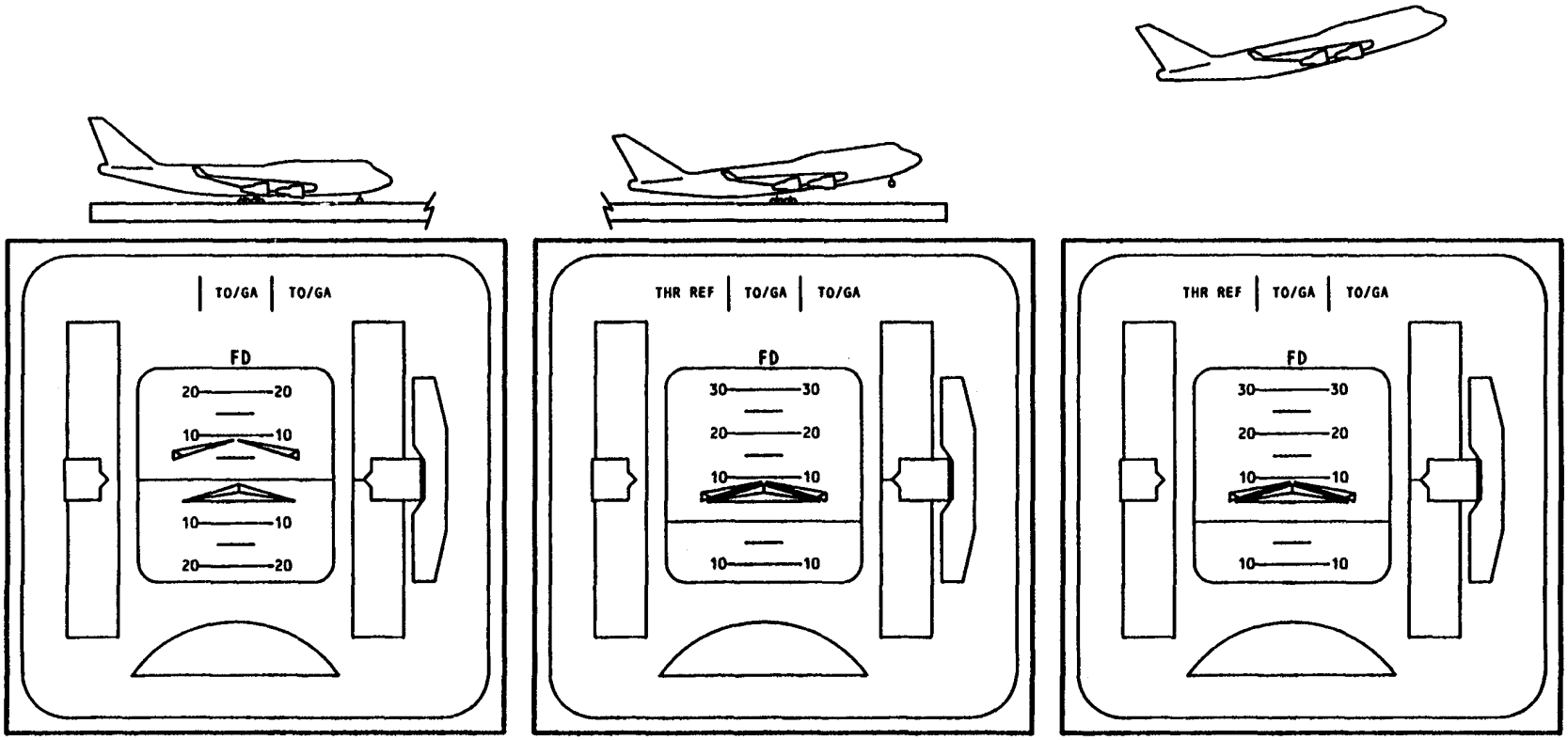
The pitch command is an attitude reference until the vertical speed is 600 feet/minute. With vertical speed between 600 and 1200 feet/minute, the command is a mix of attitude and speed command. For greater than 1200 feet/minute it is a speed command.

This vertical speed requirement gives windshear protection. The takeoff airspeed reference is as follows:

- The greater of the airspeed at rotation +10 knots or V2 +10 knots. If the airspeed exceeds this value for 5 seconds, the reference becomes the lesser of current airspeed or V2 +25 knots.
- If an engine fails, the reference is the airspeed at engine-out with a lower limit of V2 and an upper limit of V2 +10.
- If a higher MCP speed is selected, the reference increases to that speed.

For takeoff with an engine out, the operation is similar but the attitude/airspeed mix function occurs between 0 and 600 feet/minute.

The roll command changes to a ground track reference at liftoff.



(1) TAKEOFF STARTS
- ROLL F/D COMMAND IS WINGS LEVEL
- PITCH F/D COMMAND IS 8° PITCH UP

(2) ROTATE/IN AIR
- PITCH CMD CHANGES TO SPEED REFERENCE AT ROTATION (PITCH ATT 2° NOSE UP)
- ROLL CMD SWITCHES TO TRACK HOLD AT 5' RADIO ALTITUDE

(3) CLIMB OUT
- PITCH CMD HOLDS SPEED
- ROLL CMD HOLDS TRACK

Figure 2 Takeoff Mode

AUTOPILOT TO CMD

General

Push an autopilot CMD switch to engage the autopilot to command. This action also engages a roll and pitch mode. The mode depends on the flight director status.

A/P to CMD Operation - F/D On

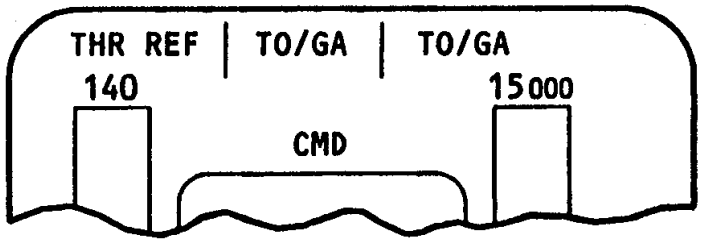
If the Autopilot is engaged with flight director(s) on, the current roll and pitch mode remain the same except:

- If the F/D is in T/O on the ground, the AFDS modes are heading hold and vertical speed.
- If LOC capture, LOC becomes the arm mode and the active mode is heading hold until LOC capture.
- If G/S capture, G/S becomes the arm mode and the active mode is vertical speed until G/S capture.

The FMAs show the pitch and roll mode and CMD. The appropriate mode switch on the MCP is also on.

A/P to CMD Operation - F/D Off

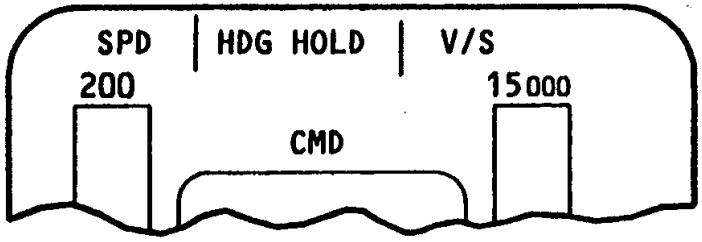
If the autopilot is engaged with F/Ds off, the AFDS modes are heading hold and vertical speed. The FMAs show CMD status, HDG HOLD, and V/S. The HDG HOLD and V/S mode switches are also on.



PFD
F/D ON

CMD MODE IS SAME AS F/D MODE OR:

- HDG HOLD AND V/S IF F/D IN TAKEOFF ON THE GROUND
- HDG HOLD OR V/S IF F/D IN LOC OR G/S



PFD
F/D OFF

CMD MODE IS HEADING HOLD AND VERTICAL SPEED

Figure 3 Autopilot to CMD

ROLL OPERATION INTRODUCTION

The AFDS provides roll commands for takeoff through rollout (go-around if required). The takeoff mode (on ground) is a flight director mode only. While in takeoff roll, the flight director provides a wings level command when on the ground. A track reference is available for flight director and autopilot in flight.

During climb and cruise, heading hold, heading select and L NAV are available. The heading hold mode provides commands to hold the heading. The heading select mode provides commands to hold the heading selected on the AFDS MCP. The LNAV mode provides commands to steer the airplane to the FMC route.

In an approach, the LOC mode provides command for alignment with the runway. Also multi-channel autopilots engage for autoland and rollout. The go-around mode provides commands to hold the airplane to a track reference.

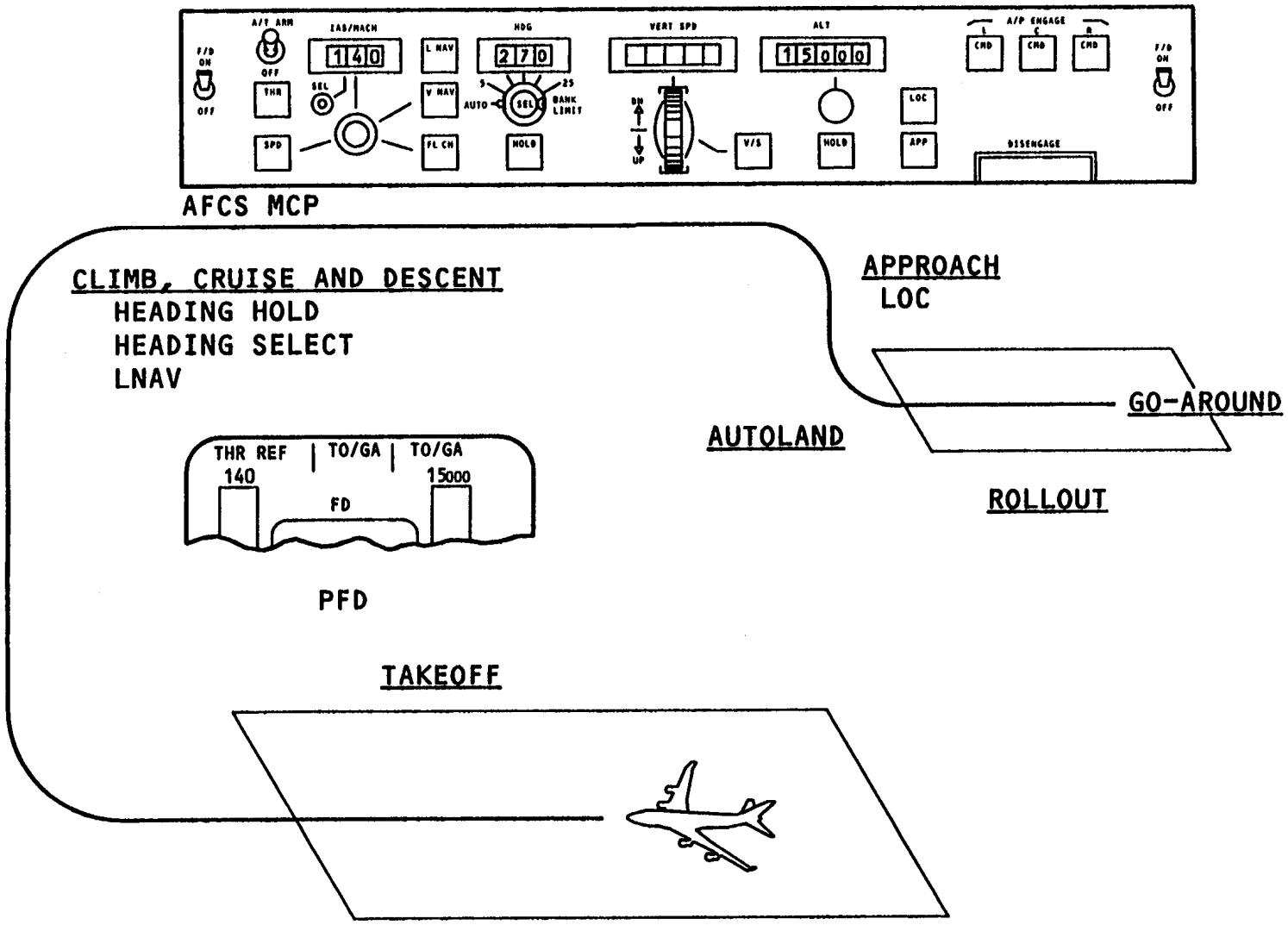


Figure 4 Roll Operation Introduction

LNAV MODE

General

In LNAV, lateral steering commands are from the master FMC, based on the navigation data base and the active flight plan.

LNAV Arm

LNAV is armed when the MCP LNAV switch is pushed (except if LOC is engaged). The FMA displays LNAV in white.

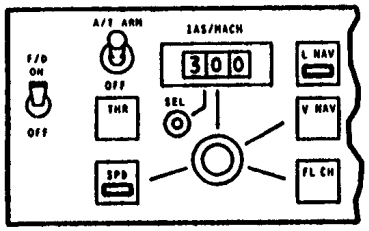
LNAV Engage

If armed, LNAV engages (FMA green) if:

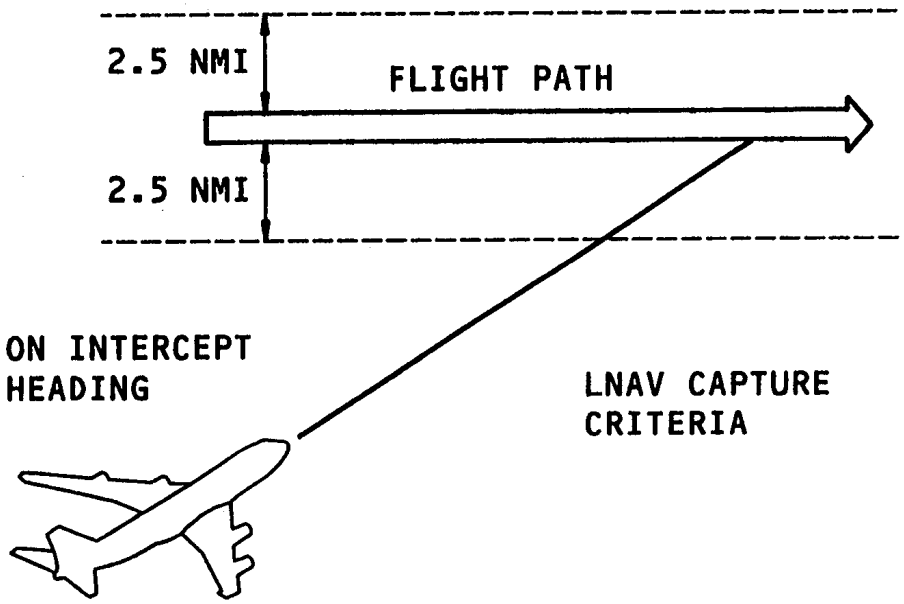
- Flight plan has been entered, activated and executed
- >50 feet AGL
- No more than one engine out
- Data required to calculate the lateral guidance command is valid
- Aircraft position satisfies the LNAV capture criteria
-

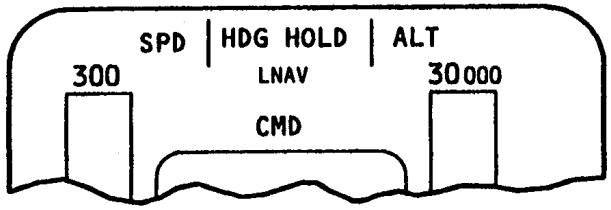
LNAV Operation

With the LNAV mode active, the FMC provides steering commands to keep the airplane on the flight path.

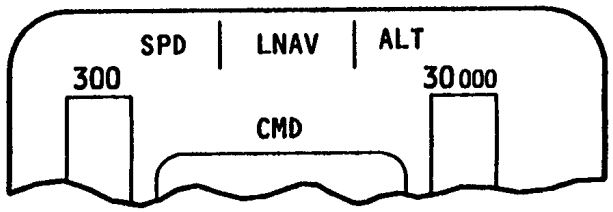


AFCS MCP





PFD



PFD

Figure 5 LNAV Mode

HEADING HOLD MODE

General

When heading hold is active the airplane rolls wings level and maintains heading.

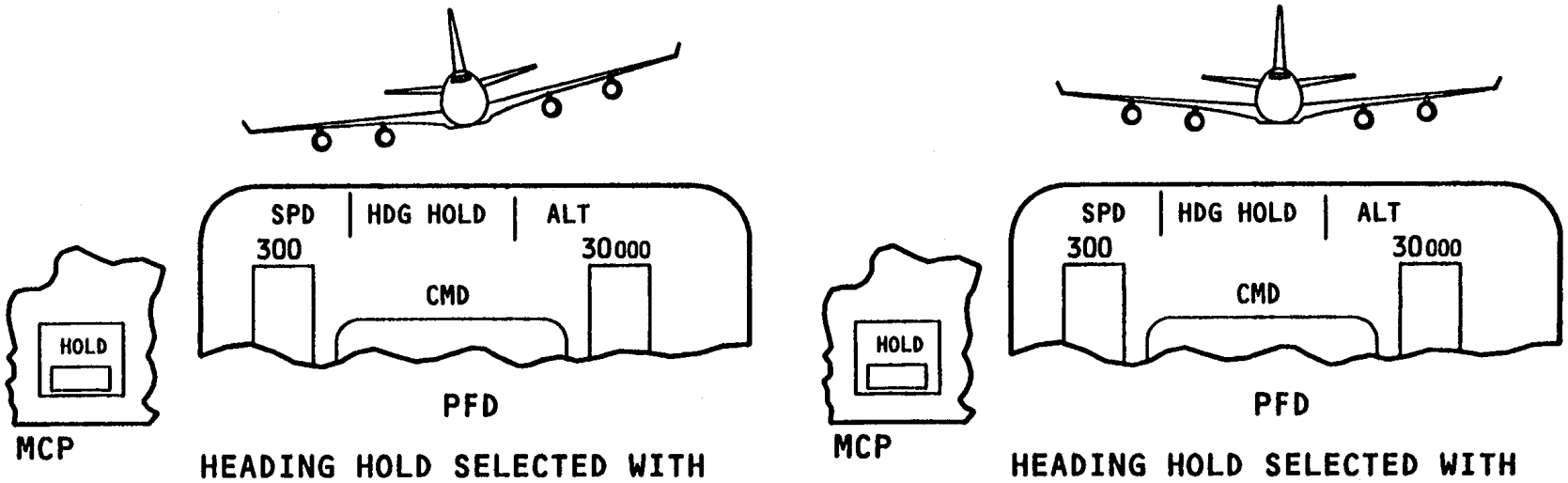
Mode Control

To engage the heading hold mode:

- Push the HDG HOLD switch with autopilot engaged or flight director on.
- Heading hold may be automatically engaged in some default conditions.

Operation

Selection of the heading hold mode causes the airplane to roll wings level. When the airplane is within three degrees of wings level the heading hold mode provides commands to hold the heading at that time.



HEADING HOLD MODE SELECT SWITCH

- PUSH TO REQUEST HEADING HOLD MODE
- HEADING HOLD MODE SELECTED AUTOMATICALLY

HEADING HOLD SELECTED WITH AIRPLANE IN BANK

- HEADING HOLD SWITCH/LIGHT - ON
- AIRPLANE ROLLS DOWN TO WINGS LEVEL
- FMAs DISPLAY HDG HOLD
- AIRPLANE HOLDS HEADING EXISITING WHEN ROLL ATTITUDE LESS THAN 3° (+2 SEC)

HEADING HOLD SELECTED WITH WINGS LEVEL

- HEADING HOLD SWITCH LIGHT - ON
- AIRPLANE HOLDS EXISTING HEADING
- FMAs DISPLAY HDG HOLD

Figure 6 Heading Hold Mode

HEADING SELECT MODE

General

In the heading select mode, the AFDS captures and holds the heading selected on the MCP. The selected heading shows on the MCP and by a cursor on the navigation display. The bank limit is controlled by a bank limit selector on the MCP. Selection of the AUTO position with the bank angle selector cause the bank angle limit to vary with airspeed.

Mode Control

Push the HDG SEL switch to engage the heading select mode.

The heading select mode is inhibited by:

- LOC and G/S capture
- Go around and less than 400 feet

This switch does not have a light, therefore there is no indication on the MCP. The FMAs show HDG SEL (green).

Operations

Two procedures are available for use of the heading select mode. These are:

- Select the heading before the HDG SEL switch is pushed. The FCC commands a turn toward the smallest heading error.
- Push the HDG SEL switch and then select a new heading. The airplane follows the direction of rotation of the heading select knob.

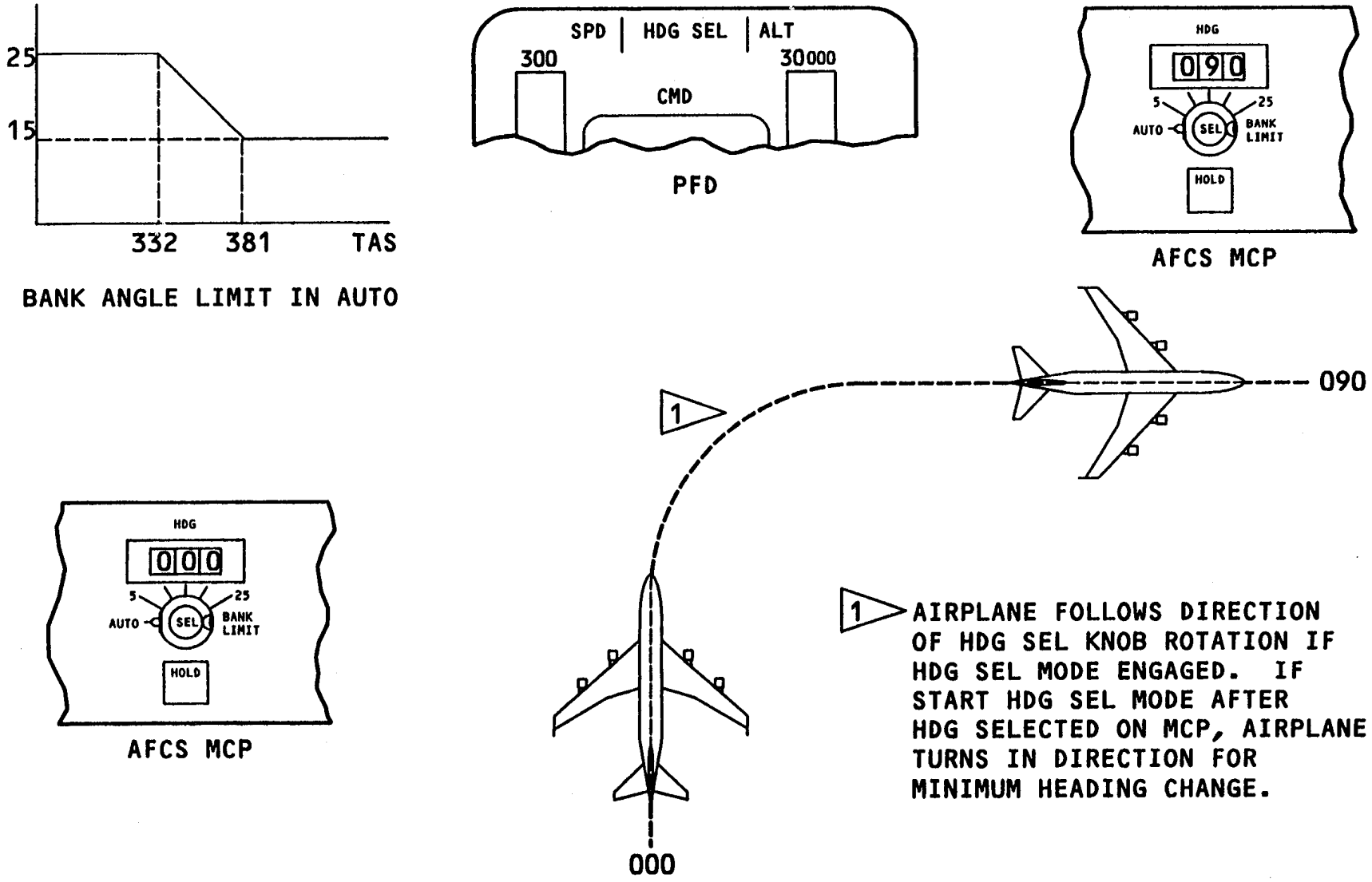


Figure 7 Heading Select Mode

PITCH OPERATION INTRODUCTION

The AFDS provides pitch commands for takeoff through autoland (go-around if required). Pitch commands are to the flight director for all modes and to the autopilot for all modes except takeoff on the ground.

The takeoff mode on the ground is a flight director mode only. In takeoff, the flight director command is initially a pitch up command and changes to speed control with windshear protection after rotation.

The VNAV mode uses a vertical command from the FMC. Sub-modes are VNAV SPD, VNAV PTH and VNAV ALT. VNAV SPD uses the AFDS to control airspeed. In VNAV PTH and VNAV ALT, the FMC supplies information to hold vertical position.

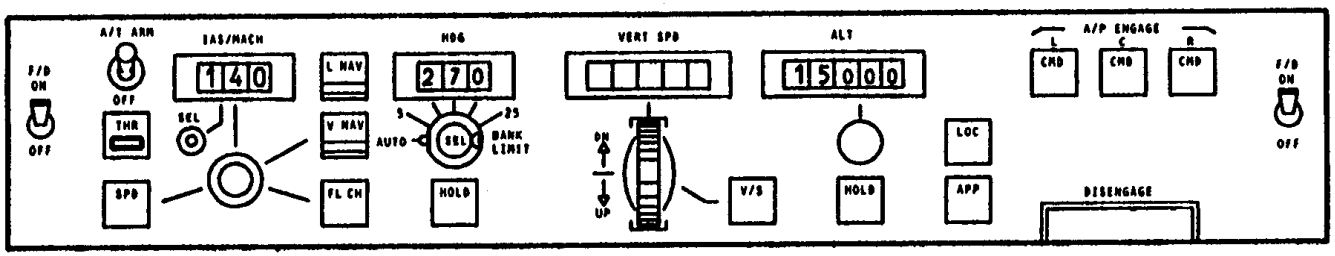
V/S mode provides commands to hold the selected vertical speed. V/S provides command for climb, altitude hold and descent.

Flight Level Change (FL CH) mode controls the airplane speed in climb and descent. A speed knob provides selection of the desired speed.

The ALT HOLD mode provides commands to hold altitude.

The approach mode provides commands for a glide slope descent. Engagement of two or more autopilots provides autoland operation.

Push a GA switch to start the go-around mode. The FCC controls airspeed in go-around.



AFCS MCP

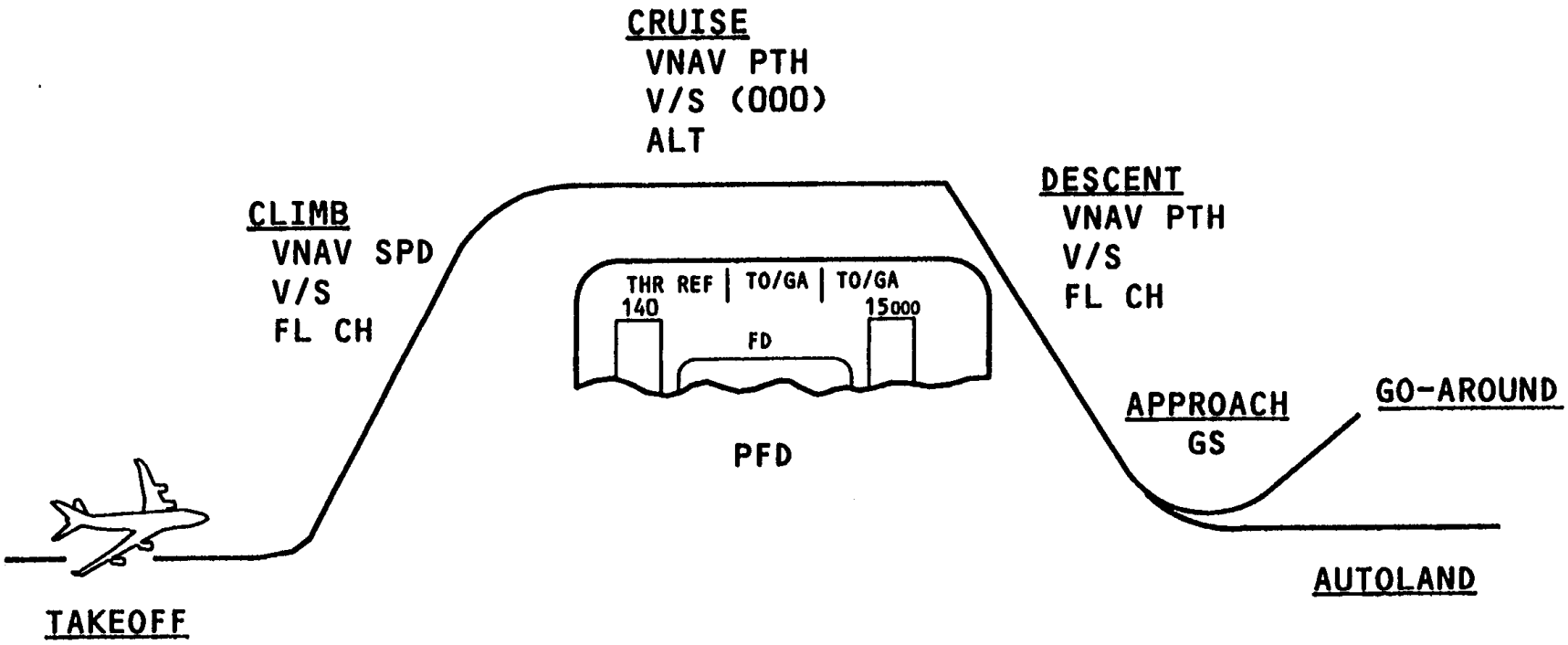


Figure 8 Pitch Operation Introduction

VNAV MODE

General

Vertical navigation mode (VNAV) is for vertical navigation based on FMC commands. A combination of throttle and elevator commands provides control for the complete flight vertical profile. This discussion describes the use of elevator control. The VNAV mode consists of four sub-modes. These modes are ARM, VNAV SPD, VNAV ALT and VNAV PTH. Speed and altitude interventions allow the pilot to make changes to the flight plan in the FMC.

VNAV Control

Arm of the VNAV mode is possible from any pitch mode except G/S. However, the FMC vertical flight profile must be valid to engage the VNAV mode.

Push the VNAV mode switch to arm the FCC for VNAV control. The FMAs show VNAV ARM (white). Push the VNAV mode switch a second time to cancel the VNAV mode while armed. If the FMC guidance is valid, the AFDS changes to VNAV engage mode.

VNAV SPEED Operation

The VNAV SPD mode uses the autopilot to hold the FMC speed in these flight segments:

- Climb
- Descent (optional pilot selection)
- Descent (reversion from VNAV PTH if the airplane exceeds a speed limit)

VNAV PATH OPERATION

The VNAV PTH mode uses the autopilot to control a vertical path in these flight segments:

- Capture and hold the altitude
- Descent to a lower altitude

VNAV SPD changes to VNAV PTH to capture the FMC altitude. The VNAV PTH mode levels the airplane and holds the FMC altitude. The VNAV PTH mode changes to VNAV SPD if the airplane speed approaches a speed limit.

With the MCP altitude set to a lower altitude, the airplane starts the descent at top of descent. The active mode remains VNAV PTH. The throttle retards and the FMAs show IDLE.

The VNAV PTH descent continues until near the approach altitude. The autothrottle returns to the speed mode. The VNAV PTH mode then holds the approach altitude.

VNAV ALT

The VNAV ALT mode occurs in either of these conditions:

- When in VNAV SPD and the MCP select altitude is captured before the FMC altitude
- When in VNAV PTH (descent) and the MCP altitude captures before the FMC altitude
- When in VNAV PTH and the FMC target altitude is such that it would cause the airplane to leave the MCP selected altitude.

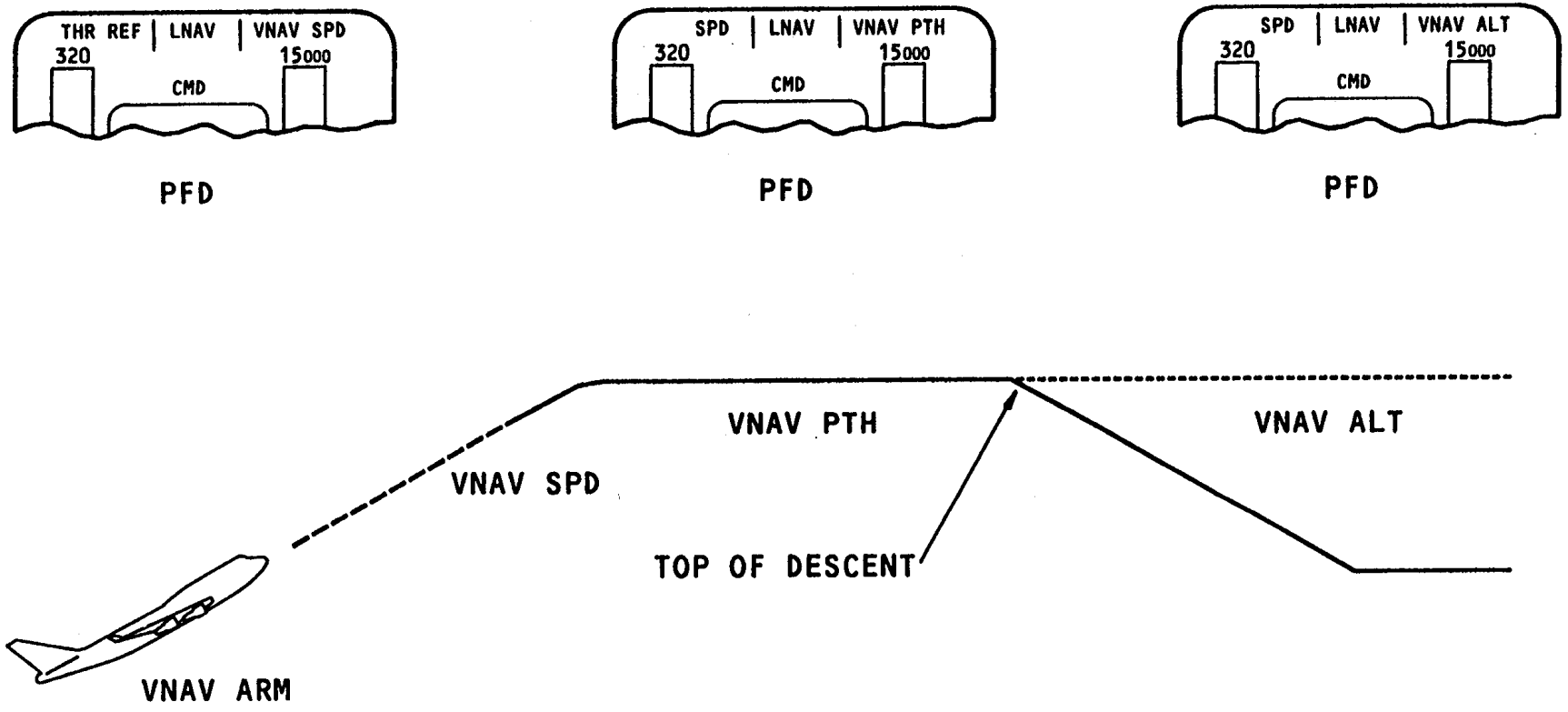


Figure 9 VNAV MODE

VERTICAL SPEED MODE

General

The V/S mode is a pitch mode that controls the vertical speed of the airplane. Vertical speed control limits are between +6000 feet/minute and -8000 feet/minute. Selection of the vertical speed reference is by the V/S select knob.

A display above the knob shows the selected vertical speed. The display is blank before the V/S mode is engaged.

Mode Control

Selection of the V/S is by a push of the V/S mode switch or it may engage as a default mode from other pitch modes. The V/S mode turns on the V/S switch/light and the FMAs show V/S. The vertical speed window on the MCP unblanks and synchronizes to the present airplane V/S.

It will synchronize to 000 if the previous mode was:

- ALT (altitude hold).
- Takeoff or go-around and the vertical speed is negative.

WE Operation

When in the V/S mode, rotate the V/S select knob to change the display and the AFDS controls the airplane to the desired V/S. Push the V/S select switch again to synchronize the V/S display to present airplane V/S.

The V/S mode is also used for altitude hold. When in the V/S model select a vertical speed of 000. The airplane levels and holds the barometric altitude. V/S mode remains engaged and the FMAs show V/S.

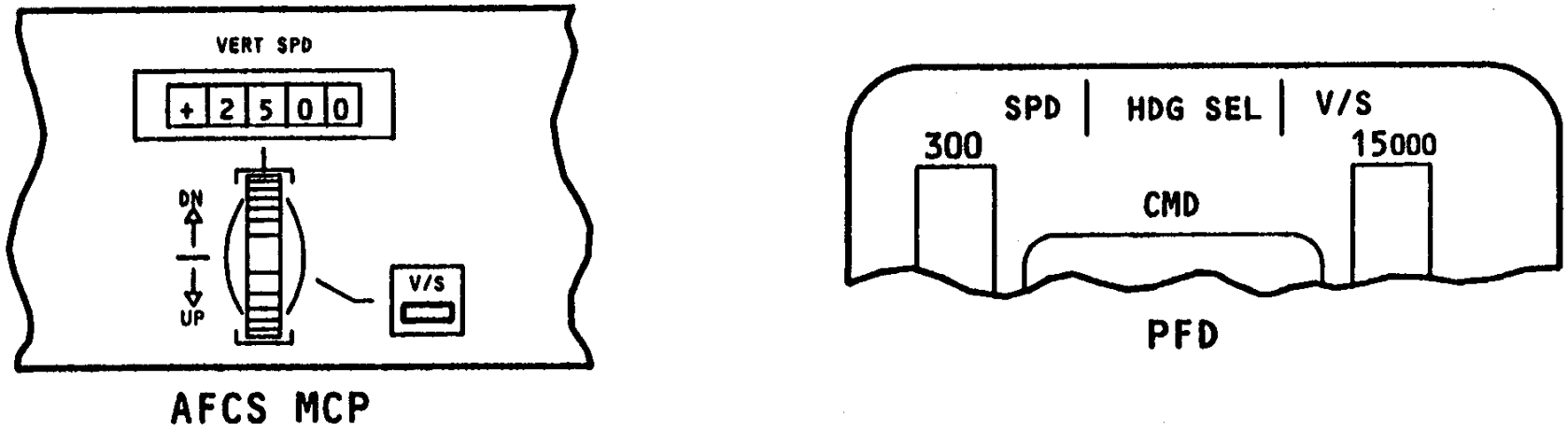


Figure 10 Vertical Speed Mode

FLIGHT LEVEL CHANGE MODE

General

Flight level change (FLCH) mode combines autothrottle and autopilot modes, for climb or descent. The autothrottle controls thrust while the autopilot controls MCP selected airspeed.

Mode Controls

Selection of a target altitude is necessary before FLCH is requested. Push the FLCH button to engage the FL CH mode. The FLCH switch/light turns on. The FMAs show THR for autothrottle and FLCH SPD for pitch.

If VNAV was engaged before the FLCH button was pushed, the MCP speed display shows the present FMC target speed. If VNAV was not engaged, the display shows the higher of present airspeed or present MCP speed. Selection of a different speed is possible after FLCH engages.

Selection of a new speed is made by the speed select knob.

Operation

In the FLCH mode, the throttles are moved to achieve a climb or descent while the autopilot controls to MCP speed. The speed control protects so that the airspeed will not go higher than flap limit or VMO/MMO limit. It also will not go lower than a safe stall speed (ALPHA control). The airplane levels off at the selected altitude and the AFDS pitch mode changes to ALT.

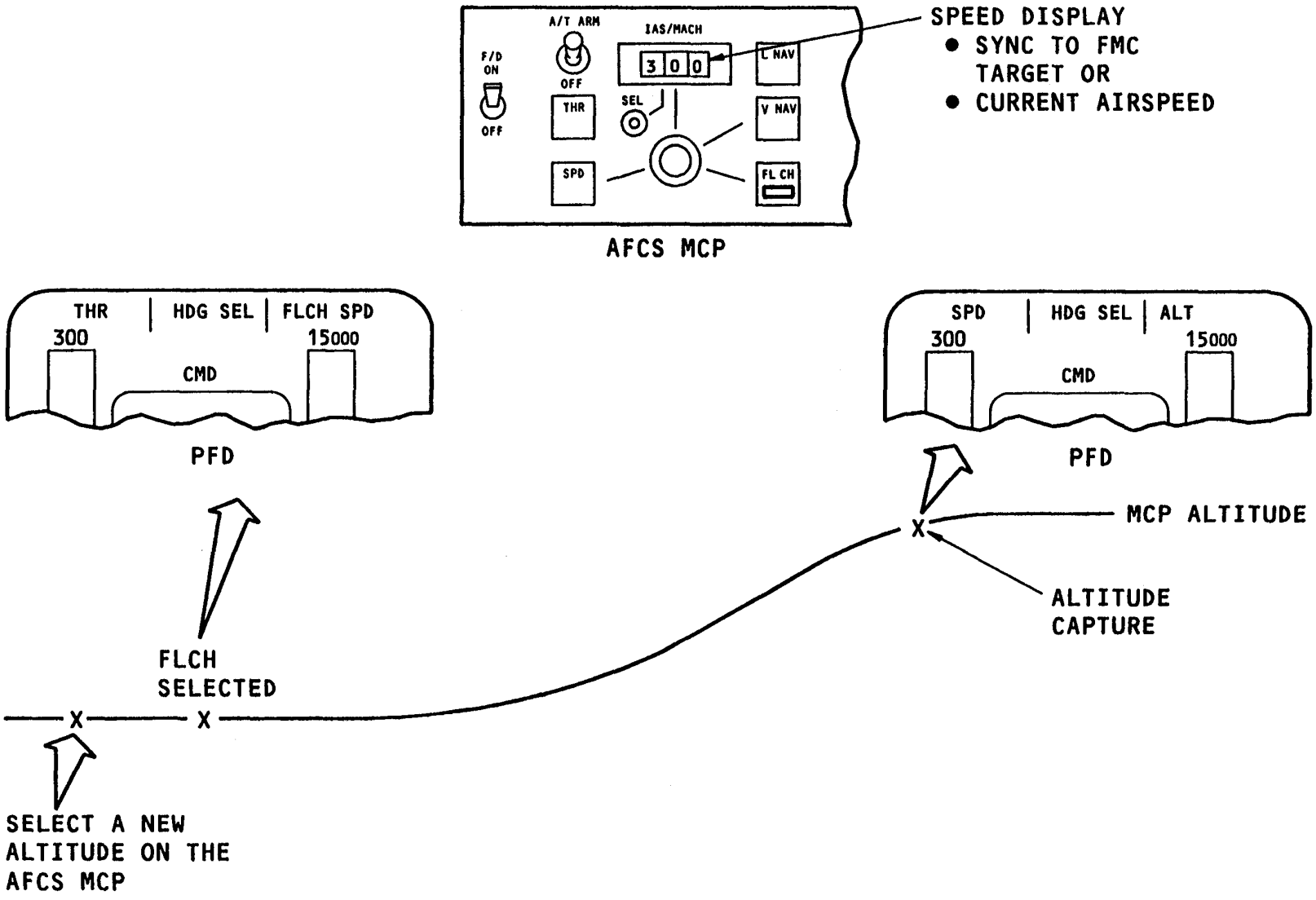


Figure 11 Flight Level Change Mode

ALTITUDE HOLD MODE

General

Altitude hold control is by three methods:

- Push the ALT HOLD pushbutton on the MCP
- In V/S mode, select a V/S of 0000
- Capture and hold the selected MCP altitude

Altitude Hold With the ALT HOLD

Pushbutton

Push the altitude hold pushbutton at the desired altitude. The AFDS holds the altitude existing at the time the switch was pushed. The ALT HOLD mode switch/light turns on and the FMAs show ALT.

Altitude Hold with Vertical Speed

When in the V/S mode select a vertical speed of 000. The airplane levels and holds barometric altitude. V/S mode remains engaged and the FMAs show V/S.

Altitude Hold with Altitude Capture

Altitude capture begins as the airplane approaches the selected altitude. The altitude capture maneuver limit is 0.05g. The FMAs show ALT (green). The airplane holds the selected MCP altitude.

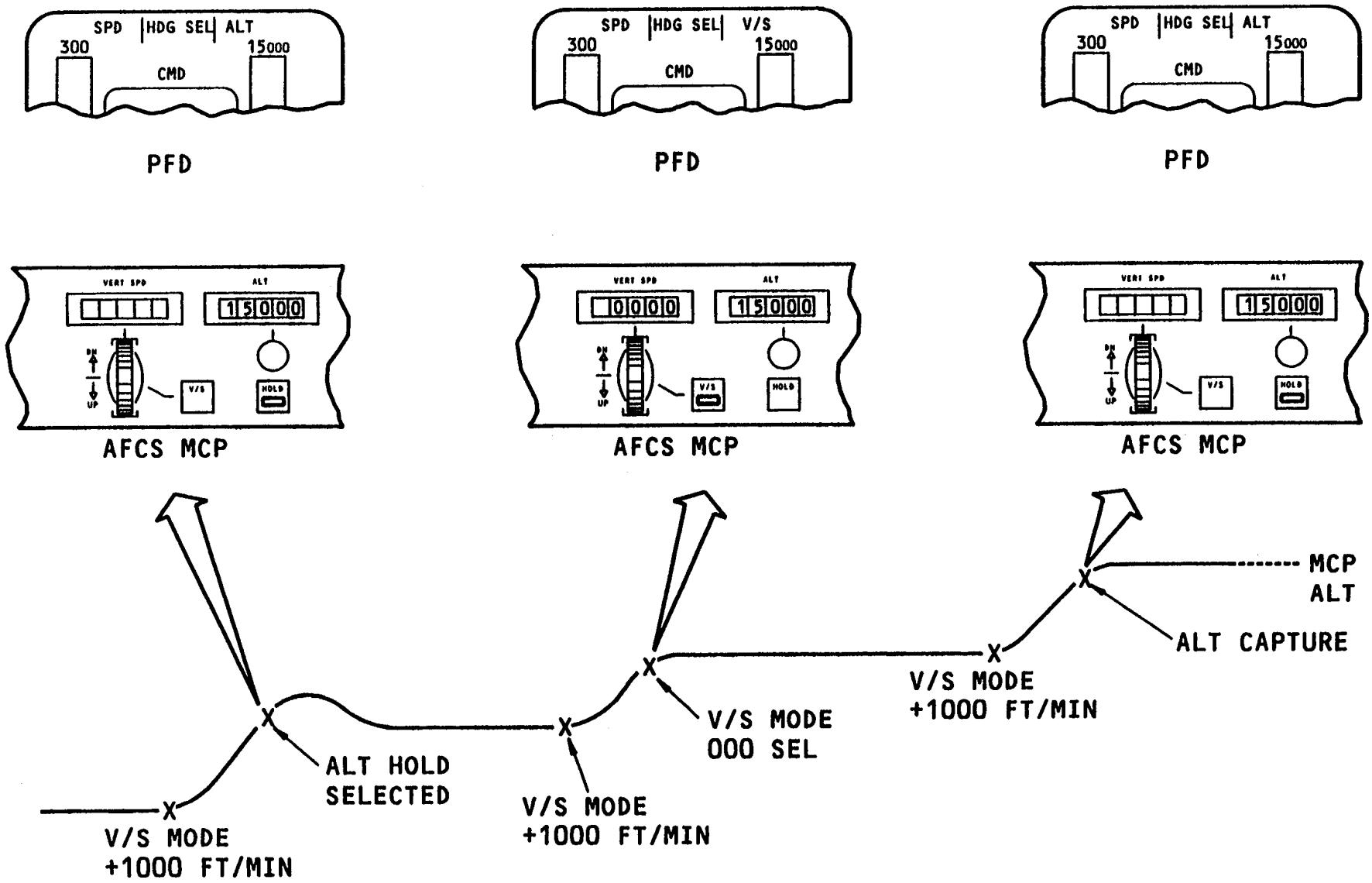


Figure 12 Altitude Hold Mode

APPROACH INTRODUCTION

An approach with two or three autopilot channels engaged provides autoland capability. Push the APP mode switch to arm the system for the approach. All A/P CMD lights turn on. Selection of the approach mode is necessary for multi-channel operation. LOC and G/S capture prepares the system for autoland. Autoland (multi-channel engaged) starts at a radio altitude of 1500 feet with localizer and glide slope captured with a 5 second delay. At this time the other valid autopilots engage. Autoland uses multi-channel autopilot for the final approach, flare and rollout. A single autopilot engaged allows approach operations through flare.

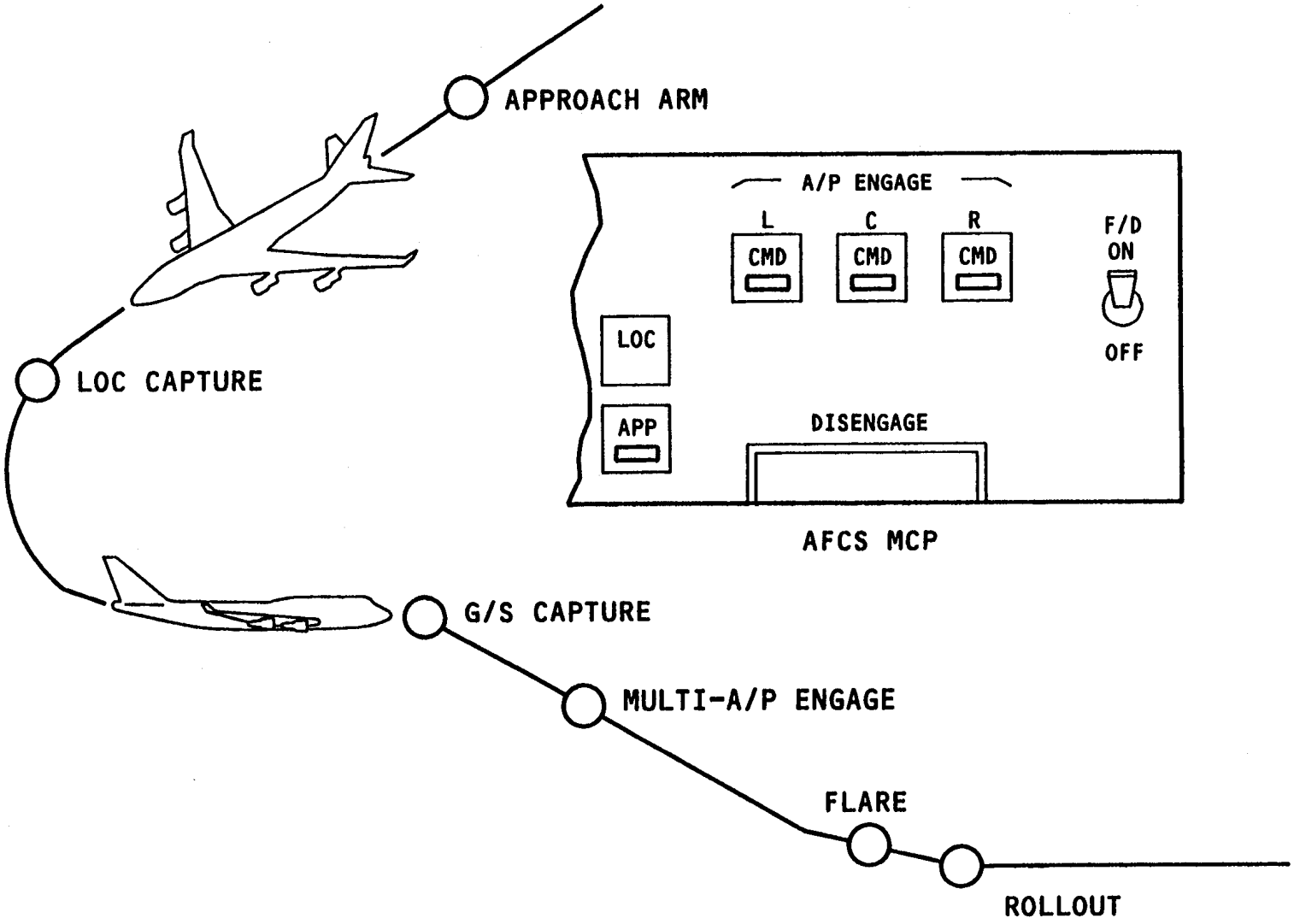


Figure 13 Approach Introduction

LOCALIZER MODE

General

The localizer mode provides lateral guidance and control for a single-channel or F/D approach. The ILS system provides localizer deviation signals to the FCCs. A localizer only approach requires the pilot to select a vertical descent path.

To prepare for the approach:

- Tune the LOC frequency
- Select the runway heading

This may be done automatically or manually.

Mode Control

Push the LOC mode switch to arm the localizer mode. A second push before localizer capture cancels LOC arm. The FCC calculates the localizer capture as a function of ground speed, intercept angle and LOC deviation. At LOC capture the roll mode engages to LOC and the FMAs show LOC (green). The MCP heading display changes to the runway heading.

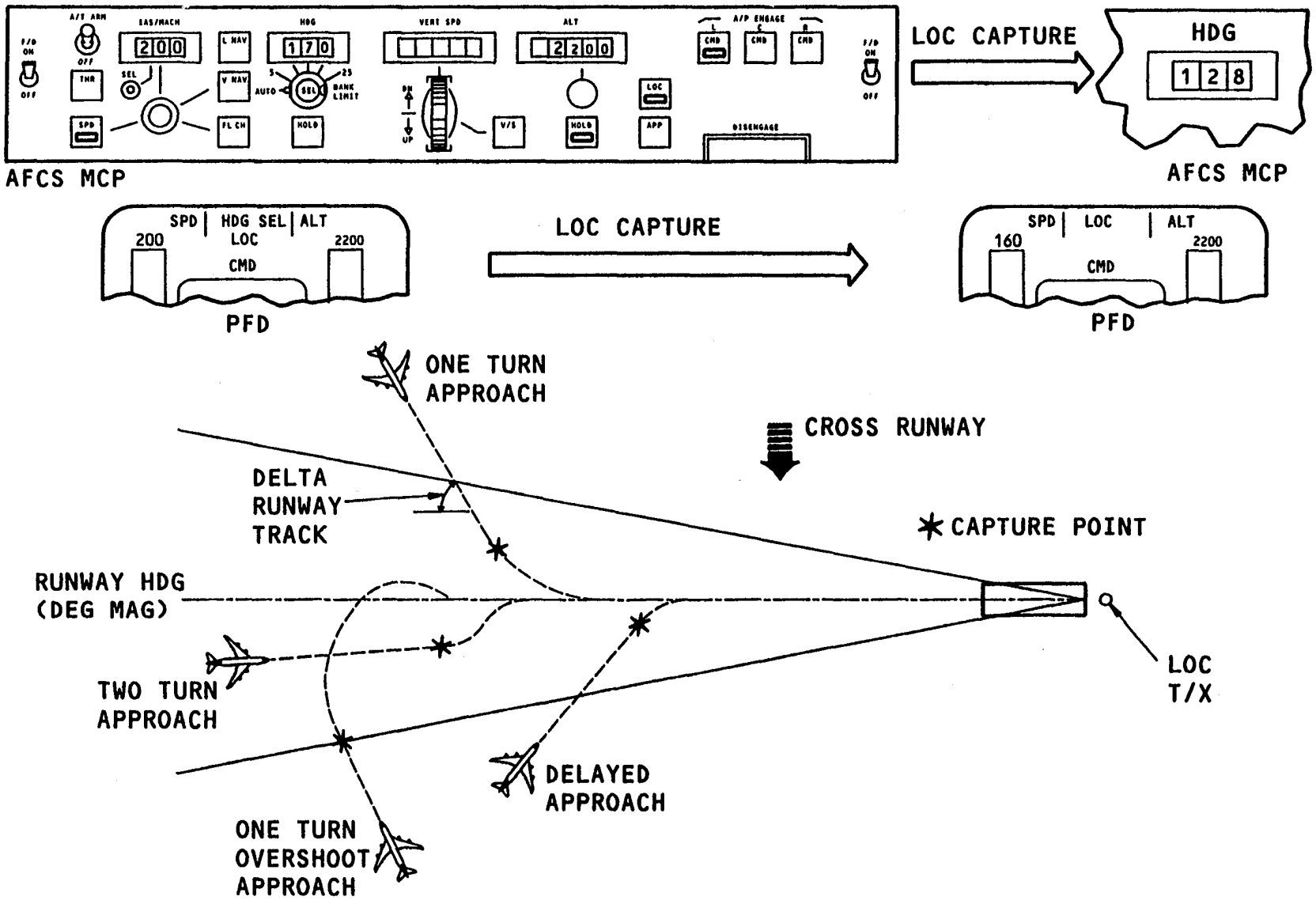


Figure 14 LOCALIZER MODE

APPROACH MODE

General

The approach mode provides localizer and glide slope. The approach mode is possible with flight directors, single or multi-channel autopilot(s).

Preparation for the approach requires:

- Tune the ILS frequency
- Select the runway heading

This may be done automatically or manually.

Mode Control

Push the APP switch to arm the approach mode. This arms the localizer and glide slope modes.

Approach Operation

In this example, an approach is made with ALT HOLD and HDG SEL as the active modes. Push the APP mode switch to arm the system for the approach. The APP and ALT HOLD lights are on. The FMAs show, ALT (green), HDG SEL (green), LOC (white), and G/S (white).

The FCC calculates the localizer capture as a function of ground speed, intercept angle and LOC deviation. At capture, the roll mode changes to LOC capture and the FMAs show LOC (green). The MCP heading display changes to the runway heading.

G/S capture is also a variable.

Distance from the beam center and deviation rate determines the G/S capture. At G/S capture the FMAs show G/S (green).

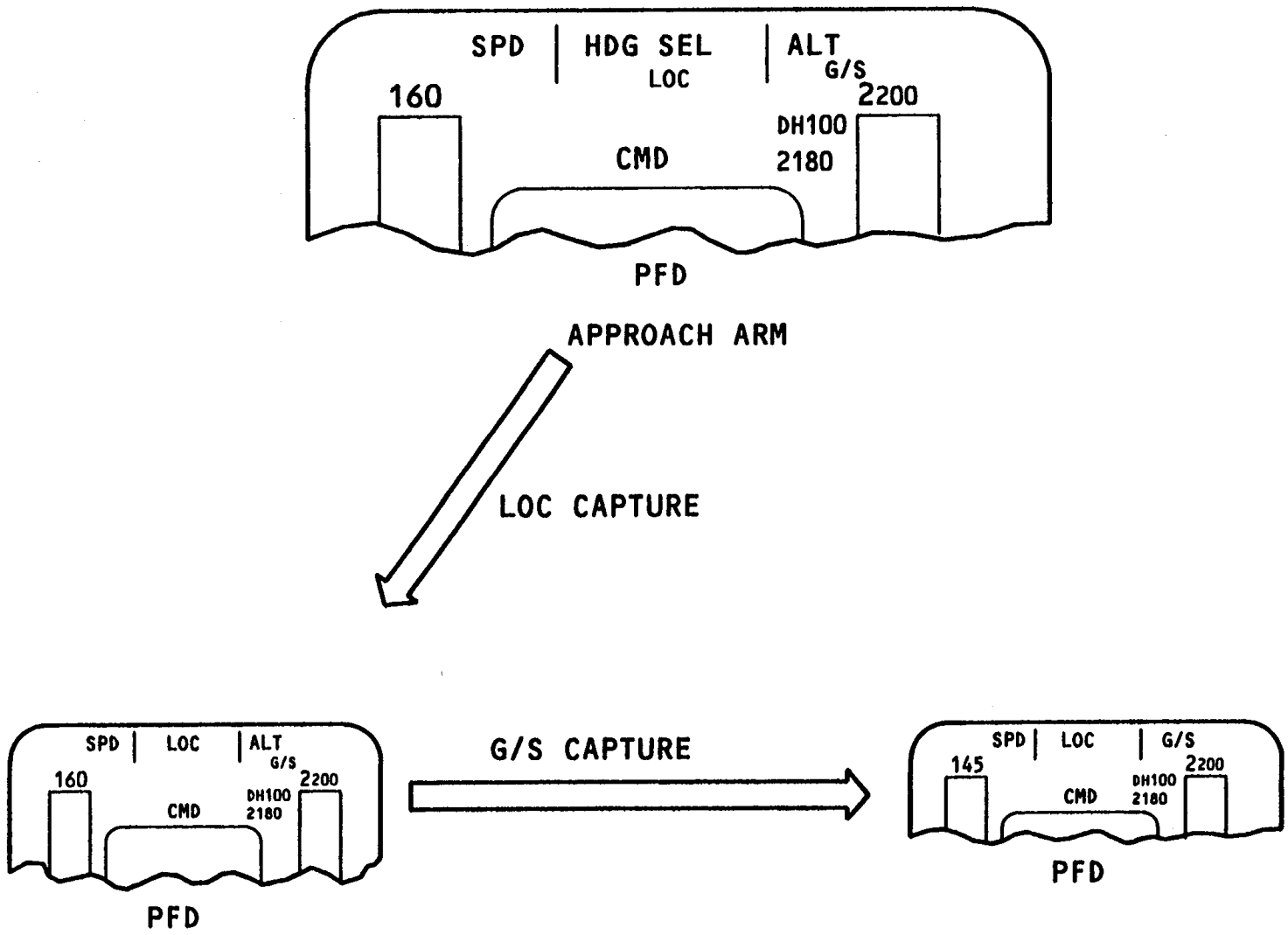


Figure 15 Approach Mode

AUTOLAND - PITCH

General

An approach with two or three autopilot channels engaged provides autoland capability. The pitch autoland modes are:

- Glideslope
- Flare
- Throttle retard
- Nose let down

Operation

The armed autopilot channels engage 5 seconds after the airplane passes through 1500 feet radio altitude if LOC and G/S are captured. The autopilot displays on the PFD are:

- Status LAND 3 or LAND 2
- Modes ROLLOUT arm and FLARE arm

Above the flare height, G/S is the pitch command. At flare height, the command is such that a touchdown occurs 450 feet past the glideslope transmitter with a descent rate of 1.5 feet/second. The variable flare height provides consistent touchdown

performance for a wide range of approach ground speeds.

A throttle retard command is sent to the FMC at 25 feet radio altitude.

A nose let down command causes the nose gear to hold firmly to the runway. This occurs with the radio altitude less than 5 feet and after the flare pitch command is less than 2 degrees.

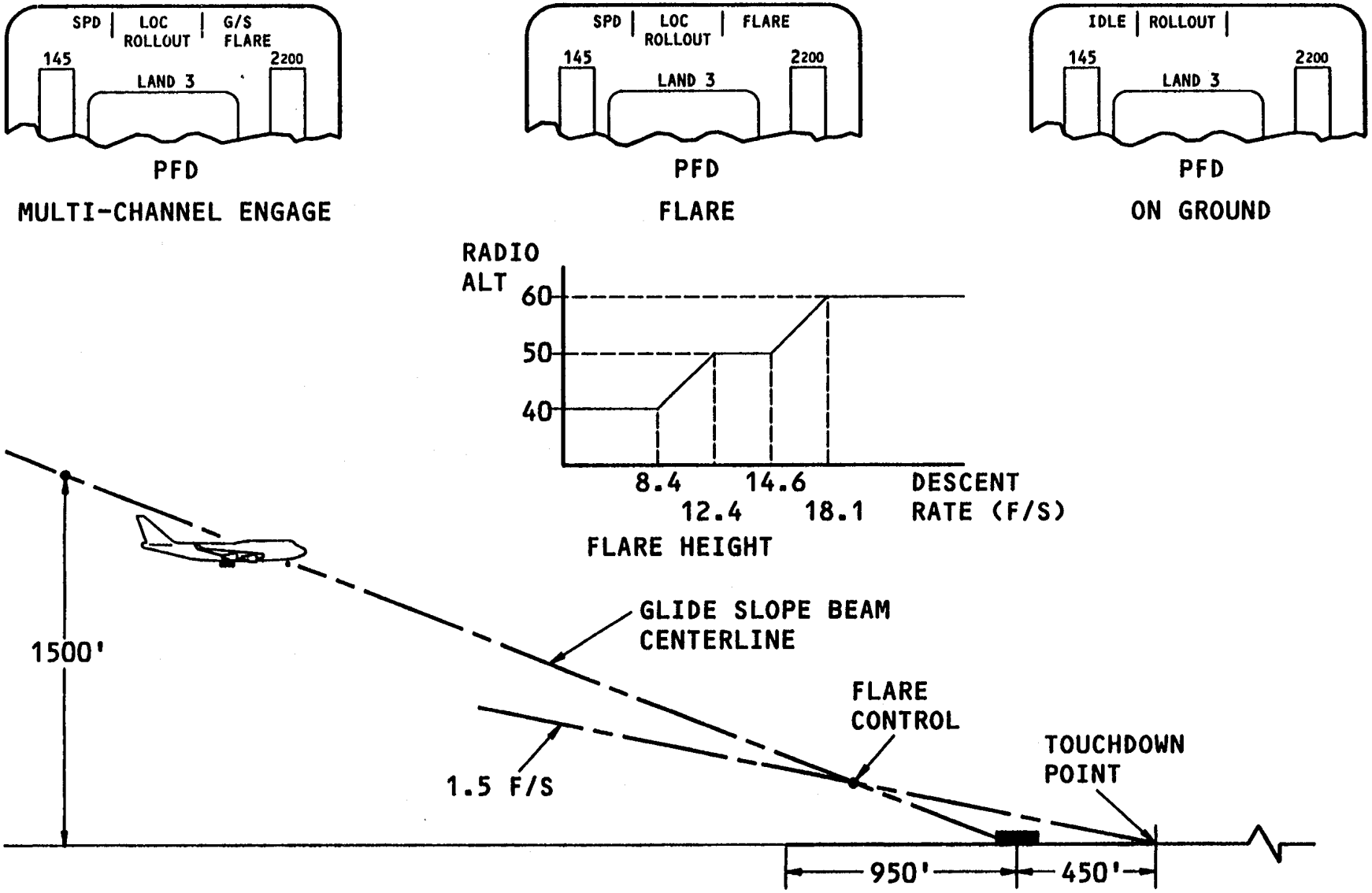


Figure 16 Autoland - Pitch

AUTOLAND - ROLL AND YAW

General

The roll/yaw control modes are:

- Localizer
- Runway alignment
- Rollout

Operation

Localizer control is used until the rollout mode starts.

The runway alignment function starts at multi-channel engaged. For the first part of the autoland, it is used for engine-out protection. Rudder and aileron control reduce the effects of the engine-out.

At 500 or 200 feet radio altitude, depending on the magnitude of the crab angle, decrab control is added. If the crab angle is greater than 5 degrees, the decrab function starts at 500 feet and a maximum of 5 degrees crab is removed. If the crab angle is less than 5 degrees, the decrab function starts at 200 feet and all of the crab angle is removed. This function uses rudder and aileron control.

The wings are commanded level at 5 feet radio altitude. At 2 feet, the rollout mode starts. In rollout, rudder control is used to control to the runway centerline (zero localizer deviation).

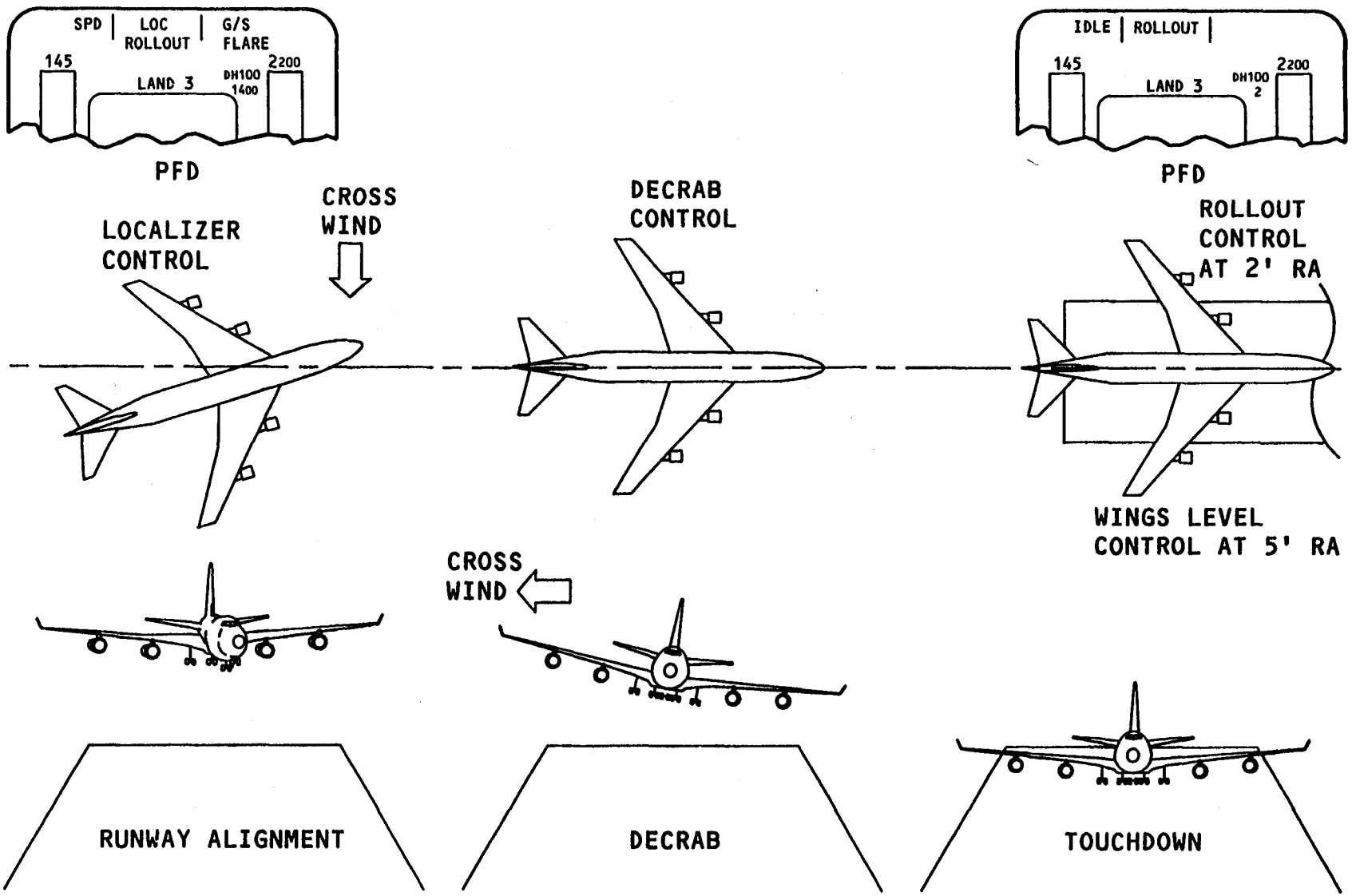


Figure 17 Autoland - Roll and Yaw

GO-AROUND MODE

General

The go-around (G/A) mode provides control for climb after an aborted approach.

Mode Control

The G/A mode arms when the glide slope is captured or when flaps not up if not in the takeoff mode. Push either G/A switch to start the G/A mode. The approach mode cancels and the G/A modes engage. The FMAs show TO/GA for pitch and roll modes.

Change to a cruise roll or pitch mode is possible above a radio altitude of 400 feet. Selection of a cruise pitch or roll mode is possible independently. If multi-channel engaged, selection of a cruise mode returns the system to single channel operation (first in CMD).

Operation

The pitch command is an attitude reference until the vertical speed is 600 feet/minute. With vertical speed

between 600 and 1200 feet/minute, the command is a mix of attitude and speed command. For greater than 1200 feet/minute, it is a speed command. This vertical speed requirement gives windshear protection. The speed reference is the greater of the MCP speed or the airspeed at G/A start. For G/A with an engine out, the operation is similar but the attitude/airspeed mix function occurs between 0 and 600 feet/minute vertical speed and the maximum speed is MCP plus 10 knots.

The FCC has a F/D auto-on function which causes F/D commands to show for this mode when the TO/GA switch is pushed with airspeed more than 80 knots. This function gives F/D go-around commands with windshear protection without the crew selection of F/D on with the MCP switches.

The AFDS roll G/A mode holds the track of the airplane at the time the G/A mode starts. The A/P engage status stays as it was before G/A was started. If multi-engine before G/A, G/A is done with multi-engine. If single channel engage before, G/A is done single channel.

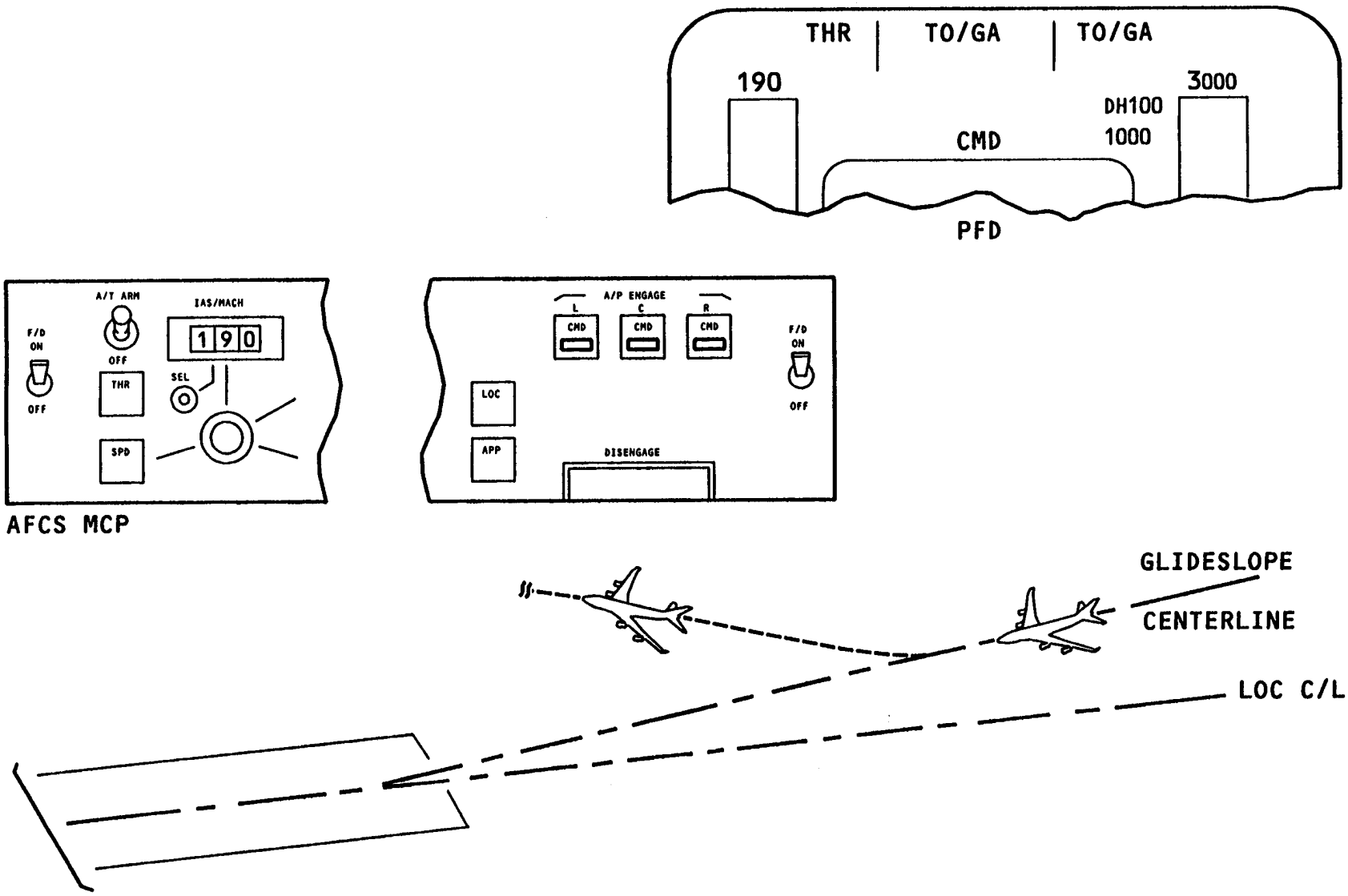


Figure 18 Go-Around Mode

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