

## General

The aircraft is equipped with an Automatic Flight System (AFS) for guidance from takeoff to landing.

The two AFS flight control computers (FCC) receive data from:

- Airframe sensors.
- Air data computers.
- Engine control computers.
- Flight Control Panel (FCP).
- Various other sources.

The FCCs process the data and send:

- Display signals to the EIS CRTs.
- Control signals to the pitch, roll, yaw, and thrust actuators.

The AFS provides the following functions:

- Automatic ILS approach.
- Longitudinal Stability Augmentation System (LSAS).
- Speed envelope limiting (autothrottle and LSAS).
- Dual autopilot (AP), Flight Director (FD) and autothrottle system (ATS)/engine trim control.
- Automatic pitch trim in AP and LSAS.
- If installed, full-time parallel actuation roll Control Wheel Steering (CWS) with roll attitude hold when the AP is not engaged.
- Windshear warning with AP, FD, and ATS compensation.
- Yaw damping/turn coordination.
- Elevator Load Feel (ELF) control.
- Flap limiting (FL).
- Automatic Ground Spoiler (AGS).
- Stall warning with stickshaker and auto slat extend.

For a description of yaw damping, ELF, FL, stall warning, and AGS refer to the Flight Controls chapter.

For a description of altitude alerting refer to the Warning and Alerting chapter.

The AFS consists of the following:

- Flight Control Panel (FCP).
- Two FCCs.
- Duplex ATS system.
- Elevator load feel servos.
- Flap limiter servos.
- Two Control Wheel Steering (CWS) force transducer assemblies.

AFS controls and indicators include the following:

- Flight Control Panel (FCP).
- Two Primary Flight Displays (PFD).
- Two Flight Mode Annunciators (FMA).
- AP disconnect switches.
- AP disengage warnings.
- ATS disconnect switches.
- ATS disengage warnings.
- Go-around (GA) switch.
- Flight director transfer and off switches.
- EIS Control Panels (ECP).

### **Flight Control Panel (FCP)**

The FCP is on the Glareshield Control Panel (GCP). The FCP provides the controls for basic AP/FD mode selection and for crew intervention in FMS SPD, PROF and NAV modes. FCP selector knobs allow select and preselect of reference speeds, altitudes, and headings. These values will appear on the FCP windows and on the PFD.

FCP IAS/MACH, HDG/TRK, and altitude select knobs operate as follows:

- Turn to preselect a value.
- Pull to select a value.
- Push to hold a value.

As an exception, the altitude select knob sets the clearance altitude when FMS PROF mode is coupled.

FCP changeover buttons are used to select the unit of measurement or function shown in the window above each select knob.

## **Primary Flight Display (PFD)**

The PFDs are located on the Captain's and First Officer's instrument panel. The PFDs show aircraft speed, altitude, vertical speed, attitude, heading, and flight modes. The PFD symbology maintains the Basic-T with attitude in the center, airspeed on the left, altitude/vertical speed on the right, and direction of flight on the bottom. In addition, the PFD shows glideslope and localizer deviations, flight modes, bearing info when on emergency power, radio altitude, pitch and roll limits, limit speeds, slip/skid, flight crew or FMS selected speeds, altitudes, heading, failure flags, and warnings.

Normal (on-side) sources are not annunciated. Abnormal (off-side) sources are annunciated near the associated symbology. Refer to the Aircraft General chapter for a complete description of abnormal source annunciation.

## **Flight Mode Annunciator (FMA)**

The FMA annunciations appear across the top of the PFD. The FMA shows what the aircraft is being controlled to, and how the commanded state should be achieved. Each FMA annunciates speed control modes, AP/FD lateral modes, AP/FD vertical modes, and associated control targets.

## **AP Disconnect Switches**

The AP disconnect switches are installed on the outboard horn of the Captain's and First Officer's control wheels. Operation of either switch disconnects the AP.

## **AP Disengage Warning System**

The AP disengage warning system consists of a flashing red AP OFF on the FMA and a cyclic aural warning (tone and voice). After this warning, pushing either AP disconnect switch changes the AP OFF to a steady white FMA (amber if the disconnect was the result of a failure and no AP is available). The AP OFF warning light is reset if the AP is re-engaged. The aural tone is reset when either of the disconnect switches are pushed after at least one cycle of the tone is complete or when the AP is re-engaged.

## **ATS Disconnect Switches**

The ATS disconnect switches are on throttle levers 1 and 3. Operation of either switch disconnects the ATS.

## **ATS Disengage Warning System**

The ATS disengage warning system consists of a flashing red ATS OFF on the FMA. All disconnects, except those due to landing rollout thrust reversal, actuate the warning. Pushing either ATS disconnect switch changes the flashing red ATS OFF to a steady white (or amber if ATS not available). The warning is reset if the ATS is reengaged.

## **Go-Around (GA) Switch**

The GA switch is on the center throttle. Pushing the switch in flight below 2,500 feet AGL with flaps down or slats extended engages the FD go-around mode. If the AP is on, it will follow the FD commands. If a windshear is detected while on approach, pushing this switch engages AP/FD windshear guidance.

## **FLT DIR and FLT DIR OFF Switches**

The FLT DIR and the FLT DIR OFF switches are on the Captain's and First Officer's source input select panels. The FLT DIR switches allow FD1 commands to appear on the First Officer's PFD or FD2 commands to appear on the Captain's PFD. The FLT DIR OFF switches allow the FDs to be selected off.

## **Automatic Flight System (AFS) Panel**

The AFS control panel, on the forward overhead panel, is used for manual inputs to the flap limiter and elevator feel. It is also used to turn on or off yaw damper and LSAS control channels. Refer to the Flight Controls chapter for a description of yaw damper, LSAS, flap limiter, elevator feel, and the AFS control panel.

## **EIS Control Panels (ECP)**

The ECPs are on the GCP, one at each outboard end. These panels control the operation of the Captain's and First Officer's PFD and navigation displays (ND).

## **Roll Control Wheel Steering (CWS)**

If installed, the AFS roll CWS provides lateral stability through electronic control of a single inboard aileron when the AP is not engaged.

With no force on the control wheel, the aircraft holds the current roll attitude. Forces on the control wheel command an aircraft roll rate proportional to the applied force, so that when the force is removed from the control wheel, the aircraft holds the new roll attitude.

Attempts to achieve bank angles in excess of 30 degrees require increasing pilot override force on the control wheel proportional to the amount of the bank above 30 degrees. If the pilot releases that override force, the aircraft will immediately roll back to, and hold 30 degrees of bank.

CWS is available when either FCC is operational and at least one yaw damper channel is active.

Pulling down both of the AFS OVRD OFF switches on the FCP disengages the roll CWS (as well as the AP and ATS systems).

# **Autopilot/Flight Director**

## **Flight Director Engage/Disengage**

The FD provides visual commands to fly the aircraft. The flight crew can manually follow the commands or monitor the AP as it follows the commands.

Both FDs are always engaged unless selected off with the respective FLT DIR OFF switch.

On the ground prior to takeoff, the FD takeoff mode engages automatically if either FD is engaged. When the FDs are engaged, FD1 pitch and roll commands are displayed on the Captain's PFD. FD2 pitch and roll commands are shown on the First Officer's PFD.

Turning an FD off removes the command bars from the associated PFD, and resets the mode (unless AP is on).

If an FD is turned off, then back on, the command bars will appear and the FD will acquire the current mode of the AP or other FD.

If both APs and both FDs are off, turning on an FD will cause the FD to command:

- A roll to wings level.
- Heading hold.
- Vertical speed hold if climb/descent is more than 300 fpm or altitude hold if climb/descent is less than 300 fpm.

## **Autopilot Engagement**

Pushing the AUTO FLIGHT switch on the FCP controls the AP channels 1 and 2 as follows:

1. If neither AP channel (1 or 2) is engaged, the armed channel will engage.
2. After first AP engagement, each push transfers the AP channel between AP1 and AP2. The channel that is not engaged will be armed (unless inop).
3. If one of the AP channels is engaged and the other channel is inoperative, no transfer will occur.
4. The engaged AP channel will appear on the PFD below the FMA (AP1 or AP2).

The armed status alternates between the 2 AP channels to ensure equal use as follows:

- After power application with neither AP engaged, the first channel to be powered becomes the armed channel.
- If one AP is engaged and the other is not, the disengaged channel is armed.
- The armed status will alternate each time the AP is disengaged.
- A failed channel will not arm.

Pushing the AUTO FLIGHT switch results in AP operation as follows:

- AP engagement is inhibited on the ground and below 100 feet AGL. An engage attempt will result in an AP disconnect warning.
- AP engagement above 100 feet engages the AP takeoff mode if an FD is in the takeoff mode.
- For AP engagement with both FDs selected off, the AP will roll the aircraft to wings level and hold the wings level heading. The altitude hold mode is also engaged if the rate of climb/descent is below 300fpm; otherwise the vertical speed mode is engaged and the AP holds either the vertical speed or the pitch limit (+25 degrees and -10 degrees).

If the AP is engaged with either or both FDs on, the AP will:

- Engage in the existing FD mode and maneuver the aircraft within the attitude limit to acquire and track the FD mode if the engaged FD mode is heading/track select, level change speed select, pitch TO/GA, FMS NAV, or FMS PROF.
- Engage in the existing FD mode if the engaged mode is altitude capture or glideslope engage. If the pitch command error exceeds limits, the AP will synchronize the AP/FD to the existing vertical speed flight path angle and engage the V/S-FPA mode.
- Engage in the existing FD mode and synchronize the AP/FD reference to existing conditions if the engaged FD mode is V/S-FPA, altitude hold, or level change speed on pitch hold.
- Roll the aircraft toward wings level then engage the AP heading/track hold mode when the bank angle decreases to less than 3 degrees if the engaged FD mode is heading track hold or roll TO/GA. If the AP is engaged when the bank angle is less than 3 degrees, the AP will synchronize the AP/FD reference to the existing heading/track angle and engage the heading/ track hold mode.
- Engage in the localizer mode if the engaged mode is LOC engage and the FD roll attitude command error is less than 3 degrees. If the FD roll attitude command exceeds 3 degrees, the AP will roll the aircraft towards wings level, then engage the AP heading/track hold mode when the bank angle lessens to less than 3 degrees.

## **Autopilot Disconnects**

The primary method of disconnecting the APs is by pushing either pilot's disconnect button on the respective control wheel. AFS OVRD OFF switches are provided on the FCP to disconnect the AP/AT if the normal disconnect switches fail. All AP disconnects, intentional or unintentional, will result in an AP OFF warning.

RCWS and certain other FCC functions are inhibited during an AP disconnect button push.

AP disconnects will also occur as follows:

- Excessive force is applied to the controls.

- Control wheel trim switches or long trim handles are actuated (except single or dual autoland engaged).
- During cruise flight when a bank of 60 degrees is exceeded or roll rate exceeds 10 degrees per second or there is excessive acceleration G forces in combination with pitch rates.
- Associated LSAS failed or off.
- Altitude below 100 feet AGL when any mode other than autoland or GA is engaged.
- AFS failures.
- Any control surface commanded position not in agreement with actual position.

## **Autopilot/Flight Director Operations**

### **General**

AP/FD pitch modes are:

- FCP vertical speed/altitude hold (basic pitch mode).
- FCP flight path angle control.
- FCP speed select and hold (flight level change).
- FMS computed speed control.
- FMS vertical flight profile control.

AP/FD roll modes are:

- FCP magnetic heading select/hold (basic roll mode).
- FCP magnetic track select/hold.
- FMS lateral navigation.

AP/FD combined pitch and roll modes are:

- FMS non-precision approach.
- FD and AP ILS approach.
- AP automatic landing.
- Windshear flight path angle and stickshaker guidance.

### **AP/FD FCP Vertical Speed/Flight Path Angle**

The vertical speed mode will engage when V/S is selected on the FCP after one of the following flight crew actions:

- AP engaged and the existing vertical speed is greater than 300 fpm. In this case the V/S-FPA display window on the FCP displays the existing vertical speed and the AP controls to that vertical speed.
- One or both FDs are re-engaged with the AP off and the existing vertical speed is more than 300 fpm.

- The pitch thumbwheel on the FCP is rotated to select the desired vertical speed in the V/S-FPA display window except when the AP is engaged in land mode, dual FD approach mode below 1500 feet, or takeoff/GA mode below 400 feet.
- The V/S-FPA changeover button on the FCP is pushed to V/S from FPA while operating in the flight path angle mode. The vertical speed reference will be the vertical equivalent to the displayed flight path angle at the time of FPA to V/S changeover selection.

Engaging the AP/FD vertical speed mode sets the ATS to control speed. The FMA annunciates V/S in the vertical control window and THRUST in the speed control window.

During an altitude intercept, if the aircraft is in the altitude capture phase of the intercept (FMA annunciates ALT HOLD), manually adjusting the vertical speed wheel (V/S) will cancel the altitude capture. Dashes in the V/S-FPA window will be replaced by the existing V/S, and the V/S may then be adjusted if desired. The capture mode will not re-engage until the V/S wheel has come to rest for two seconds. Repeated adjustments of the wheel at intervals of less than two seconds will defeat the capture function. The target altitude will continue to be displayed, but the autopilot may no longer be able to intercept it.

### **AP/FD Altitude Control**

Altitude control consists of a capture mode and a hold mode. The AFS controls altitude to the FCP altitude display window value automatically whenever the FMS PROF is not engaged.

When the FMS PROF mode is engaged, altitude is controlled by the FMS altitude targets in PROF climb or the FMS steering commands in PROF descent. The final altitude capture is always the FCP selected value.

The capture mode provides a transition phase between any other cruise mode and the FCP-selected, baro-corrected altitude or FMS PROF constraint altitude.

Capture is always armed except when in takeoff or go-around modes below 400-foot RA and in the glideslope engage mode.

Capture will engage automatically when a 0.05-g circular path to the selected altitude is intercepted. The pilot may intervene with V/S control at any time during the altitude capture maneuver, if it is deemed necessary.

If the altitude display window setting on the FCP is changed when the aircraft is within 250 feet of target altitude, a 0.09-g circular path will be commanded when:

- The aircraft is within the 0.05-g path with a high rate of climb or
- The aircraft is past the 0.05-g path with the correct rate of climb.

Changing the altitude display window setting on the FCP while in the altitude capture phase, cancels the capture mode, triggers the mode in control prior to capture, and rearms altitude capture.



In altitude capture and hold modes, the ATS controls to the FCP-selected speed or FMS computed speed (FMS SPD engaged). The speed control window on the FMA will show THRUST and the altitude control window on the FMA will display HOLD.

The altitude hold mode may be engaged automatically from the altitude capture or vertical speed/flight path angle mode when the AP/FD is initially engaged and the rate is less than 300 fpm and selected altitude error is less than 60 feet.

The altitude hold mode may be engaged manually by pushing the altitude select knob on the FCP. Subsequent knob rotation selects the next increment for the existing flight level. The altitude control and speed control windows on the FMA show the same legends and colors as in altitude capture.

### **AP/FD Speed Select/Hold (Flight Level Change)**

The AP/FD will capture and hold the FMA airspeed/Mach during climb/descent when the climb/descent is commanded by pulling the FCP altitude select knob.

The commanded speed will be the FMS speed if the FMS SPD is engaged.

The commanded speed will be the FCP selected speed if the FMS SPD is not engaged.

The commanded speed may be changed manually with the IAS/MACH select knob on the FCP. Rotating the IAS/MACH select knob preselects a new speed reference. Pulling the IAS/MACH select knob selects the FCP speed. Pushing the IAS/MACH select knob selects the existing speed.

Rotating the IAS/MACH select knob on the FCP or pushing the FMS SPD switch on the FCP changes the commanded speed reference only. AP/FD control modes are not affected. An FMS speed reference failure will change the speed reference to existing aircraft speed, change the FMA reference number color to white and flash the speed mode legends 5 times.

Compatible control of the AP/FD and ATS modes is computed by the AFS when FMS PROF is not engaged.

When the aircraft passes through 26,000 feet in climbout, the speed control will automatically change from IAS to the equivalent Mach if the desired Mach was not preselected.

If the desired Mach number was preselected, the reference will change automatically to Mach at the preselected Mach number. Operation is the same for the Mach-to-IAS changeover in descent.

## **AP/FD Heading/Track Select/Hold**

Heading or track select is engaged by pulling the HDG/TRK select knob on the FCP. If the HDG/TRK display window is blank when the knob is pulled, the current heading or track is selected and the heading select or track select mode engages.

The AP/FD captures the selected heading by turning the aircraft or commanding a bank in the direction the HDG/TRK select knob was turned.

Additional changes may be made while still in the turn. After the aircraft stabilizes on the selected heading or track, control will transition to heading or track hold. The roll control window on the FMA shows HEADING or TRACK and displays the digital heading or track.

Heading or track angle hold is engaged by pushing the HDG/TRK select knob on the FCP. If the aircraft is in a bank at the time of hold selection, the aircraft will roll wings level and the reference heading or track will be the existing value at the time the HDG/TRK knob was pushed. The HDG/TRK display window on the FCP will display the held reference value.

The commanded bank angle limit will be the bank angle selected with the bank angle limit selector (5 to 25 degrees) and the FMS computed bank angle limit. If the bank limit is selected to AUTO, the limit value will be the least of a value varying linearly from 5 degrees at 340 KIAS to 25 degrees at 210 knots KIAS and the 1.3g buffet limit. At 1.3 V stall, the limit is further constrained to a maximum roll angle of 15 degrees. The 1.3g buffet and the 1.3 Vstall speed protection is contingent on FMS availability.

If the bank angle limit selector is set to the AUTO position, the bank angle limit value will vary as follows:

- Between 15 degrees and 25 degrees from zero Mach to Mach 0.17.
- Limited to 25 degrees between Mach 0.17 and Mach 0.55.
- Reduced linearly to 20 degrees at Mach 0.80, 10 degrees at Mach 0.87, and wings level at Mach 0.93.

If the FMS is not available, the AFS provides the Mach bank angle limit schedule. In this case, the Vmin protection is lost. The bank angle limit selector is overridden in the NAV, localizer, or TO/GA modes (computed limits apply).

## **AP/FD Approach**

The AFS provides automatic flying of precision approaches to ILS category I, II, IIIA and IIIB weather minimums and manual guidance (flight director) for flying precision approaches to ILS category I and II weather minimums. The AFS also provides AP/FD for MLS approaches to category I minimums. Non-precision approaches may be made either manually or automatically by coupling the FMS NAV and PROF modes or using the AFS track and flight path angle (FPA) modes.

The approach functions include localizer capture, localizer track, glideslope capture, and glideslope track. The AFS approach and land modes are armed by pushing the APPR/LAND switch on the FCP when the AP or FD is in any lateral or vertical control mode except take-off or go-around and there is a valid ILS frequency.

The localizer may be intercepted at angles up to 90 degrees, but high IAS and/or intercept angles greater than 30-40 degrees may result in overshoot.

After the APPR/LAND switch has been pushed, LAND ARMED is displayed above the FMA roll control window. At localizer capture LOC is annunciated in the FMA roll control window, LAND ARMED transfers to above the FMA altitude control window and the PFD bank angle limit becomes 30 degrees. If the AP is engaged it will automatically capture and track the localizer. If flying FD, the FD will supply commands to manually capture and track the localizer.

When the aircraft is stabilized on the localizer (localizer track), the bank angle limit will reduce to 10 degrees. At 200 feet the bank angle will be further reduced to 5 degrees.

As the aircraft intercepts the glideslope, the glideslope deviation diamond will begin to move. At glideslope capture, G/S is annunciated in the FMA altitude control window under the LAND ARMED annunciation. If flying AP, the aircraft will capture and track the glideslope. If flying FD, the FD will supply commands to manually capture and track the glideslope. During glideslope capture the pitch attitude is limited to +15 and -5 degrees. Glideslope capture is inhibited if course error is more than 80 degrees. Selection of any other pitch or roll mode prior to land engage will cancel the land armed mode.

During ILS approach, the ATIS speed reference is the FMS approach speed if FMS speed is engaged. If FMS speed is not engaged, the reference is the IAS/MACH display window setting in the FCP.

VOR approaches may be flown in the NAV and PROF modes by selecting the appropriate VOR database approach and engaging NAV for lateral guidance and PROF for vertical guidance down to the MDA or by following raw data with the use of appropriate FCP controls. VOR approaches may be flown in NAV, TRACK, HEADING or VOR.

### **FD Only ILS Operation**

The approach is restricted to ILS category II minimums.

The LOC and G/S annunciations will be white. When the glideslope is captured, G/S APPROACH ONLY will be annunciated in the FMA altitude control window and LAND ARMED will be removed.

Failures in any FD mode will result in removal of the command bar (for that channel and axis only) on the affected PFD.

For single FCC operation in modes where dual FD operation is required (takeoff, go-around, ILS category II approach), the AFS provides continuous FD command comparison monitoring of the two channels within the FCC. A comparison failure within the FCC will result in the removal of the command bar from both PFDs for the affected axis only. Once removed due to a failure, the FD command bars will not be displayed again until the dual mode is cancelled.

Below 1500 feet RA, dual FD approach mode can only be exited by pushing the go-around button.

## **Autoland**

Autoland adds align, flare, nose lowering, and rollout modes to the normal approach modes (localizer capture, localizer track, glideslope capture, glideslope track).

The SINGLE LAND and NO AUTOLAND alerts indicate the land availability of the aircraft. SINGLE LAND indicates that a CAT II approach may be continued automatically. NO AUTOLAND indicates that there is insufficient equipment redundancy to perform an automatic landing.

Automatic landings have been demonstrated using a reference approach speed of  $1.3V_s + 5$  kts. under the following wind conditions:

- Headwinds to 25 kts.
- Tailwinds to 10 kts.
- Crosswinds to 15 kts.

When available, DUAL LAND mode will automatically engage when the aircraft is in approach, tracking both the localizer and glideslope, and has been below 1500 feet RA for ten seconds. If the requirements for DUAL LAND are not met but SINGLE LAND is available, SINGLE LAND will engage between 1500 feet (for ten seconds) and 400 feet RA.

If the equipment redundancy requirements for DUAL LAND and SINGLE LAND are not met, or if a land mode is not engaged prior to 400 feet RA, the AFS will revert to APPROACH ONLY. In the APPROACH ONLY mode, the aircraft will continue to automatically track the localizer and glideslope but the autoland function will not be available. The AP must be disengaged prior to 100 feet and a manual landing performed.

When the aircraft is tracking localizer and glideslope in an FD approach, engaging the AP between ten seconds after descending below 1500 feet (approximately 1360 feet) and prior to five seconds before 400 feet (approximately 460 feet) will also engage DUAL LAND or SINGLE LAND mode depending on equipment redundancy.

The ILS receivers are inhibited from further tuning when the GS or LOC modes are captured.

When the aircraft is below 1500 feet and is tracking both the localizer and glideslope, the electrical busses will be split to provide complete electrical isolation between AP systems. If the busses do not split, DUAL LAND will not be available.

When a land mode is engaged, all other modes except go-around are inhibited.

Prior to land engagement the aircraft is controlled by a single channel of the engaged AP. The second channel of the engaged AP and both channels of the second AP are on stand-by.

At DUAL LAND engagement the three AP channels on stand-by become operational and their associated control surface actuators are engaged. Also at this time, the upper and lower rudder actuators engage in the parallel mode. The FMA roll and altitude annunciations turn green and LOC, G/S DUAL LAND is displayed. The AP annunciation below the FMA which annunciates AP1 or AP2 in all other modes, switches to AP.

Reversion to SINGLE LAND may occur if:

- The second AP is invalid.
- The autothrottles are invalid or not engaged.
- The electrical busses are not split.
- The sensor redundancy required for DUAL LAND is not achieved.

At SINGLE LAND engagement the FMA roll and altitude annunciations will remain white and LOC, G/S SINGLE LAND is displayed. The AP annunciation below the FMA displays AP1, AP2 or AP. If AP1 or AP2 is displayed, the two channels of the engaged AP are operational in addition to parallel engagement of one rudder. If AP is displayed, both APs are engaged and all surface actuators are controlled as in a DUAL LAND.

A reversion from DUAL LAND to SINGLE LAND is indicated by the FMA altitude control window annunciating G/S SINGLE LAND in white accompanied by the roll control window annunciation turning white. Also, the altitude annunciations flash five times to alert the pilot to the reversion. DUAL LAND reversions are inhibited below 100 feet.

A reversion from SINGLE LAND to APPROACH ONLY is indicated by the FMA altitude control window annunciating G/S APPROACH ONLY and flashing five times.

When descending through 150 feet RA in either SINGLE or DUAL LAND, the FMA roll control window annunciates ALIGN. If a crosswind is present, a side slip runway alignment maneuver is initiated to remove any existing crab angle. The crab angle is removed by the rudder and the up-wind wing is lowered to maintain the localizer center.

At about 50 feet, FLARE mode is initiated. The AP commands an exponential flare path and the throttles retard if engaged. The FMA annunciates FLARE DUAL LAND or FLARE SINGLE LAND in the altitude control window and RETARD in the speed control window.

At touchdown, main wheel spin-up is sensed and ROLLOUT mode is initiated. The auto ground spoilers partially extend (full extension at nose gear compression). The FMA annunciates ROLLOUT in both the roll and altitude control windows. Pitch is reduced from that required for flare to the attitude required for nose wheel touchdown. The localizer centerline is maintained throughout rollout with rudders.

At initiation of reverse thrust, the ATS disengages.

The AP should be disconnected at the completion of ground rollout before attempting to turn off the runway.

An approach terminated by leveling off at the selected MDA without entering a land mode can be accomplished by setting the altitude in the FCP altitude window to the MDA baro altitude displayed on the PFD.

### **AP/FD Go-Around**

Pushing the GA switch on the center throttle during approach conditions (RA less than 2500 ft. and flaps or slats extended) causes the following:

- Aircraft will exit any mode it is in.
- FDs pop up and go to go-around mode even if selected off.
- If AP on, AP will follow FD commands.
- AP/FD rolls wings level if bank more than 3 degrees (current heading held if bank less than 3 degrees).
- Bank angle limited to 10 degrees.
- ATS goes to go-around limits.
- Parallel rudder active (in case of engine failure) or LOC modes are captured.
- Reference speed and PITCH appear on FMA.
- GO-AROUND appears in altitude window.
- Windshear pitch guidance provided if windshear warning active. WINDSHEAR will appear on the FMA.

AP GA remains engaged after a momentary touchdown if GA is selected before main gear spinup. Selection after spinup disengages the AP. FD GA can be engaged from below 2500 feet RA to 20 seconds after nose gear compression.

### **FD Takeoff**

The FD takeoff mode is automatically established on the ground if:

- On-ground conditions exist for more than 20 seconds and,

- The FMS V2 speed has been manually confirmed, and
- Either or both FDs are on and working.

The pitch command bar on the PFD is removed until V2 is manually confirmed on the FMS TAKEOFF page.

After touchdown during landing roll, FD takeoff mode is inhibited until the AP and ATS are disengaged. The AUTO FLIGHT switch will not engage the AP below 100 feet if the FD is in takeoff. If autoflight is attempted below 100 feet, the AP OFF red box flashes until the AP disconnect switch is pushed.

Prior to takeoff, the Vspeeds are entered on the MCDU and verified by the pilot for display on the PFD. During takeoff roll through rotation, the FD commands wings level and the FD pitch cues will be about 0 degrees below 80 knots, will rise to about 6 degrees at 80 knots, and then rise to about 15 degrees at rotation speed.

If speed at engine out (EO) is below V2, the target speed will be V2. If speed at EO is between V2 and V2 + 10, the target speed will be that speed. If the speed at time of EO is more than V2 + 10, the target speed will be V2 + 10.

If not already engaged, the FD will engage automatically after liftoff and provide pitch windshear guidance if windshear warning becomes active.

The AP takeoff and parallel rudder modes are engaged above 100 feet by pushing the AUTO FLIGHT switch.

Lateral takeoff control will retain the FD heading reference if the aircraft is on heading and wings level. If the aircraft is not on heading with wings level, a wings level command will be initiated.

Selecting any other roll mode during takeoff will exit the AP roll takeoff and parallel rudder modes without exiting pitch takeoff.

Pitch takeoff exit (if roll axis still in takeoff) sets the roll mode to heading hold at the roll takeoff reference. AP pitch takeoff may be cancelled (above 400 feet) by selecting any other pitch mode. AP pitch takeoff will be cancelled automatically at altitude capture.

Parallel rudder operation is an engaged AP mode in which the FCC controls the rudder to counter asymmetric thrust or to align the aircraft at 150 AGL during autoland. This mode engages automatically when the AP is on during takeoff or go-around, and during DUAL LAND, or SINGLE LAND. During this mode the pilot can feel the rudder motion in the rudder pedals and the bank angle limiter on the PFD indicates 10 degrees or less. This mode stops when another lateral mode is selected (heading select, heading hold, or NAV) during takeoff or go-around, or when the aircraft configuration is changed to clean.

# **FMS Coupled Operations**

## **General**

The FMS lateral navigation (NAV), vertical profile control (PROF), optimum speed control, (FMS SPD), and nonprecision approach (NAV and PROF) functions are coupled to the AP/FD through targets or steering commands.

The FMS also provides AP/FD TO/GA speed references, variable bank angle limit control, Vmin speed protection, and thrust limiting.

Normally, both FCCs will select the FMC on the same side as the FCC in control. Both FDs will control to the same steering command.

If the other FCC is selected by pushing the AUTO FLIGHT switch, both FCCs will select and synchronize to the on-side FMC. The FMA NAV and AP legends (1 or 2) will show the same side selection.

Failure of the selected FMC while the AFS is coupled will result in a reversion to the equivalent FCP mode (AFS basic control mode if no equivalent FCP mode exists). The new FMA mode will flash five times to warn the pilot of the change. The FCCs then select the functional FMC and the desired FMS mode can be reengaged by the pilot on the FCP (NAV, PROF, FMS SPD). When the FCCs are controlling to commands from the on-side FMC, the FCCs do not select the off-side FMC if the FMC cancels a mode. In this case, only the affected FMS mode will be cancelled and the AFS will revert to its basic mode. The FMA mode legend will then flash five times. The pilot must push the AUTO FLIGHT switch to select the other FMC. The pilot must then reengage the desired FMS mode on the FCP.

If only one FMC is functional prior to coupling to the AFS, the FCCs will both select the functional FMC. The FMA NAV and AP legend numbers (1 or 2) will not be the same if the functional FMC is not on the same side as the selected FCC.

If both FMCs are functioning and in different FMS/AFS control modes (FMC independent mode operation) when the pilot pushes the AUTO FLIGHT switch, the FCC will uncouple from the FMS and revert to the basic AFS mode. The FMA mode legend will flash 5 times. The desired FMS control mode must then be reengaged by the pilot.

## **FMS Speed Control**

FMS SPD is selected as the AFS reference speed by pushing the FMS SPD switch. FMS SPD may be engaged independent of PROF engagement. Compatible control of the AP/FD and ATS modes is computed by the AFS when PROF is not engaged. FMS SPD switch engagement is cancelled when an FCP speed is selected.



Engaging the AP/FD go-around mode cancels the FMS SPD switch and selects current airspeed or FMS VMIN GA reference (whichever is higher).

IAS to MACH and MACH to IAS changeover is computed by the FMS when the FMS SPD mode is engaged.

The FMS speed edit occurs if a speed is preselected and the FMS SPD switch is pushed within ten seconds. The IAS/MACH preselect window on the FCP will be blank.

### **FMS Vertical Profile Control**

FMS vertical profile mode control is engaged by pushing the PROF switch. When the FMS PROF mode is engaged, the AP/FD responds to the requirements of the preplanned vertical profile.

The FCP altitude display window setting is always the absolute ceiling or floor altitude in all AFS modes including FMS PROF except during engine out when the altitude display window may be violated during driftdown.

Compatible control of the AP/FD and ATS modes is computed by the FMS when PROF is engaged.

PROF mode will not engage if any of the following are true:

- Both autopilot and flight director are disengaged.
- In DUAL LAND or SINGLE LAND.
- Below 400 feet radio altitude.

As a customer option, PROF may be armed on the ground.

PROF mode disengages if any of the following are true:

- The pitch wheel is rotated to engage the V/S-FPA mode.
- The altitude knob is pushed or pulled.
- Go-around or glideslope becomes the active pitch mode.
- Radio altitude becomes less than 100 feet.
- Windshear detection or guidance mode becomes active.
- Autothrottle Speed Protection becomes active.

### **FMS Lateral Navigation**

Pushing the NAV switch on the FCP arms the AFS/FMS NAV mode. NAV ARMED is then displayed on the FMA.

NAV ARMED is reset by:

- Pushing the FCP HDG/TRK select knob to select the existing heading.
- Selecting APPR/LAND.
- Selecting the optional VOR or LOC ONLY modes.

When the FMS NAV capture criteria are satisfied, the roll control window on the FMA changes to NAV1 or NAV2 and the AFS captures and controls to the FMS lateral flight plan in response to steering commands from the selected FMC.

The FMS steering command is limited to an optimum maximum bank angle which also provides a stall speed and initial buffet bank angle limit. The FMS bank limit is used by the FCC to provide bank angle limiting. Bank angle limiting is displayed on the PFD attitude sphere.

If NAV is not engaged, and the NAV switch is pushed (aircraft within NAV capture threshold) the FMS/AFS will momentarily cycle through the NAV ARMED phase to verify the capture criteria. It will then annunciate NAV1 or NAV2 and control to the FMS lateral flight plan.

NAV mode may be armed on ground once all engines are started. NAV can be cancelled on ground by pushing the heading select knob. NAV guidance will be available in FD at 100 feet AGL. If NAV was armed on the ground, NAV guidance will auto engage at 100 feet in FD mode. In air below 400 feet, NAV can be disengaged by pushing the heading select knob or pushing the GA switch. Pushing GA switch reengages parallel rudder if the AP is engaged. The earliest altitude at which AP NAV can be coupled is 400 feet. Below 400 feet, when NAV is armed or engaged, the AP cannot be engaged unless NAV is exited. If the pilot attempts to engage the AP while NAV is armed/engaged, an AP disconnect warning will occur (AP OFF box flashes red and a CAWS warning sounds). To clear the warning, the AP disconnect switch must be pushed or the AP engaged above 400 feet. Below 400 feet, if the AP is engaged, NAV cannot be engaged until above 400 feet. Parallel rudder is only available with AP engaged. If NAV is armed on the ground, parallel rudder is not available unless NAV is cancelled.

Engaging another lateral control mode cancels the NAV mode. The NAV mode may also be disengaged by the FMS.

### **FMS VOR Approach Mode**

If this option is installed, VOR control is provided by the FMC to FCC NAV steering command. The mode is requested from the NAV radio page on the MCDU by entering a VOR frequency and the desired VOR radial to the station.

Upon receiving the VOR mode request, the AFS is armed to capture the VOR radial. VOR ARMED is then annunciated on the FMA.

VOR ARMED is reset by:

- Clearing the VOR course entered on the MCDU.
- Pushing the HDG/TRK select knob on the FCP to select the existing heading.
- Selecting APPR/LAND.
- Selecting NAV.
- Selecting the LOC ONLY mode.

When the FMS VOR capture criteria are satisfied, the roll control window on the FMA changes to VOR1 or VOR2 to indicate which VHF NAV receiver is selected by the FMC. The AFS then captures and controls to the VOR radial in response to steering commands from the selected FMC.

Over the VOR station, control is to the selected VOR course only and the FMA will show VOR1 or VOR2 CRS.

The FMS steering command is limited to an optimum maximum bank angle which also provides a stall speed and initial buffet bank angle limit. The FMS bank angle limit is used by the FCC to provide bank angle limiting.

If VOR is not engaged and the VOR is requested (if aircraft within VOR capture threshold), the FMS/AFS will momentarily cycle through the VOR ARMED phase to verify the capture criteria. It will then annunciate VOR1 or VOR2 and control to the selected VOR RADIAL.

The flight crew can select and manually track a VOR radial at any time. The FMS will track a VOR radial only during FMS VOR approach mode. This mode is inhibited as follows:

- On the ground.
- In the land mode.
- In AP roll TO/GA modes below 400 ft.
- Above 18,000 feet. In this case, the FMS tracks FMS-calculated great circle routes between waypoints.

Engaging another lateral control mode cancels the VOR approach mode. The VOR approach mode may also be disengaged by the FMS or may be deselected on the MCDU by clearing the selected course (radial to the station) or selecting another VOR frequency.

### **FMS ILS Localizer Only**

If the LOC ONLY option is installed, ILS localizer control with disabled glideslope control is provided.

The mode is requested from the NAV radio page on the MCDU by entering the ILS frequency and runway heading and selecting the LOC ONLY prompt.

Upon receiving the LOC ONLY mode request, the AFS is armed to capture the localizer. LOC ARMED is annunciated on the FMA.

LOC ARMED is reset by:

- Pushing the HDG/TRK select knob on the FCP to select the existing heading.
- Selecting APPR/LAND.
- Selecting NAV.
- Selecting the optional VOR mode.

When the FCC localizer capture criteria are satisfied, the roll control window on the FMA changes to LOC ONLY and the AFS captures and controls to the ILS localizer using the same FCC control laws as when APPR/LAND is selected. Align and rollout submodes are not available.

Engaging another lateral control mode cancels the LOC ONLY mode. The LOC ONLY mode may also be disengaged by the FMS or may be deselected on the MCDU by selecting another ILS frequency.

(FCC-908) Engaging another lateral control mode cancels the LOC ONLY mode. However, once LOC ONLY has been annunciated in the FMA, de-selecting the LOC ONLY prompt on the MCDU will no longer cancel LOC ONLY. This method can only be used to cancel the LOC ARMED status.

## **Automatic Pitch Trim**

One automatic pitch trim (APT) channel is contained in each FCC. Only one of these channels is operational at a time. In land modes or LSAS, the second channel auto engages if the first channel fails.

The horizontal stabilizer is automatically positioned to off-load any steady state elevator deflections. The trim rate is varied with airspeed to provide best performance for all flight conditions.

APT is available during LSAS operation and in all AP modes except flare.

APT is inhibited if:

- Control column force more than 2 lb.
- Bank angle more than 5 degrees.
- LSAS is in speed protection.

Nose-up trim is delayed for 10 seconds when the AP TO and GA modes are initially engaged.

## **Autothrottle System (ATS) and Engine Trim**

### **General**

The ATS automatically positions the throttles to maintain engine thrust required for the mode selected. The engine thrust trim system will maintain the engines at a common thrust setting to eliminate the need for throttle adjustments. The trim system can operate during manual and ATS operation. It is engaged any time two or more engines are operating above an N1 threshold.

Each FCC contains one ATS control channel that drives a separate section of a dual actuator. This provides two channels of control with fail passive monitoring.

The ATS is designed for full flight envelope operation. It can be engaged on the ground. It can remain engaged until it is automatically disengaged when reverse thrust is applied during landing rollout.

The ATS operates in the following modes:

IAS Hold - Provides control of throttles to maintain the current airspeed.

IAS Select - Provides control of throttles to acquire and maintain a selected reference speed.

Mach Hold - Provides control of throttles to maintain the current MACH number.

Mach Select - Provides control of throttles to acquire and maintain a selected reference Mach number.

Thrust Limit/Target - Provides control of throttles to acquire and maintain thrust at the thrust limit/target.

Retard - Provides control of throttles to reduce thrust at the appropriate radio altitude for landing.

Clamp - Inhibits ATS control during takeoff at approximately 80 knots without causing disengagement of the ATS. Full manual throttle is available during this mode.

### **ATS Engage**

The ATS is engaged when the AUTO FLIGHT switch on the FCP is pushed. The ATS will also engage when the PROF switch is pushed. Both ATS channels will engage if they are operational.

The ATS engages automatically to provide high speed or low speed protection if the aircraft speed exceeds the  $V_{max}/V_{min}$  limits.

### **ATS Disengage**

The ATS will engage with AFS engagement in most cases. The ATS may be disengaged by any of the following:

- Pushing either throttle 1 or 3 ATS disconnect switches.
- Placing any throttle in reverse thrust.
- System failure (may result in single or dual channel disengagement depending on the fault).
- Pushing down the AFS OVRD OFF switches on the FCP.

Annunciation of ATS disengagement is provided on the FMA. A disengage warning is provided for all cases except when the disengagement is due to reverse thrust operation.

The warning consists of a flashing red ATS OFF display. The display is reset by ATS engagement or by pushing the ATS disconnect switches.

If reset by reengagement, the ATS OFF display disappears. If reset by an ATS disconnect switch the flashing stops and the ATS OFF display changes color to white if ATS reengagement is possible. The display will turn amber if a condition prevents further use of the system.

### **ATS Clamp Mode**

In CLAMP mode the ATS is engaged, but the ATS servos cannot move the throttles. CLAMP mode is enabled in the following conditions:

- Takeoff mode on the ground and two or more engine thrust commands are less than 70 percent of the maximum takeoff setting.
- Takeoff mode is engaged and IAS exceeds 80 knots.
- In flight when command input places the throttles in flight idle and further thrust reduction is required.
- Windshear mode after throttles have reached the maximum rated thrust.

CLAMP mode is annunciated on the FMA.

### **ATS Unclamp**

The ATS will resume normal operation out of the CLAMP mode for the following conditions:

- Takeoff mode on the ground and two or more engine thrust commands exceed about 70 percent of the maximum takeoff setting.
- The aircraft is in flight above 400 feet and the takeoff mode is terminated by selection of any other vertical path control mode by the AP/FD or FMS.
- A command is generated for increased thrust while the ATS is operating in the in-flight idle CLAMP mode.
- Exit of windshear mode.

In a similar manner, the engine trim system resumes normal operation when:

- In-flight termination of the takeoff mode occurs.
- The mid-select engine exceeds the N1 threshold.

### **ATS Thrust Control**

The ATS provides automatic thrust limiting for all thrust and speed control modes. The N1 of each engine is constrained between the maximum limit defined by the FMS and a flight idle limit.

The N1 is also constrained by the engine full authority digital electronic control (FADEC).

The ATS thrust limit control modes are:

- Takeoff.
- Go-around.
- Climb.

- The pitch thumbwheel on the FCP is rotated to select the desired vertical speed in the V/S-FPA display window except when the AP is engaged in land mode, dual FD approach mode below 1500 feet, or takeoff/GA mode below 400 feet.
- The V/S-FPA changeover button on the FCP is pushed to V/S from FPA while operating in the flight path angle mode. The vertical speed reference will be the vertical equivalent to the displayed flight path angle at the time of FPA to V/S changeover selection.

Engaging the AP/FD vertical speed mode sets the ATS to control speed. The FMA annunciates V/S in the vertical control window and THRUST in the speed control window.

During an altitude intercept, if the aircraft is in the altitude capture phase of the intercept (FMA annunciates ALT HOLD), manually adjusting the vertical speed wheel (V/S) will cancel the altitude capture. Dashes in the V/S-FPA window will be replaced by the existing V/S, and the V/S may then be adjusted if desired. The capture mode will not re-engage until the V/S wheel has come to rest for two seconds. Repeated adjustments of the wheel at intervals of less than two seconds will defeat the capture function. The target altitude will continue to be displayed, but the autopilot may no longer be able to intercept it.

### **AP/FD Altitude Control**

Altitude control consists of a capture mode and a hold mode. The AFS controls altitude to the FCP altitude display window value automatically whenever the FMS PROF is not engaged.

When the FMS PROF mode is engaged, altitude is controlled by the FMS altitude targets in PROF climb or the FMS steering commands in PROF descent. The final altitude capture is always the FCP selected value.

The capture mode provides a transition phase between any other cruise mode and the FCP-selected, baro-corrected altitude or FMS PROF constraint altitude.

Capture is always armed except when in takeoff or go-around modes below 400-foot RA and in the glideslope engage mode.

Capture will engage automatically when a 0.05-g circular path to the selected altitude is intercepted. The pilot may intervene with V/S control at any time during the altitude capture maneuver, if it is deemed necessary.

If the altitude display window setting on the FCP is changed when the aircraft is within 250 feet of target altitude, a 0.09-g circular path will be commanded when:

- The aircraft is within the 0.05-g path with a high rate of climb or
- The aircraft is past the 0.05-g path with the correct rate of climb.

Changing the altitude display window setting on the FCP while in the altitude capture phase, cancels the capture mode, triggers the mode in control prior to capture, and rearms altitude capture.

- If climbing and under IAS control, auto-transition occurs when the existing MACH number equals the preselected Mach number (or 26,000 feet if Mach was not preselected).
- If descending and under control of Mach number, auto-transition occurs when the existing IAS equals the preselected IAS (or 26,000 feet if IAS was not preselected).

If descending at Mmo with wing tip tanks less than 90% full, the auto transition occurs between 30,670 feet and 26,670 feet when computed airspeed exceeds Vmo-10.

Auto-transition is annunciated on the FMA speed window by a change in the control target.

## **Speed Envelope Limiting**

The AFS provides full flight regime speed protection using the following:

- ATS self-engagement.
- ATS speed control.
- LSAS speed limiting and stall protection.
- AP/FD automatic pitch mode transitions.

## **Automatic Engagement and Speed Control**

The ATS (if available but not engaged) will auto-engage and transition to a speed-on-thrust mode when the Vmax or Vmin limit is about to be (or has been) exceeded. The AP/FD (if engaged) reverts to a compatible pitch mode. ATS engagement is annunciated by a flashing white A/T OFF on the PFD and HI SPEED (or LO SPEED) PROTECTION flashing above the FMA speed window as appropriate.

## **LSAS Speed Limiting and Stall Protection**

If the AP is not engaged and the ATS is not available, or unable to maintain a safe speed, LSAS speed limiting will engage automatically to provide overspeed or stall protection. LSAS overspeed limiting is accomplished by changing pitch. The target speed that LSAS chooses in high speed protection is variable between Vmo/Mmo, for throttles at idle, and Vmo/Mmo plus 6 knots for throttles at full power. LSAS will not auto trim in the nose down direction in a high speed encounter.

LSAS does not provide flap, slat or gear overspeed protection.

LSAS stall protection engages at stickshaker warning angle-of-attack (PLI on the PFD turns amber). Stickshaker warning is 75 to 85 percent actual stickshaker angle-of-attack depending on flap setting.

If windshear command guidance is on, LSAS stall protection is delayed until actual stickshaker angle-of-attack.



After the angle-of-attack is reduced below stickshaker warning, LSAS stall protection is discontinued and ATS speed control to FMS Vmin is resumed.

The pilot may counteract the LSAS overspeed or stall protection by pushing on the control column with enough force to defeat the LSAS elevator inputs. This force is approximately 50 pounds. If the pilot releases the control column force rapidly, LSAS will dampen the resulting elevator instability. For further information refer to LSAS description in the Flight Controls chapter.

### **AP/FD Speed Mode Reversions**

Detection of speed limit violations in FMS SPD or PROF modes disengages the FMS and the AFS will resume control (if engaged).

If the FCP level change/speed on pitch mode is engaged, the ATS is off, and a Vmax or FMS Vmin speed limit violation occurs the following will happen:

At 5 knots over or underspeed:

- The AP/FD pitch control mode reverts to V/S FPA at the existing vertical speed/flight path angle.
- ATS engages in speed-on-thrust speed protection with a Vmin or Vmax speed target.
- The FMA flashes THRUST and V/S or FPA five times before becoming steady.
- The FMA flashes HI SPEED PROTECTION or LO SPEED PROTECTION.

At 10 knots over or underspeed:

- The AP/FD pitch mode reverts to pitch speed protection with a Vmin or Vmax speed target.
- The throttles are clamped at their existing positions.
- The FMA flashes PITCH five times before becoming steady.
- The FMA flashes HI SPEED PROTECTION or LO SPEED PROTECTION.

If the level change/speed on pitch mode is engaged, the ATS is on, and a Vmax or FMS Vmin speed limit violation occurs, the following will happen at 5 knots over or underspeed:

- The AP/FD remains in speed on pitch mode but with an increased “g” limit and a Vmin or Vmax speed target.
- ATS speed protection will not engage at any time.
- The FMA flashes HI SPEED PROTECTION or LO SPEED PROTECTION.

If the V/S FPA mode is engaged, the ATS is off, and a Vmax or FMS Vmin speed limit violation occurs, the following will happen:

At 5 knots over or underspeed:

- The ATS engages in speed-on-thrust speed protection with a Vmin or Vmax speed target.
- The FMA flashes THRUST and V/S or FPA five times before becoming steady.
- The FMA flashes HI SPEED PROTECTION or LO SPEED PROTECTION.

At 10 knots over or underspeed:

- The AP/FD pitch mode reverts to pitch speed protection with a Vmin or Vmax speed target.
- The throttles are clamped at their existing positions.
- The FMA flashes PITCH five times before becoming steady.
- The FMA flashes HI SPEED PROTECTION or LO SPEED PROTECTION.

If the V/S FPA mode is engaged, the ATS is on, and a Vmax or FMS Vmin speed limit violation occurs, the following will happen at 5 knots over or underspeed:

- The AP/FD will revert to pitch speed protection with a Vmin or Vmax speed target.
- The ATS mode will change to climb thrust or idle clamp to provide compatible mode control. Since the ATS was previously in a speed mode, the throttles will already be at the maximum or minimum position to control speed.
- The FMA flashes PITCH five times before becoming steady.
- The FMA flashes HI SPEED PROTECTION or LO SPEED PROTECTION.

Terminating a speed protection mode requires pilot manual disengagement or selection of another mode.

### **Speed-On-Pitch AP/FD Speed Protection (FCC-908)**

ATS speed limiting and ATS speed protection are the primary means used by the FCC to limit speed excursions outside the normal speed envelope. Whenever the altitude FMA window displays HOLD, ATS speed protection is the only speed protection mode that is available. However, whenever the altitude FMA displays a mode other than HOLD, AP/FD Speed-on-Pitch (SOP) speed protection is also available to prevent overspeed or underspeed.

The typical sequencing and scheduling of both ATS and SOP speed protection is as follows:

1. Aircraft begins to violate Vmin or Vmax.
2. Aircraft reverts to Speed-on-Thrust (if engaged in a Speed-on-Pitch mode), and autothrottles engage (if off) no later than Vmin-5 (low speed) or Vmax+5 (high speed). The FMA displays speed protection indications.
3. If the speed violation continues, SOP speed protection comes on no later than Vmin-10 (low Speed) or Vmax+10 (high speed)

This typical mode sequencing for the two speed protection modes is affected by specific flight conditions and by throttle position. If the throttles are already positioned at an appropriate thrust limit for the speed limit being violated, the FCC will not wait until  $V_{min}-10$  (or  $V_{max}+10$ ) to engage SOP speed protection. The following example is provided to clarify this operation.

1. Aircraft is in a  $V_{max}-5$  knot descent. Autopilot is on, autothrottles are off, and throttles are at idle.
2. Aircraft begins to exceed  $V_{max}$ .
3. Since throttles are already at idle, SOP speed protection comes on not later than  $V_{max}+5$ . Throttles remain at idle, elevator motion pitches the nose up, and the aircraft decelerates.

### **Longitudinal Stability Augmentation System (LSAS) (FCC-908)**

Changes provide enhanced commonality between trijet-model approach/landing handling characteristics and control column force deterrent as the aircraft is rotated to near tail-strike pitch attitudes during takeoff and landing. These changes, referred to as Low Altitude Stability Enhancement (LASE), are as follows:

1. Modified Pitch Rate Damper (PRD) - The existing high-altitude PRD operates throughout the entire flight envelope. The PRD will continue to provide 30% of its high altitude pitch rate damping from 16,500 feet down to field elevations.
2. New Pitch Attitude Protection (PAP) Subfunction - The LSAS control law will implement a pitch attitude limiting function that will be enabled below 100 feet radio altitude. As with all LSAS elevator commands, the PAP will be limited to a total of 5 degrees of elevator authority. The PAP subfunction will be further limited to only command nose-down elevator displacements. If the aircraft approaches a tail strike pitch attitude, the pilot-flying will perceive the effect of PAP as an increase in the control column force required to maintain the pitch attitude. The pitch attitude limit used by PAP will vary linearly from 30 degrees at 40 feet radio altitude down to a minimum of 9.5 degrees at 0 feet radio altitude. The PAP subfunction will be active for both takeoff and landing.
3. New Positive Nose Lowering (PNL) Subfunction - This new subfunction will only be applied during landing phase, and will not affect AUTOLAND operations or Auto Flight System (AFS) autoland performance. The PNL subfunction will apply approximately 3 degrees of nose-down elevator command at main wheel spinup, at the same time that the FCC commands the Auto Ground Spoilers (AGS) to extend. As the spoilers extend beyond 10 degrees, the second phase of PNL will increase the nose-down elevator command to approximately 4 degrees. This subfunction, in combination with the enhanced PRD, will control the elevator to avoid aircraft nose-rise after touchdown, and to assist in de-rotation.

These LSAS changes will not affect the maximum override forces for LSAS, which are dependent upon the position of the Elevator Load Feel (ELF) actuator for any given airspeed. For the takeoff and landing phases, where PAP and PNL are active, the control column forces required to override LSAS are approximately 10 to 15 pounds.

## **Altitude Alert System**

The altitude alert system automatically alerts the flight crew that the aircraft is approaching the preselected altitude or that the aircraft is deviating from a preselected and acquired altitude.

The altitude alert system is always on except when the FD or AP is engaged in the glideslope mode. In this case, the altitude alert system is inhibited.

The altitude alert activates as follows:

1,000 feet from the FCP window altitude - PFD altitude box turns steady amber (and optional tone).

If more than 0.12g required to capture FCP window altitude - Steady amber PFD altitude box and tone. Active only on first approach to the FCP window altitude and is inhibited when aircraft is within 150 feet. If more than 0.12g is required to capture the FCP window altitude and that altitude is more than 1000 feet from the current baro-altitude, the PFD altitude box will be flashing amber. This condition requires an initial vertical speed of more than 5200 fpm and is rare.

Deviation of 150 feet or more from FCP window altitude - Flashing amber PFD altitude box and tone. The flashing amber altitude box will reset when the aircraft returns to the set altitude or a new altitude is selected.

Altitude alerting is not affected by the AFS OVRD switch on the FCP

*NOTES: The tone consists of a C-chord followed by an optional ALTITUDE voice warning.*

*As an option the altitude alert system is inhibited if the AFS is in glideslope capture mode or flap setting is more than 31.5 degrees (landing).*

## **Windshear Alert and Guidance**

### **General**

The windshear alert and guidance system (WAGS) provides detection, alerting, and guidance through windshear.

On takeoff the WAGS is available from 80 KTS to 1500 feet RA. On landing WAGS is available from 1500 feet RA to 50 feet RA.

The WAGS is part of the AFS and gets data from the two central air data computers (CADC), the inertial reference system (IRS), and other AFS components. The CADC and the IRS can sense windshear conditions and will send this data to the WAGS. The WAGS will then provide visual warnings on the PFD and FMA and aural warnings through the CAWS. FD and AP are provided through the AFS.

## **Indications**

A red WINDSHEAR (decreasing performance) or an amber WINDSHEAR (increasing performance) is displayed on the PFD top left corner when the WAGS detects windshear.

The CAWS generates a tone and TAILWIND SHEAR (or HEADWIND SHEAR) voice warning. Windshear modes are also annunciated on the FMA.

The WAGS provides FD and AP pitch guidance for windshear during takeoff and go-around.

The PLI (on PFD) shows the difference between aircraft AOA and stickshaker AOA. The cyan PLI turns amber as the aircraft approaches stickshaker AOA. At stickshaker AOA the PLI turns red. The PLI is for indication only and is not to be used for guidance command.

The WAGS inhibits the GPWS when windshear guidance is active and the aircraft is responding properly. If WAGS commands are not being followed, the GPWS will be enabled.

## **Guidance**

When an increasing or decreasing performance windshear is detected, guidance is provided for best flight path angle through the windshear and a positive flight path relative to the ground.

When windshear is detected and guidance is active, the system provides FD and/or AP guidance during takeoff and go-around. The system commands a 1 degree flight path angle until appropriate airspeed is achieved. The system then commands pitch guidance to maintain this speed. For takeoff this speed is  $V_2+30$ . For go-around this speed is  $1.3V_s + 20$ .

Above 450 RA the system allows a zero (or slightly decreasing) flight path. Below 450 RA, if a positive flight path angle is not possible, the system will guide to stickshaker AOA and altitude loss may occur as necessary in order to prevent a stall.

## **Pop-Up FD and ATS**

If the WAGS detects windshear and the FD is off, windshear guidance and maximum power functions are still available. On takeoff, after liftoff, the FD pops up on the PFD and the ATS goes to max available TO thrust.

On approach, FD and ATS are automatic if:

- N1 is more than 95% GA rating or,
- Pilot pushes the GA button or,
- Pilot advances throttles above 95% GA rating.

FD and ATS remain engaged throughout the windshear maneuver even after reversion to TO or GA modes.

### **Windshear Guidance Reversion**

During windshear guidance, selecting another pitch mode will terminate pitch guidance (not a recommended procedure). Guidance can be resumed by pushing the GA button (if below 1500 RA with slats and/or flaps extended).

When windshear no longer exists, all detection annunciations stop.

Windshear pitch and roll guidance will continue until safe conditions exist as follows:

- Altitude is above 1000 feet RA and,
- Rate of climb is at least 750 fpm for 15 seconds and,
- If in TO, speed at least  $V_2 + 5$  for 15 seconds.
- If in GA, speed at least  $V_{ref} - 5$  for 15 seconds.

### **Takeoff Roll and Takeoff**

The WAGS is enabled above 80 KTS.

When windshear is detected the alerts will appear on the PFD and FMA. The precursor tone and associated aural warnings will sound through the CAWS.

When a windshear is detected, the amber or red WINDSHEAR on the PFD will flash three times then remain steady. The CAWS activates a tone followed by three cycles of TAILWIND SHEAR or HEADWIND SHEAR.

If windshear is detected before  $V_1$ , the pilot will abort by retarding the throttles to the aft stops. At this time, all WAGS functions are cancelled except FMA annunciations which remain in view until slowing through 30 KTS. If a windshear is detected after  $V_1$  and the takeoff is continued, the WAGS will provide guidance after nose strut extension.

Decreasing performance windshear alerting (red) has priority over increasing performance windshear alerting (amber). When either windshear is detected on takeoff, the ATS remains clamped (except FLEX, DERATE, or ALT TO where the ATS unclamps, sets TO thrust, and reclamps).

The FMA speed, roll, and altitude windows will show changes in the WAGS modes. For a decreasing performance windshear, the system will limit bank to 5 degrees, and will display HDG XXX degrees in the roll window and WINDSHEAR in the speed and altitude windows of the FMA, (after flashing the annunciations five times). For increasing performance windshear, the roll window will retain TO heading while WINDSHEAR is displayed in the speed and altitude windows after flashing five times.

### **Approach and Go-Around**

When windshear is detected, the annunciations will appear on the PFD and FMA. The precursor tone and voice warnings will sound through the CAWS. After flashing 5 times, WINDSHEAR will appear in the FMA and the PFD speed bug will indicate a minimum speed of  $1.3V_s + 20$  KTS. The ATS, if engaged, will control to  $1.3V_s + 20$  KTS for both increasing and decreasing performance shears. The ATS will not control to a speed below the pilot selected speed.

Guidance is not activated during approach unless the GA button is pushed, or the throttles are advanced manually or automatically above 95% N1 GA thrust limit after windshear is detected.

When guidance is activated, the FMA speed, roll, and altitude windows will show changes in the WAGS mode. For a decreasing performance windshear, the system will: limit bank to 5 degrees and display HDG XXX degrees in the speed and altitude windows of the FMA (after flashing 5 times).

For increasing performance windshear, the roll window will retain the heading. WINDSHEAR will be displayed in the speed and altitude windows after flashing 5 times.

ATS, if disengaged, will engage automatically and advance to maximum available GA thrust. The FD, if off, will pop up automatically. Guidance continues until windshear no longer exists and reversion (safe) conditions exist as noted previously.

If windshear is detected after a GA has been initiated, the aural and visual annunciations will be activated and guidance will begin automatically.

### **GPWS and TCAS Inhibits**

The GPWS is inhibited during windshear guidance when FD commands are being followed within + or - 5 degrees. The TCAS is also inhibited during windshear guidance, except for traffic advisory (TA) annunciations on the ND.

### **Windshear System Modes**

The pitch limit indicator (PLI) is in view for all modes. Detection failures are annunciated on the EAD and CFDS.

STANDBY

- Detection - Inactive.
- Guidance - Disabled.
- Autothrottle - No action.
- Thrust limits - No action.

TAKEOFF ROLL - Speed more than 80 kts

- Detection - Active.
- Guidance - Disabled.
- Autothrottle - If TO derated, unclamp, go to max TO thrust and reclamp.
- Thrust limits - If TO derated, advance to max rated TO thrust.

ENROUTE - Radio altitude more than 1500 ft.

- Detection - Inactive.
- Guidance - Disabled if windshear encounter not in progress.
- Autothrottle - No action.
- Thrust limits - No action.

APPROACH - Radio altitude less than 1500 ft.

- Detection - Active to 50 ft. radio altitude.
- Guidance - Armed.
- Autothrottle - Speed bias for incr or decr perf windshear.
- Thrust limits - Advance to max GA thrust after windshear detection.

*NOTE: WAGS guidance activated by GA activation or thrust more than 95% GA thrust rating while a detection is present.*

GO-AROUND - TOGA activation

- Detection - Active.
- Guidance - Armed. Will engage upon windshear detection.
- Autothrottle - Advance to max GA thrust and clamp.
- Thrust limits - Advance to max GA thrust.

*NOTE: Change to enroute if RA more than 1500 ft.*

TOUCHDOWN - Landing gear touchdown

- Detection - Inactive below 50 ft. RA.
- Guidance - Disabled.
- Autothrottle - No action.
- Thrust limits - No action.

*NOTE: When speed below 80 kts, WAGS resets to standby.*

## **Windshear Annunciations and Autothrottle Operation**

TAKEOFF ROLL/TAKEOFF

Aural Warning



Incr Perf - Tone followed by “HEADWIND SHEAR” voice (3 times).

Decr Perf - Tone followed by “TAILWIND SHEAR” voice (3 times).

PFD Upper Left

- Incr Perf - Amber WINDSHEAR.
- Decr Perf - Red WINDSHEAR.

FMA - White WINDSHEAR in speed and altitude control windows.

Thrust limits - Set to max TO thrust setting.

Autothrottle - If derated TO, unclamp, go to max TO thrust and reclamp.

## APPROACH

Aural Warning

Incr Perf - Tone followed by “HEADWIND SHEAR” voice (3 times).

Decr Perf - Tone followed by “TAILWIND SHEAR” voice (3 times).

PFD Upper Left

- Incr Perf - Amber WINDSHEAR.
- Decr Perf - Red WINDSHEAR.

FMA - White WINDSHEAR in speed control window.

Thrust limits - Set to max GA thrust setting.

Autothrottle - Control to 1.3 VS+20 kts or pilot selected, whichever is greater. No change in pitch or roll modes. No pitch or roll WAGS guidance until G/A activation or thrust exceeds 95% G/A thrust rating while windshear is detected.

## GO-AROUND

Aural Warning

Incr Perf - Tone followed by “HEADWIND SHEAR” voice (3 times).

Decr Perf - Tone followed by “TAILWIND SHEAR” voice (3 times).

PFD Upper Left

- Incr Perf - Amber WINDSHEAR.
- Decr Perf - Red WINDSHEAR.

FMA - White WINDSHEAR in SPEED and ALTITUDE control windows.

Thrust limits - Set to max GA thrust setting.

Autothrottle - Advance to max GA thrust and clamp.

## **FMA Fault Annunciations**

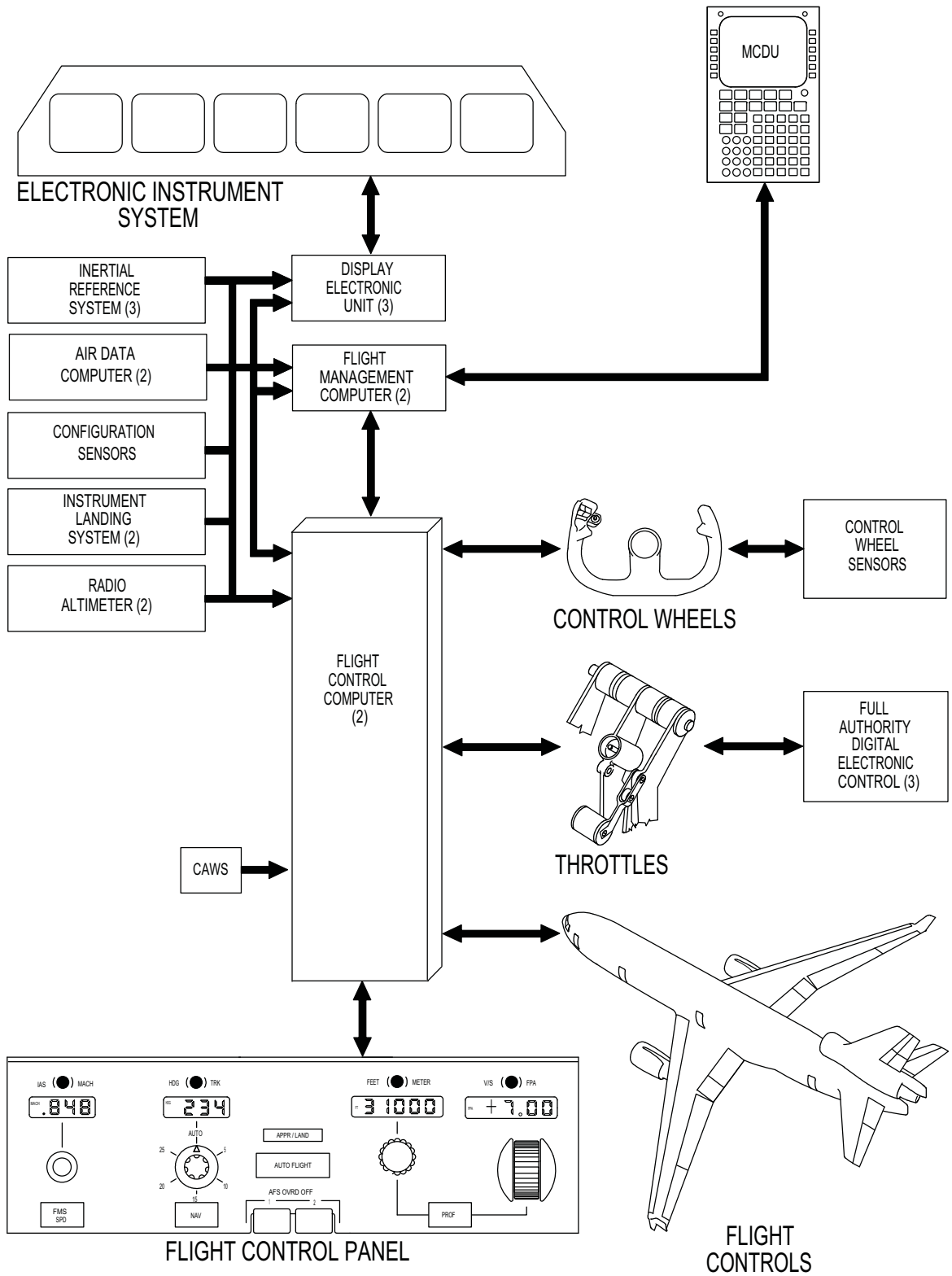
Autopilot or autothrottle faults are annunciated by a box around the affected modes. The box is labeled AP OFF for autopilot disconnects or ATS OFF for autothrottle disconnects. This box is red and flashes until canceled by pushing the autopilot or autothrottle disconnect switch.

When the autopilot or autothrottle is not engaged, the box and label are white if available and amber if not available. For normal autopilot operation, AP1 is shown when FCC1 autopilot is in control, AP2 when FCC2 autopilot is in control, or AP when both autopilots are engaged for DUAL LAND operations.

Autothrottle Speed Protection (ASP) is annunciated by a box around the affected modes labeled ATS OFF. This annunciation is white and flashes. In addition, HI SPEED or LO SPEED will flash alternately with PROTECTION as appropriate. The flashing continues until one of the following:

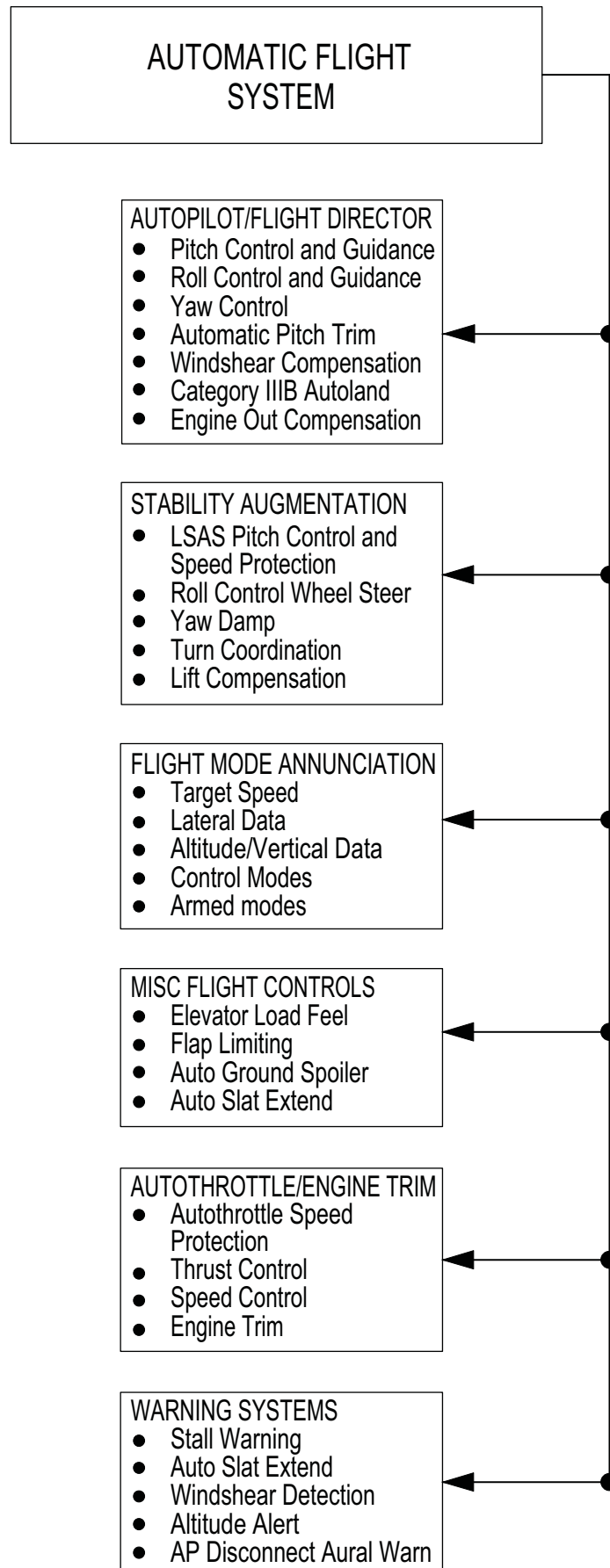
- Selecting a FCP speed within ATS control envelope.
- Disconnecting and/or re-engaging autothrottle within the normal speed envelope.
- Selecting level change, V/S, FMS SPD or FMS PROF within the normal speed envelope.

# Major Components



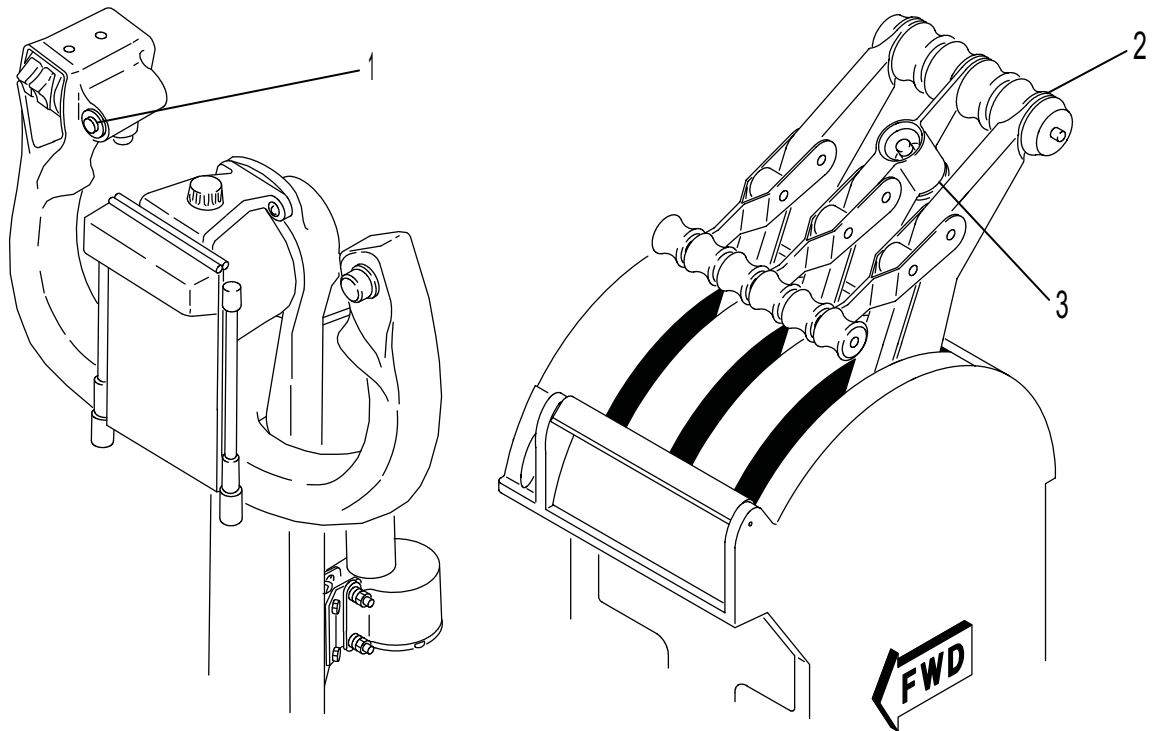
DB1-2-442D

# Automatic Flight System Functions Chart



DB1-2-1829

## AP, ATS Disconnect and GA Switches



LB1-3-0036

### 1. AP Disconnect Switches (2)

Pushing either disconnect switch disconnects the autopilot system. This activates the AP disengage warning system, causing an AP OFF light on the PFD to begin flashing red. RCWS, if installed, is disabled while pushing this switch.

If at any time the AP OFF legend light is flashing red, pushing either of the AP disconnect switches will cause the flashing to stop and the AP OFF display to change color to white or amber if the disconnect was a result of a detected failure and no autopilot is available.

### 2. ATS Disconnect Switches (2)

Pushing either ATS disconnect switch disconnects the autothrottle system. If at any time the ATS disengage warning system is activated, an ATS OFF light on the PFD will begin flashing red. By pushing either ATS disconnect switch, the flashing will stop and the ATS OFF display changes color to white if re-engagement is possible or amber if a condition is present which prevents further use of the system.

### 3. GA Switch

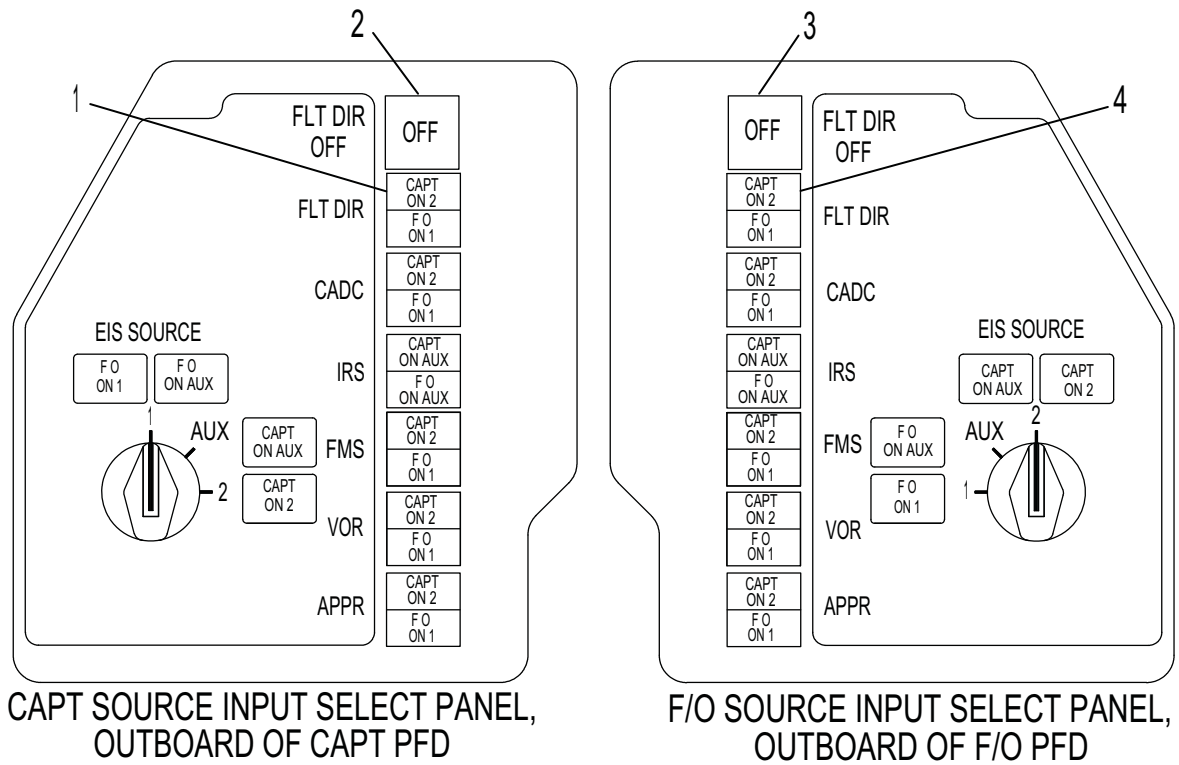
Pushing during approach conditions (RA less than 2500 ft. and flaps or slats down) causes:

- FDs pop up to go-around mode even if selected off.
- If AP on, AP will follow FD commands.
- ATS goes to go-around limits.
- Parallel rudder active (in case of engine failure).
- Bank angle limited to 10 degrees.
- Reference speed and PITCH appear on FMA.
- GO-AROUND appears in altitude window.
- Exits LAND mode (if engaged or armed), localizer capture mode or glideslope capture mode.
- Windshear pitch guidance provided if windshear warning active. WINDSHEAR will appear in FMA speed and altitude windows.

***CAUTION: If the FMS does not recognize a GA switch push, climb thrust will be annunciated on the EAD. The ATS will drive to GA thrust, causing an ATS disconnect. Pushing the GA button again should display GA thrust and allow ATS re-engagement.***

***NOTE: If the flap displays on the PFD and the CONFIGURATION page show Xs, FD go-around will not be available due to flap synchro failure.***

# Flight Director Switches



LB1-3-0037

## 1. Captain's FLT DIR Switch - amber

Pushing the switch allows the Captain to direct the FD 2 commands to PFD 1. CAPT ON 2 will illuminate amber. Both PFDs will show FD2 in the upper left corner near the attitude sphere. Pushing the switch again restores normal on-side FD operation.

## 2. Captain's FLT DIR OFF Switch - amber

With the FD on (OFF not illuminated), pushing the switch selects the Captain's FD to OFF. OFF then illuminates amber and the command bars are removed from the PFD. Pushing the switch when OFF is illuminated engages the FD and extinguishes the light.

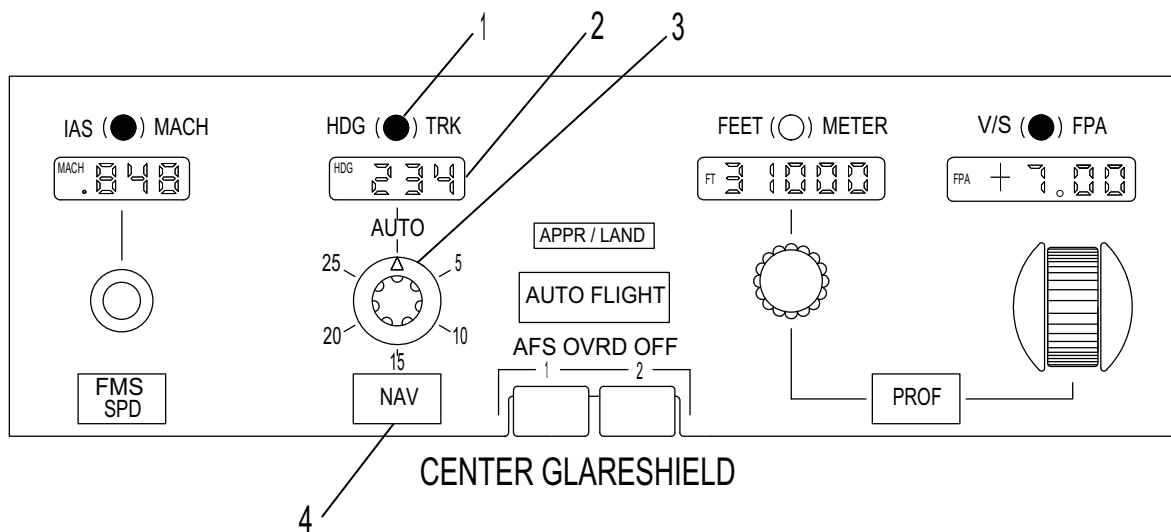
## 3. First Officer's FLT DIR OFF Switch - amber

With the FD on (OFF not illuminated), pushing the switch selects the First Officer's FD to OFF. OFF then illuminates amber and the command bars are removed from the PFD. Pushing the switch when OFF is illuminated engages the FD and extinguishes the light.

## 4. First Officer's FLT DIR Switch - amber

Pushing the switch allows the First Officer to direct the FD 1 commands to PFD 2. F/O ON 1 will illuminate amber. Both PFDs will show FD1 in the upper left corner near the attitude sphere. Pushing the switch again restores normal on-side FD operation.

## Heading/ Track Controls and Display



LB1-3-0038

### 1. HDG/TRK Changeover Button

Pushing permits alternate selection of either heading (HDG) or track (TRK) to be displayed in the HDG/TRK display window and on the ND. Operation of this button before HDG/TRK HOLD does not affect the window target number. Operation of the button in the HDG/TRK mode compensates the window target to account for any difference in the magnetic heading and track angle but does not change existing control mode or AP/FD reference until the HDG/TRK selector is pushed or pulled.

### 2. HDG/TRK Display Window

Shows selected HDG or TRK. Window is blank when the AFS is controlling to the FMS flight plan. At initial powerup the window shows 000 as a preselected value if a valid magnetic heading is not available. If a valid magnetic heading is available at powerup, this is displayed. For powerup while airborne, the current heading is shown as the preselected value.

### 3. HDG/TRK and Bank Angle Limit Selectors

HDG/TRK Selector (Inner Knob) - Turn to preselect:

- Rapid rotation causes large changes.
- Resolution for slow knob rotation is one degree per detent.

Pull to select:

- Disengages the NAV mode (if engaged).



- Selects the preselected heading/track and cancels the previous lateral mode. The aircraft follows and captures any selected HDG/TRK while in this mode.
- The display window displays the selected HDG/TRK.
- Once the target HDG/TRK is captured, the system will automatically transition to HDG/TRK HOLD mode and the selector must be rotated, then pulled to select a new heading. During the capture phase, the selected heading/track is changed when the selector is rotated.

Push to hold:

- Disengages the NAV mode (if engaged).
- Causes the aircraft to maintain the present HDG/TRK or, if the aircraft was turning, the heading during the turn plus or minus a small predicted increment to ensure a smooth rollout with no overshoot.
- Cancels VOR, LOC, NAV, and LAND ARMED modes.
- The window displays the capture HDG/TRK.
- Turning the knob in this mode preselects a new HDG/TRK. This requires selection by pulling the knob.

Bank Angle Limit Selector (Outer Knob) -

Allows selection of maximum bank angle in 5-degree increments (5 to 25 degrees). In the AUTO position bank angle limits vary with speed (bank limits decrease as speed increases). This selector cannot override FMS-computed bank angle limits. Bank angle limits are displayed on the top of the PFD attitude sphere.

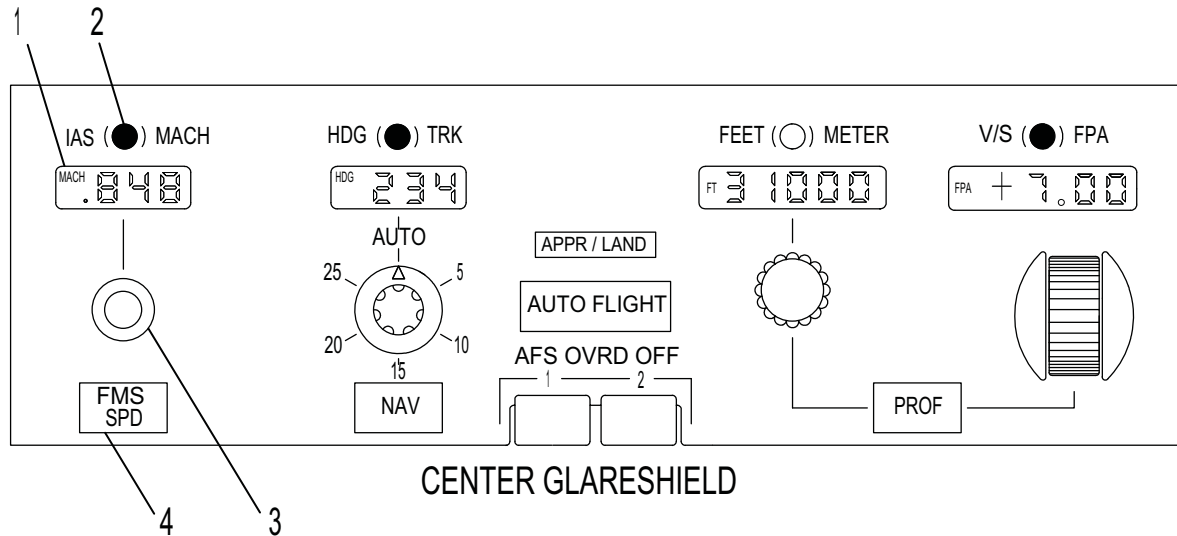
#### **4. NAV Switch**

Push to arm the FMS NAV capture mode or resume FMS lateral control if the capture criteria are satisfied.

The NAV armed mode can be cancelled by pushing HDG/TRK hold, selecting APPR/LAND arm, capturing the ILS localizer, or by capturing FMS NAV.

After NAV capture, commands are supplied from the FMS. NAV arming is available on the ground once engines are started. NAV guidance is active at 100 feet AGL in FD mode. AP NAV guidance is not available until 400 feet AGL.

## Speed Controls and Display



LB1-3-0039

### 1. IAS/MACH Display Window

The preselected or selected IAS or MACH number is displayed in this window. The range is from 100 to 499 KIAS and M 0.500 to M 0.900. The left end of the display shows IAS or MACH depending on which function is selected. The window shows dashes when the AFS is controlling to the FMS flight plan speed.

### 2. IAS/MACH Changeover Button

Pushing the button permits alternate selection of IAS or MACH to be displayed in the window.

### 3. IAS/MACH Select Knob

Turn to preselect:

- Rapid rotation causes large changes and slow rotation causes slow changes in IAS/MACH display window.
- Each detent is equal to 1 knot or 0.001 Mach.

If the IAS is displayed, pushing the IAS/MACH changeover button allows display and preselection of the desired cruise Mach. The preselected IAS is retained and displayed when the changeover button is pushed again. At the altitude where the selected IAS corresponds to the preselected Mach, the display and the selected speed reference will automatically change to the Mach mode. The inverse operation (IAS preselection) is available for descent. Changeover to the equivalent Mach or airspeed value occurs automatically at 26,000 feet if no Mach has been preselected.

Pull to select:

- Disengages the FMS speed mode (if engaged).
- The preselected target speed becomes the selected speed.
- The window displays the selected speed.
- The aircraft will follow and capture any selected speed value while in this mode with a pitch or thrust change as appropriate.
- Once the selected speed is captured, the system will automatically revert to the speed hold mode and the IAS/MACH select knob must be rotated, then pulled, to select a new speed. During the capture phase, the selected speed is changed if the knob is rotated.

Push to hold:

- Disengages FMS speed mode (if engaged).
- The aircraft will maintain the present speed plus or minus any small increment if required for a smooth capture.
- The window displays the capture speed.
- Turning the knob in this mode preselects a new speed. The knob must be pulled to select the preselected speed.

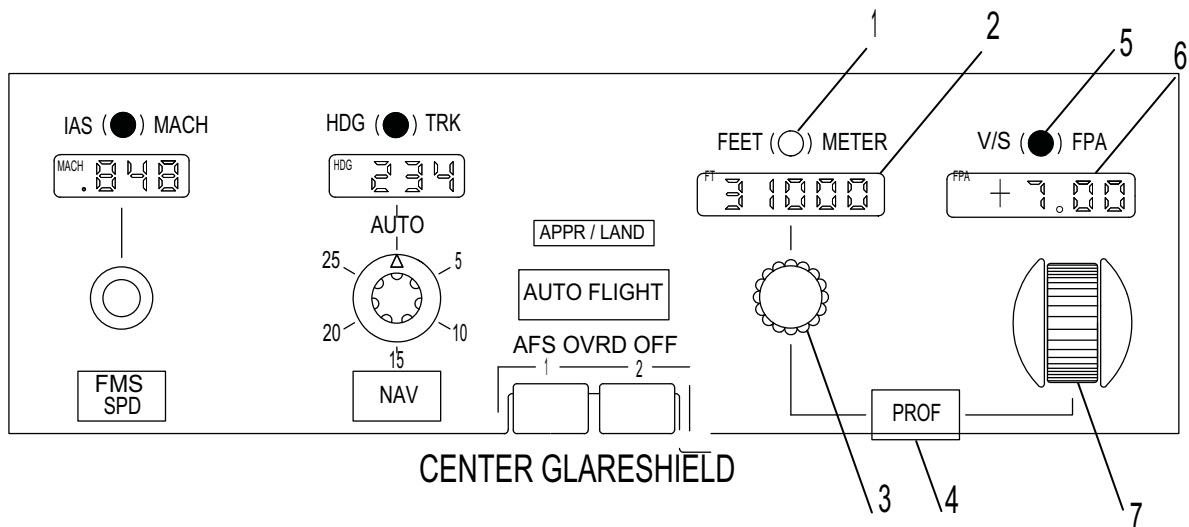
#### **4. FMS SPD Switch**

Pushing selects the armed FMS speed, typically an ECON speed, and cancels any selected or preselected speed or Mach number. The IAS/MACH display window shows IAS -- or MACH -- and the FMA speed target and speed control legend changes from white to magenta. Pushing the FMS SPD switch within 10 seconds after preselecting an FCP speed results in editing the FMS-computed speed. The window shows IAS -- (or MACH --) and the PFD FMA speed is the edited FMS speed reference in white (magenta if equal to ECON speed).

The FMS SPD mode is disengaged by pushing or pulling the IAS/MACH select knob or by engaging go-around modes.

On takeoff, pushing the PROF switch above 400 feet AGL engages PROF and FMS SPD.

# Altitude Controls and Display



LB1-3-0040

## 1. FEET/METER Changeover Button

The altitude tape on the right side of the PFD is always in feet. Pushing this button allows the pilot to select feet or meters on the FCP, FMA, and lower right corner of the PFD. When meters are selected the values are preceded by an M. When feet are selected the values are preceded by an FT.

## 2. Altitude Display Window

Displays the selected or preselected altitude for altitude alerting and AP/FD altitude control (except during G/S mode). Range is from 0 to 50,000 feet. Display at initial powerup is 10,000 feet. Window is blank if both air data computer references fail.

## 3. Altitude Select Knob

Precision altitude selection increments (one detent) for slow knob rotation are:

- 500 feet above 10,000 feet.
- 100 feet below 10,000 feet.
- If BARO is selected on the ECP, a one-foot precision selection capability permits FCP selection of MDA value.
- 50 meters if METER is selected.

Turn to preselect:

- Sets the altitude reference.

- Window displays the preselected altitude reference.
- Sets FMS clearance ceiling (climb) or floor (descent) when PROF is engaged.

Pull to select:

- Disengages PROF (if engaged) and engages flight level change.
- Disengages vertical speed/FPA or altitude hold modes.
- Flight level change mode sets the ATS to climb thrust or descent idle clamp and AP/FD pitch control to speed. The aircraft climbs or descends directly to selected altitude.
- The aircraft will capture and hold any new altitude selected while in this mode.
- The FCP altitude target becomes the displayed reference on the FMA.

Push to hold:

- Engages altitude capture/hold.
- Disengages PROF (if engaged).
- Disengages VERT SPEED/FPA mode (if engaged).
- Altitude target becomes the current altitude plus or minus a small value required to give a smooth transition to level flight. This target value is displayed in the FCP window, FMA, and on the PFD.

#### 4. PROF Switch

Push to engage the FMS vertical profile guidance if not previously engaged. After PROF engage, commands are supplied from the FMS (based on inserted flight plan). On takeoff, PROF will not engage until 400 feet AGL. On landing PROF can stay engaged until 50 feet. In takeoff mode, this switch will also engage FMS speeds.

***CAUTION: Do not engage PROF for 5 seconds after a new AFS altitude is selected via the GCP (not applicable to FCC-903 and subsequent FCC's).***

#### 5. V/S-FPA Changeover Button

Pushing permits alternate display and control of either vertical speed in fpm or FPA in tenths of degrees. When the V/S-FPA is not engaged, alternate function is not selected until the pitch thumbwheel is rotated. After V/S or FPA is engaged, the displayed value is always the selected value.

## 6. V/S-FPA Display Window

Displays vertical speed or FPA. Display is blank if V/S or FPA are not engaged. When FPA is selected, the value is in degrees and tenths. When V/S is selected, the value is in fpm.

## 7. Pitch Wheel

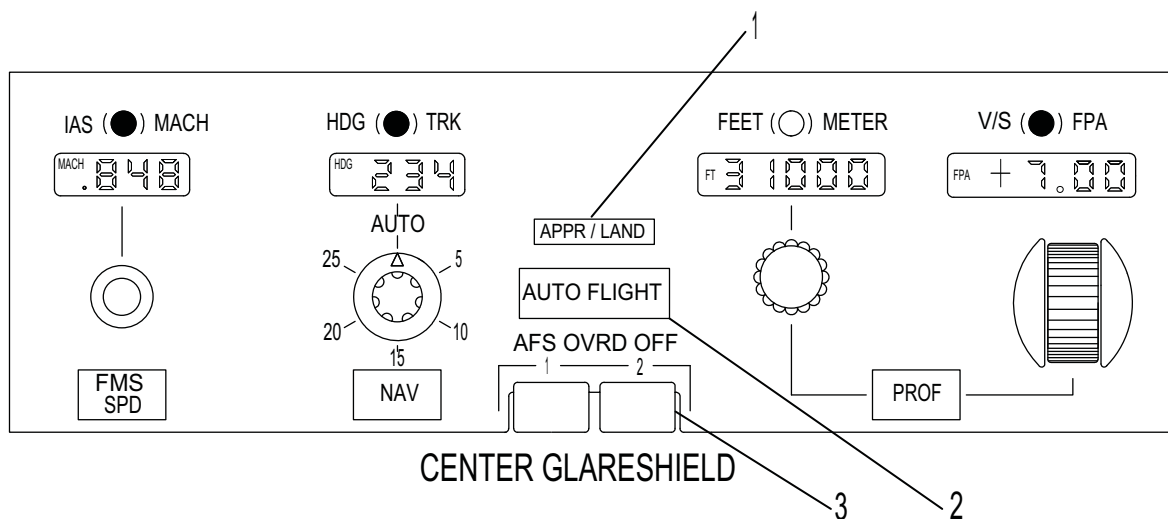
Rapid rotation results in large changes in the display window. Slow rotation results in 100 fpm (or 0.1 degree) changes per detent. A vertical speed bug is positioned on the PFD vertical speed tape corresponding to the selected vertical speed.

Roll to select:

- Disengages PROF, speed on pitch, altitude hold, and glideslope modes if LAND is not annunciated.
- Display window and target initializes to plus or minus 100 fpm (or 0.10 degree FPA) if engaged in altitude hold. Otherwise, initialization is to current vertical speed/FPA. Subsequent wheel changes result in changes in vertical speed/FPA selection.
- Pushing PROF resumes FMS profile operation at the selected vertical speed as an FMS edit.

When the pitch wheel is moved, the AP will cancel the altitude capture mode (if engaged) and will not re-engage in altitude capture until the pitch wheel has come to rest for 2 seconds. The selected altitude will not be captured if the pitch wheel is repeatedly adjusted. In this case, the AP will toggle between vertical speed mode and altitude capture.

# APPR/LAND, AUTO FLIGHT, AFS OVRD OFF Switches



LB1-3-0041

## 1. APPR/LAND Switch

Push to arm the APPR and LAND modes. LAND ARMED appears in the FMA roll control window. A tuned ILS is required to arm APPR/LAND.

## 2. AUTO FLIGHT Switch

Push to engage both ATs and one AP in the FD mode that has been selected. If no FD mode has been selected, the AP engages in HDG/TRK HOLD and either altitude hold (if aircraft about level) or vertical speed hold (if aircraft climbing/descending).

After AP engagement, each push alternates the AP between AP1 and AP2. AP mode is always retained. AP1 or AP2 will appear on the FMA (top of PFD).

On ground, pushing engages autothrottles only. Below 100 feet the AP will not engage. If the AP is engaged above 100 feet, it will remain engaged after passing below 100 feet only in LAND or GA modes.

Operating hydraulic systems required for AP and auto pitch trim are as follows:

- AP1 requires HYD system 2 for flight controls and HYD system 3 for auto pitch trim.

- AP2 requires HYD system 1 for flight controls and auto pitch trim.

### **3. AFS OVRD OFF Switches (2)**

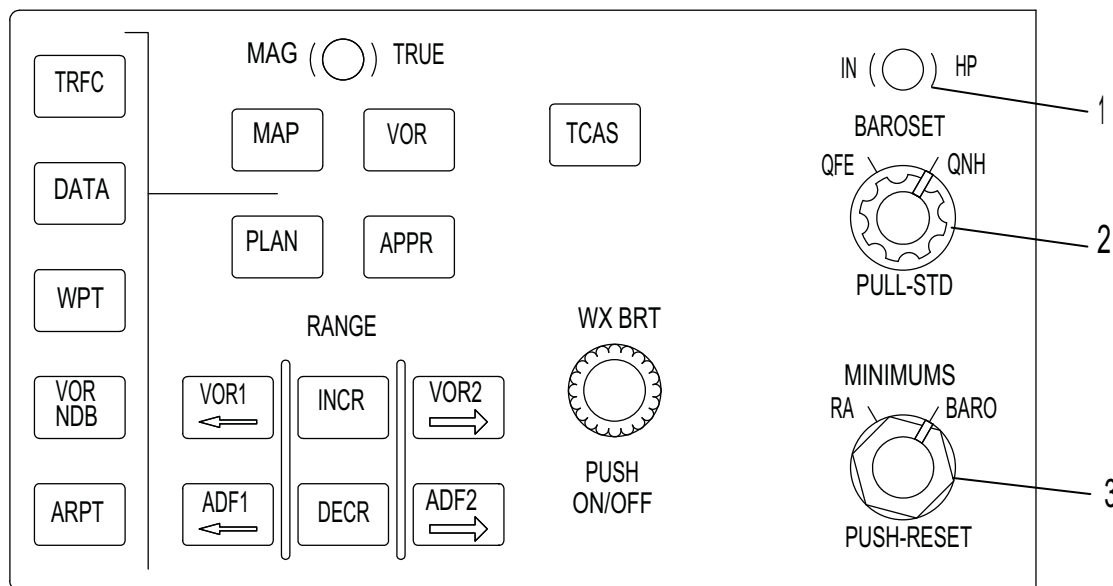
Push down for emergency disconnect of respective autopilot and autothrottle. In OFF, an amber and gray bar comes into view. Additional FCC functions are affected as follows:

Functions stay on: Altitude alerting, auto ground spoilers, auto pitch trim - LSAS, auto slat extend, elevator load feel, engine trim, flap limiting, FD, LSAS, speed protection - LSAS, stall warning, yaw damp/turn coordination, and windshear guidance.

Functions go off: AP auto pitch trim, Roll control wheel steering, and speed protection - AP & ATS.



## EIS Control Panel



GLARESHIELD, LEFT AND RIGHT SIDE

LB1-3-0042

### 1. IN/HP Changeover Button

BAROSET values may be in either inches mercury or hectopascals. Pushing this button causes the units to toggle from inches mercury to hectopascals or vice versa.

### 2. BAROSET Control Knob

The BAROSET value is adjusted by turning the inner collar. The outer collar allows the selection of either QFE (altitude above station) or QNH (altitude above sea level). Pulling this knob selects the standard BAROSET QNE (29.92 or 1013.2 Hp). BAROSET, QFE and QNH values are displayed on the PFD below the altitude scale. QFE operation is optional and may not be enabled.

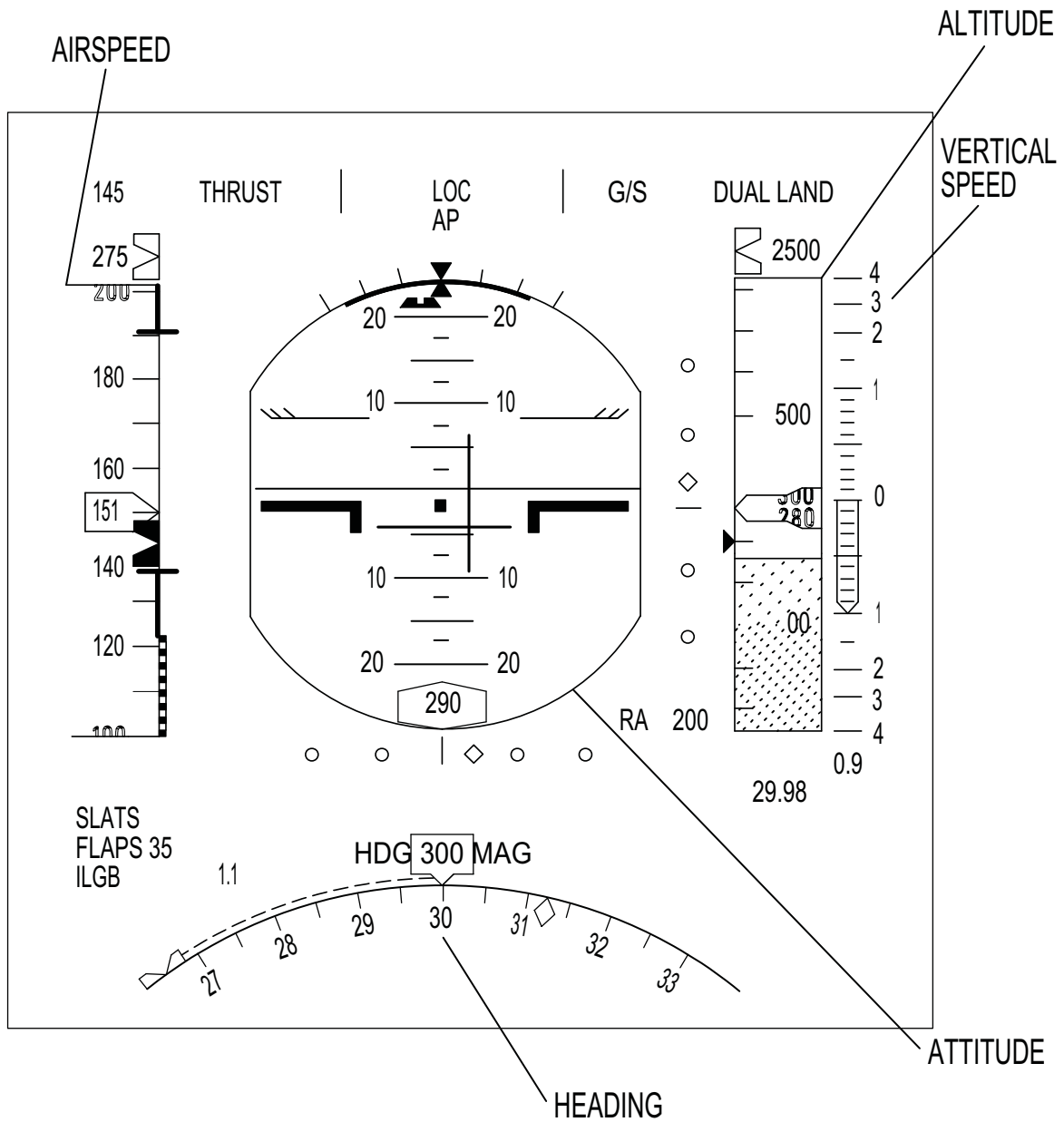
### 3. MINIMUMS Control Knob

The RA minimums bug is a solid triangle on the left side of the PFD altitude tape. To set the RA bug, turn the inner collar with the knob in RA.

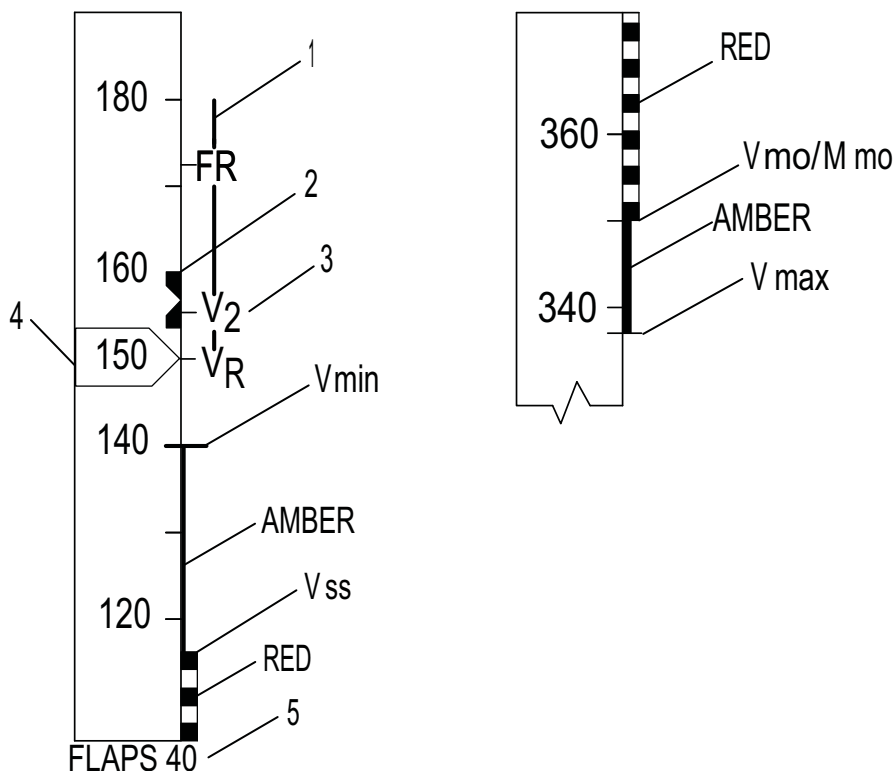
The baro minimums bug is a solid triangle on the right side of the PFD altitude tape. To set the baro bug, turn the inner collar with the knob in BARO. BARO position during initial climb can cause nuisance aural warnings.

Pushing the knob resets the PFD DH alert and silences the aural warning.

# EIS Primary Flight Display (Typical)



## PFD Airspeed Display



### 1. Airspeed Trend

Displayed as a green column. The end of the column is the airspeed to be achieved in 10 seconds.

### 2. Airspeed Bug

- White solid (bowtie or triangle) - Pilot selected AS/Mach.
- White outline (bowtie or triangle) - Pilot preselected AS/Mach.
- Solid magenta circle - FMS commanded AS/Mach.
- Outlined magenta circle - FMS speed exists but is not selected.

If selected speed is set lower than V<sub>min</sub>, the white bug stops at V<sub>min</sub> and an amber reference bug will be at the selected speed.

If selected speed is set lower than V<sub>ss</sub>, a red reference bug will be at the selected speed.

If selected speed is set higher than V<sub>mo</sub>/M<sub>mo</sub>, the white bug stops at V<sub>mo</sub>/M<sub>mo</sub> and a red reference bug will be at the selected speed.

Speed/Mach bugs can park off scale above or below the tape. A digital value will be displayed next to the bug.

Mach is displayed to the right of the airspeed when above 0.47 Mach. When Mach goes below 0.45 it is removed.

If airspeed is no-computed data (less than 53 knots and A/C on ground), the IRS ground speed and TAXI will be shown. This groundspeed display is replaced with an amber NO TAXI if any IRS is in align mode.

### 3. Speed Bugs

V1, VR, V2, FR, SR, GR, SE, FE, and GE bugs are on outside of the tape. If Vspeeds have not been computed or entered (aircraft on ground), V1, VR, and V2 are attached to dashed boxes.

FR Bug (Flap Retract, source: FMC) - The FR bug is normally green and appears only when flaps are extended. The FR bug will be removed when flaps are retracted. The FR bug turns amber if:

- Current airspeed is below FR speed or,
- Flaps are extended at FR speed + 10 knots or
- Flap display below speed tape is amber for any reason.

SR Bug (Slat Retract, source: FMC) - The SR bug is normally green and appears only when slats are extended. The SR bug will be removed when slats are retracted. The SR bug turns amber if:

- Current airspeed is below SR speed or,
- Slats are extended at SR speed + 10 knots or,
- Slat display below speed tape is amber for any reason.

GR Bug (Gear Retract, source: EIS) - The GR bug appears only when landing gear is down. The GR bug is green when the current airspeed is below the gear extend limits. The GR bug turns amber if gear is extended above 230 knots or Mach 0.7.

SE Bug (Slats Extend, source: EIS) - The SE bug is normally green and appears only when slats are retracted and speed is more than 220 knots with Mach displayed (or more than 225 knots with Mach not displayed). The SE bug turns amber when speed is more than 280 knots (Mach 0.55).

FE Bug (Flaps Extend, source: EIS) - The FE bugs (-F15, -F28, -F35, -F50) are normally green and appear only when speed is less than 255 knots and altitude is less than 18,000 feet. The bugs also appear if slats or flaps are extended and more than 60 seconds have elapsed since TAKEOFF mode was exited. The FE bugs turn amber as follows:

- The F15 bug turns amber when speed is more than 255 knots.
- The F28 bug turns amber when speed is more than 210 knots.
- The F35 bug turns amber when speed is more than 190 knots.
- The F50 bug turns amber when speed is more than 175 knots.

GE Bug (Gear Extend, source: EIS) - The GE bug is always displayed. If gear is retracted, then GE is 260 knots (0.7 Mach). If gear is extended, GE is 300 knots (0.7 Mach). GE turns amber when airspeed is above gear extend speed.

#### **4. Airspeed**

Shown at the center of tape.

- Box and digits red - A/S below  $V_s$  or exceeds  $V_{mo}/M_{mo}$ .
- Box and digits amber - A/S below  $V_{min}$  or exceeds  $V_{max}$ .

$V_{ss}$  (from FMC) is the end of a red checker column.

$V_{min}$  (from FMC) is a line at the end of an amber column extending from  $V_{ss}$ .

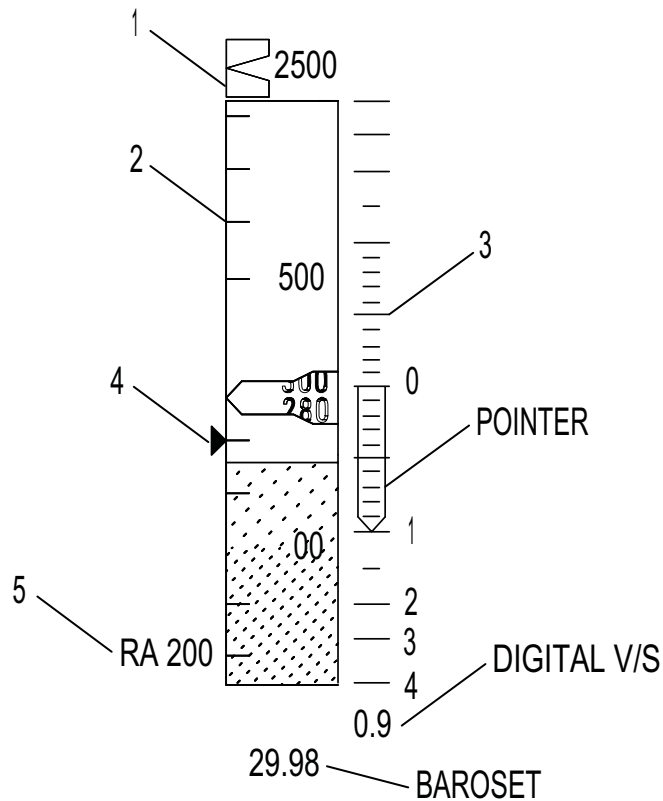
$V_{mo}/M_{mo}$  (from ADC) is a line at the end of a red checker column extending from the high end of the tape.

$V_{max}$  is a line at the end of a narrow amber column extending down from  $V_{mo}/M_{mo}$ .

#### **5. Flap/Slat**

Invalid flap positions are flagged with an amber X. Slat messages turn amber and are boxed when they are in disagreement with extended flaps.

## PFD Altitude/ Vertical Speed Display



LB1-3-0045

### 1. Altitude Bug

- White outline (bowtie or triangle) - Pilot preselected altitude.
- White solid (bowtie or triangle) - Pilot selected altitude.
- Magenta circle - FMS constraint altitude. Circle is filled when FMS engaged. It is outlined if the crew has intervened in an FMS profile, FMS altitude is beyond FCP set altitude, or the altitude has been preselected and the FMS is engaged.

Selected altitude bug may be parked off each end of altitude scale with digital display next to it.

The pilot selected altitude bug can be used as an MDA bug by dialing it down to the baro DH minimums with the FCP altitude select knob. The bug then meshes with and removes the baro DH triangle on the right. The bug is white above minimums and amber below minimums.

### 2. Altitude Tape

Tick marks are 100-foot increments. White shading is for QNH display. Green shading is for QFE display. Feet are white and meters are cyan (if selected). Altitude tape turns amber and flashes to correspond with CAWS altitude advisory alert.

Baro set is below the scale in white. It can be inches of mercury or hectopascals selectable with the IN/HP changeover button on the ECP.

QFE operation is selected from the ECP. In this case the tape turns green, baroset below the tape change to QFE value, QFE is displayed, and a QNH box appears below the baroset. This box has the QNH baroset value and QNH altitude in feet (or meters if selected).

If meters is selected from the FCP, scale and altitude stay in feet. Metric altitude is in cyan above the feet and is labeled M. If in QFE, the QNH metric is above the QNH altitude.

### **3. Vertical Speed**

Current vertical speed (V/S) is shown by a wide outline pointer. Range is +/- 4,000 fpm, with tick marks every 100 feet below 1,000 feet. Pointer appears when V/S is more than 100 fpm and remains until below 50 fpm.

If V/S is more than 100 fpm, current V/S is shown digitally above scale for positive V/S, or below scale for negative V/S. Digital readout limits are 9,900 fpm.

When the aircraft is in V/S mode, the selected V/S is shown by a filled white bug on the scale. When the selected V/S is achieved, the pointer fits in the bug.

### **4. Minimum Bug**

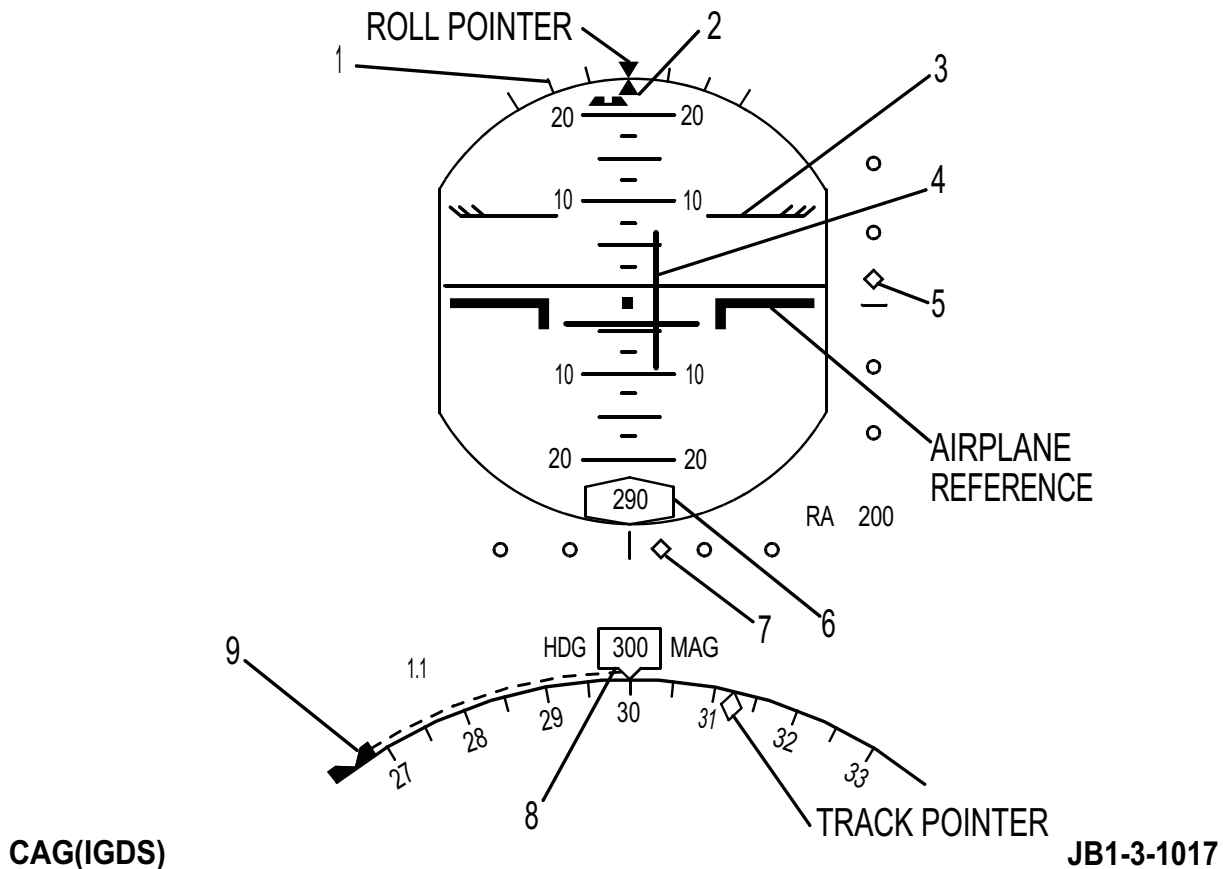
Solid triangle on the left is RA minimum bug. RA is set with the ECP MINIMUMS control knob in the RA position. This bug is white color (above minimum) or amber (below minimum).

A solid triangle on the right side is a BARO DH minimum bug. BARO DH is set with the ECP MINIMUMS control knob in the BARO position. This bug is white above minimums and amber below minimums.

### **5. Selected Minimum**

Value is amber, boxed and flashes for 5 seconds when minimum altitude is reached. It stays amber after flashing. This condition can be reset by pushing the ECP MINIMUMS control knob.

## PFD Attitude Display (Typical)



### 1. Roll Indice

A white triangle at the top shows 0 degrees roll, short ticks show 10 and 20 degrees, long ticks show 30 and 60 degrees, and a triangle shows 45 degrees roll. A white roll pointer (triangle) turns red if the roll angle will produce a stall. 45-degree and 60-degree ticks are not shown for roll angles 30 degrees or less.

Bank angle limits are ticks at the end of an arc. In NAV mode, limits are from the FMS. If not in NAV, limits are the least of either FCP set (pilot) or FMS stall protection limits. The white arc will turn red if the aircraft will stall with a roll greater or equal to bank angle limit of 5 degrees.

### 2. Slip/Skid Indicator

A trapezoid moves parallel to the horizon line in the direction of rudder required. It will turn amber when it becomes separated from the roll pointer.

### 3. Pitch Limit Indicator - cyan

Pitch Limit Indicator (PLI) is two cyan lines with feathers. The difference between the line and the aircraft reference is Angle-of-attack (AOA) remaining to stickshaker. The feathers are AOA remaining to stall. Just before stickshaker this display turns amber. At stickshaker it turns red. When slats are retracted the PLI cannot turn amber.



#### **4. Flight Director - magenta**

The Flight Director (FD) can be turned off and on with switches outboard of the PFD. The FD comes on automatically for go-around or windshear. Default condition is FDs on. During a TCAS RA, the FD can be removed by pushing the AP disconnect switch once. The FD automatically reappears when clear of traffic conflict.

FCP selected flight path angle is green line with a gap. Two short vertical lines are selected TRK targets. This symbology provides no guidance command.

Flight path vector is a small green circle with wings and tail at the current direction of flight. The vector wings are always level. The flight path vector is shown whenever Flight Path Angle (FPA) is selected from the FCP.

#### **5. Glideslope Pointer and Scale**

Glideslope deviation scale is in view after the ILS is tuned. The magenta glideslope pointer is in view when valid glideslope data is received to indicate glideslope position relative to the airplane. Pointer changes to amber and flashes if the glideslope deviation exceeds 1 dot between 500 and 100 feet RA while G/S displayed in FMA vertical mode window.

#### **6. Radio Altitude**

Displayed below 2,500 feet AGL. Box and digits are normally white but turn amber for altitudes below the minimum altitude set on the ECP.

- At about 430 feet AGL, the RA box starts to move up so that the top of the box reaches the center of the attitude indicator at 0 feet RA for split-cue FD or bottom of airplane symbol for the single-cue FD.
- An optional magenta T rising runway symbol for both single and double-cue FDs begins rising at 200 feet AGL and moves laterally with the localizer. The symbol will flash for excessive localizer deviations (.27 dots). An E symbol on top of the RA box provides localizer deviation alignment.

#### **7. Localizer Pointer and Scale**

Localizer deviation scale is in view after the ILS is tuned. The magenta localizer pointer is in view when valid localizer data is received to indicate localizer position relative to the airplane. Pointer changes to amber and flashes if the localizer deviation exceeds 1/4 dot between 300 and 0 feet RA while LOC or ALIGN displayed in FMA roll mode window.

## **8. Heading**

Heading is MAG (dim white) but changes to TRU (cyan) at latitudes greater than 73 degrees N or 60 degrees S.

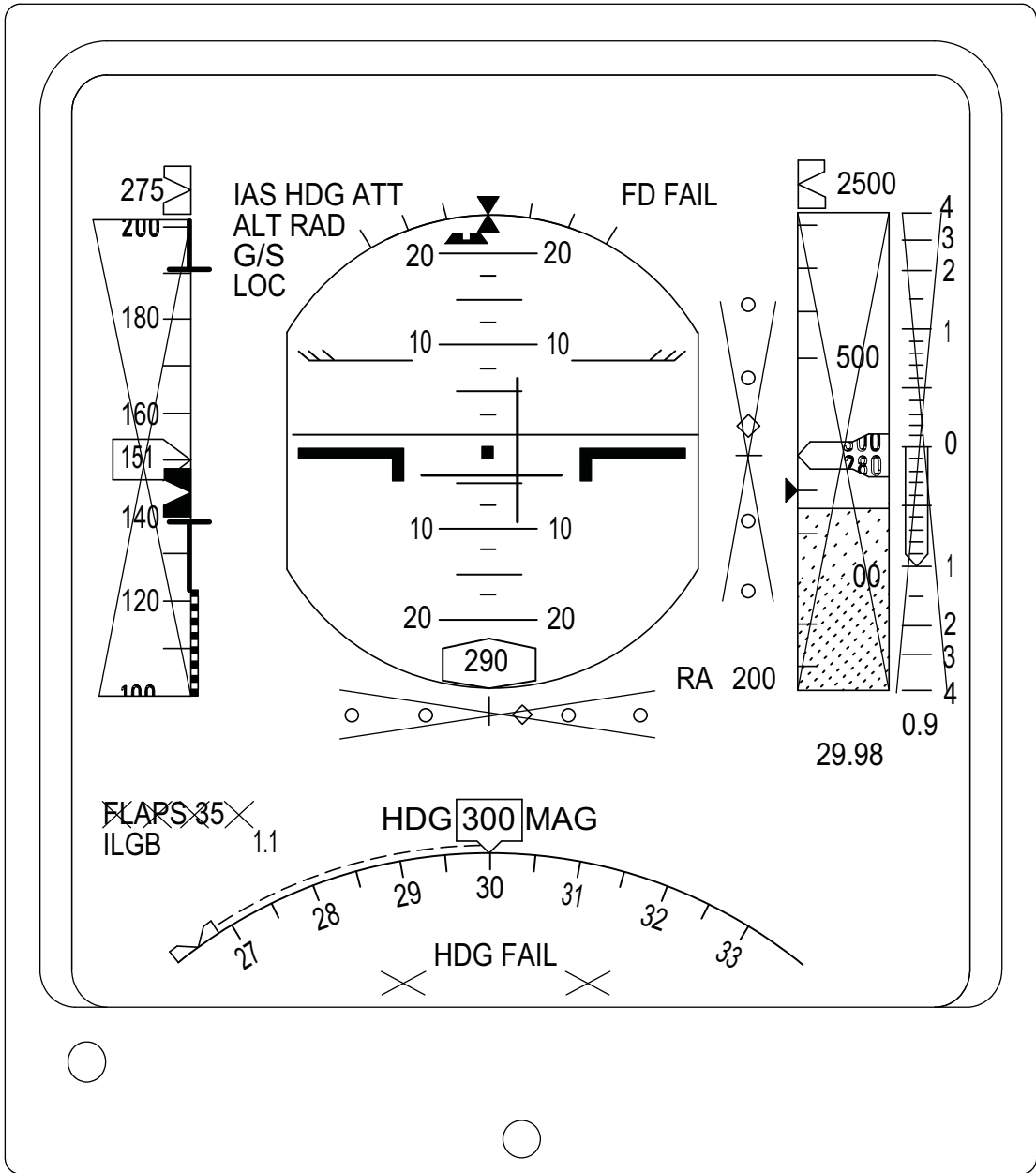
## **9. Heading Bug**

Bug is outline when preselected and filled when selected. If the HDG is off scale, the bug is parked and the HDG is shown digitally at the edge of the screen.

When the aircraft is on emergency power, frequency, bearing, and radial of VOR1 is shown below the HDG scale on the Captain's PFD (DEU1 data only).

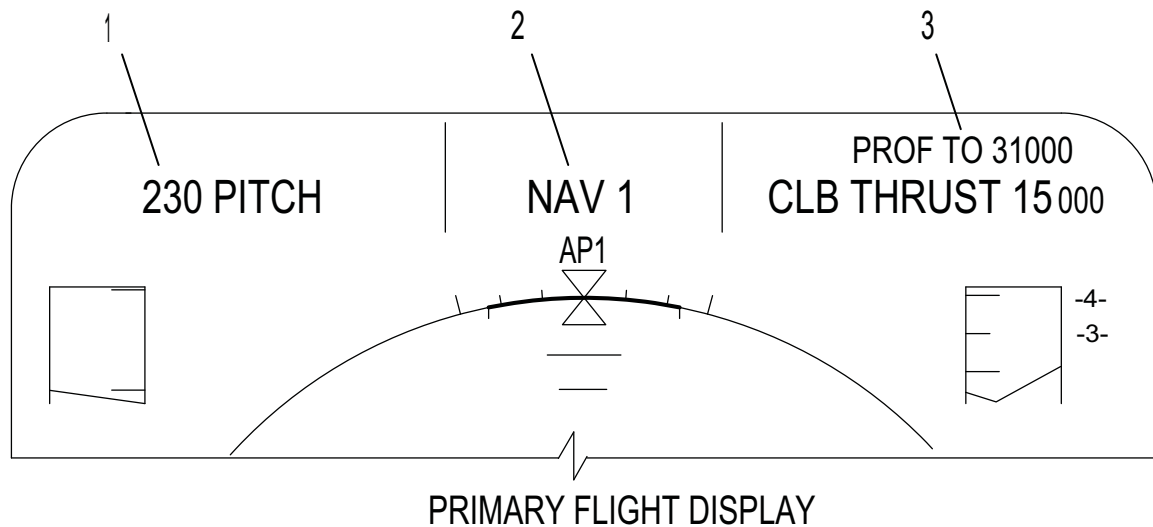
The drift angle (track) pointer is a green diamond.

# PFD Test Display (Typical)



LB1-3-0047

## Flight Mode Annunciator



### 1. Speed Control Window

Shows FCP or FMS speed and mode of control. Digits are magenta if equal to the FMS target speed (white otherwise). The mode is in magenta when the FMS speed is engaged and the airplane is controlling to an FMS or pilot selected speed. The mode is white when an AFS speed mode is engaged and controlling to a pilot selected speed (or an AFS speed reference). When mode shows THRUST and ATS is not engaged, but available, the window is surrounded by a white ATS OFF box. If ATS is not available in THRUST mode, the window is surrounded by an amber ATS OFF box.

If a speed has been commanded that cannot be maintained due to selection of a vertical speed or flight path angle, the speed and mode will flash alternately. This flashing continues until an acceleration in the direction of the speed target is achieved. If the mode changes due to an auto reversion, the new mode flashes 5 times.

If the aircraft is in a speed protection envelope, HI SPEED or LO SPEED will be displayed alternating with PROTECTION above the speed mode.

Windshear warnings are displayed by a flashing white WINDSHEAR (5) followed by a steady white WINDSHEAR.

## **2. Roll Control Window**

Shows what mode is controlling the aircraft roll axis. A digital value is displayed when in HDG or TRK mode. Engaged autopilot (AP1 or AP2) is shown.

Modes are white for pilot-selected AFS, magenta for FMS and green for DUAL LAND.

If the mode changes due to an auto reversion, the new mode flashes 5 times.

Armed modes are in small characters above the engaged mode.

## **3. Altitude Window**

Shows FCP or FMC target altitude and vertical profile mode. Digits are magenta if equal to FMS target (white otherwise). Mode is white for manual, magenta for FMS, and green for DUAL LAND.

If the mode changes due to an auto reversion, the new mode flashes 5 times.

Armed modes are shown above the engaged mode.

The GROUND PROX warning is in red and flashes alternately with the engaged mode (except windshear).

The WINDSHEAR mode annunciation has priority over all modes including GPWS/EGPWS.

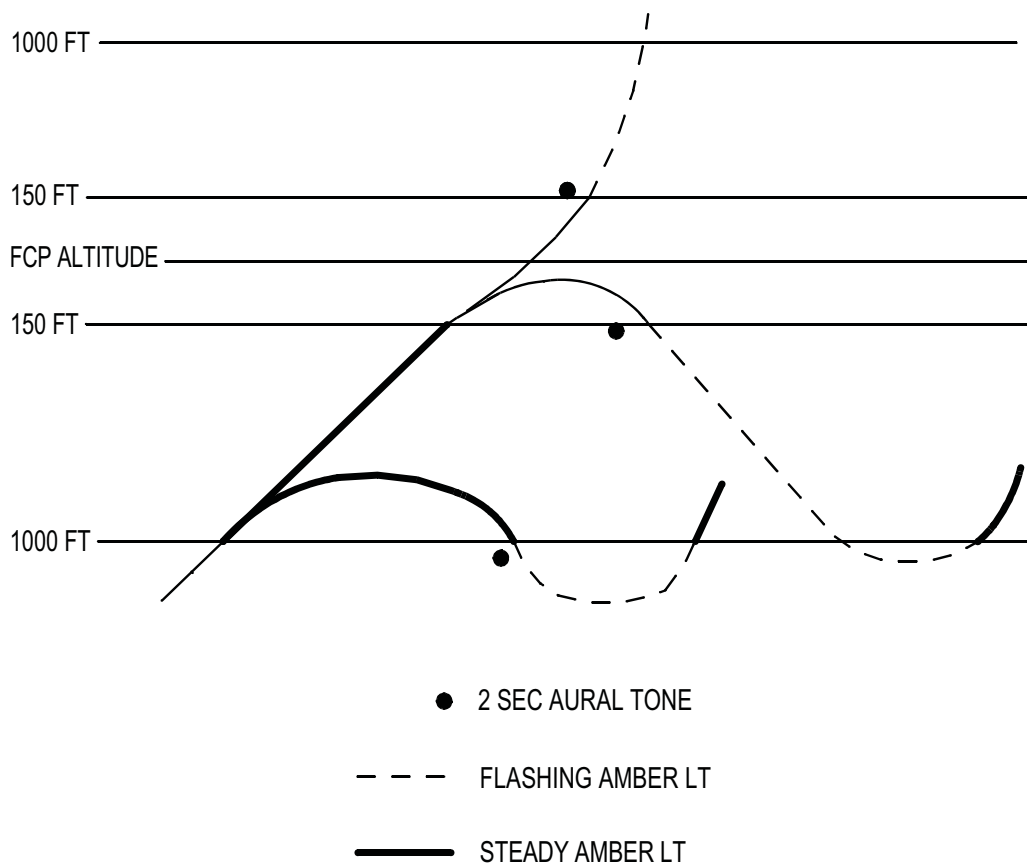
## FMA Control Window Modes

SPEED CONTROL MODES	TYPE	ANNUNCIATION	COLOR
FMS Descent	Engage	IDLE THRUST	Magenta
Speed on Pitch	Engage	PITCH	Magenta/White
Speed on Throttle	Engage	THRUST	Magenta/White
Throttle Retard	Engage	RETARD	White
Windshear FPA Control	Engage	WINDSHEAR	White
Lo Speed Protection	Armed/Engaged	LO SPEED PROTECTION	White
Hi Speed Protection	Armed/Engaged	HI SPEED PROTECTION	White
<b>ROLL CONTROL MODES</b>	<b>TYPE</b>	<b>ANNUNCIATION</b>	<b>COLOR</b>
Capture/Track VOR	Engage	VOR1 or VOR2	White
Capture/Track LOC	Engage	LOC ONLY	White
FMS Nav	Engage	NAV1 or NAV2	Magenta
Heading Hold or Select	Engage	HEADING _____	White
Track Hold or Select	Engage	TRACK _____	White
Landing Rollout	Engage	ROLLOUT	Green/White
Localizer	Engage	LOC	Green/White
Runway Alignment	Engage	ALIGN	Green/White
Takeoff Ground Roll	Engage	TAKEOFF	White
Over VOR	Engage	VOR1 (or 2) CRS	White
FMS Nav Armed	Armed	NAV ARMED	Magenta
Land Armed	Armed	LAND ARMED	White
LOC Armed	Armed	LOC ARMED	White
VOR Armed	Armed	VOR ARMED	White
<b>ALTITUDE CONTROL MODES</b>	<b>TYPE</b>	<b>ANNUNCIATION</b>	<b>COLOR</b>
Takeoff Thrust	Engage	T/O THRUST	White/Magenta
Throttles Clamp	Engage	T/O CLAMP	White/Magenta
Climb w/Climb Thrust	Engage	CLB THRUST	White/Magenta
Altitude Hold	Engage	HOLD	White/Magenta
CLIMB w/MAX Contin Thrust	Engage	MCT THRUST	White/Magenta
Vertical Speed	Engage	V/S	White/Magenta
Flight Path Angle	Engage	FPA	White
FMS Prof Descent	Engage	PROF	Magenta
GA Thrust Mode	Engage	GO AROUND	White
Glideslope	Engage	G/S	White/Green
Dual Autoland	Engage	DUAL LAND	Green
Single Autoland	Engage	SINGLE LAND	White
No Land Mode	Engage	APPR ONLY	White
III A/B Autoland Flare	Engage	FLARE	White/Green
III A/B Autoland Rollout	Engage	ROLLOUT	White/Green
Level Change Descent	Engage	IDLE CLAMP	White
FMS Speed On Elevators	Engage	IDLE	Magenta
Next FMS Prof Alt	Armed	PROF TO	Magenta
PROF Armed On Ground	Armed	PROF ARMED	Magenta
Alt Chnge in Prof Mode	Armed	VERT ALERT	Magenta
Armed to Capture G/S	Armed	LAND ARMED	White
Windshear (GA Thrust) Mode	Engage	WINDSHEAR	White
CLIMB w/GA Thrust	Engage	GA/THRUST	White/Magenta
CLIMB w/Cruise Thrust	Engage	CLB THRUST	White/Magenta

NOTE: Armed modes appear in smaller letters above the engaged mode.

LB1-3-0049

## Altitude Alert System Chart



DB1-2-1991

The altitude alert activates as follows:

1000 feet from the FCP window altitude - PFD altitude box turns steady amber.

If more than 0.12g required to capture FCP window altitude - steady amber PFD altitude box and tone. Active only on first approach to the FCP window altitude and is inhibited when aircraft is within 150 feet. If more than 0.12g is required to capture the FCP window altitude and that altitude is more than 1000 feet from the current baro-altitude, the PFD altitude box will be flashing amber. This condition is typically the reason why one may hear two successive altitude tones while approaching an altitude.

Deviation of 150 feet or more from FCP window altitude - flashing amber PFD altitude box and tone. The flashing amber altitude box will reset when the aircraft returns to the set altitude or a new altitude is selected.

### NOTES:

- *The tone consists of a C-chord.*
- *The altitude alert system is inhibited if the AFS is in glideslope capture mode.*

*NOTE: The associated cue switch is shown in parenthesis (XXX) following the alert.*

**Amber Boxed Alerts (Level 2)**

FCC (1A, 2A, 1B, 2B) DATA FAULT (CONFIG) - Respective FCC bus not valid.

STAB OUT OF TRIM (CONFIG) - LSAS or autopilot is on and the stabilizer is out of trim.

**Amber Alerts (Level 1)**

AUTOPILOT SINGLE (MISC) - Only one AP is valid.

FD G/A ONLY (MISC) - AP go-around mode is not available.

MANUAL GA ONLY (MISC) - FD and AP go-around modes not available.

NO AUTOLAND (MISC) - Autoland mode is not available.

ROLL CWS FAIL (MISC) - (If installed) Roll CWS is inoperative.

SINGLE LAND (MISC) - Autoland availability is reduced from dual land to single land.

WSHEAR DET FAIL (MISC) - Windshear detection is inoperative.