

AUTOMATIC FLIGHT CONTROL SYSTEM
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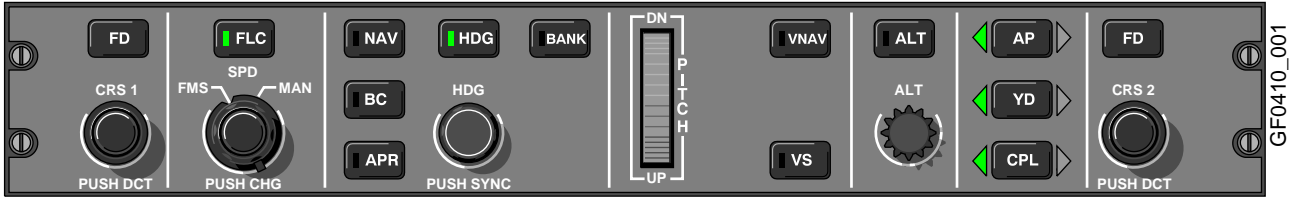
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GENERAL

The Automatic Flight Control System (AFCS) provides dual channel autopilots, dual yaw dampers, dual flight directors and automatic pitch trim. The autopilot and yaw damper functions, operate in an active standby mode, with only one channel active at a time. All computations are performed by 2 Flight Guidance Computers (FGC), located in the Integrated Avionics Computer (IAC). The FGC receives inputs from the Electronic Flight Instrument System (EFIS), the Air Data Computers (ADC), from the Inertial Reference System (IRS), from the Flight Management System (FMS), from the Fault Warning Computer (FWC) and the Data Acquisition Unit (DAU).

Selection for all AFCS functions are made on the guidance panel, located on the glareshield.



Guidance Panel

The AFCS functions controlled by the FGC include:

- Flight director modes.
- Guidance references.
- Engagement of the autopilot and yaw damper functions.
- Selection of left or right Primary Flight Display (PFD) data to be used by FGC.

Through the flight computer, the AFCS will provide flight guidance outputs for display on the Primary Flight Display (PFD). The flight director functions are as follows:

- Mode selection.
- Computation of guidance.
- Data management and source selection.
- Command bar output for display.

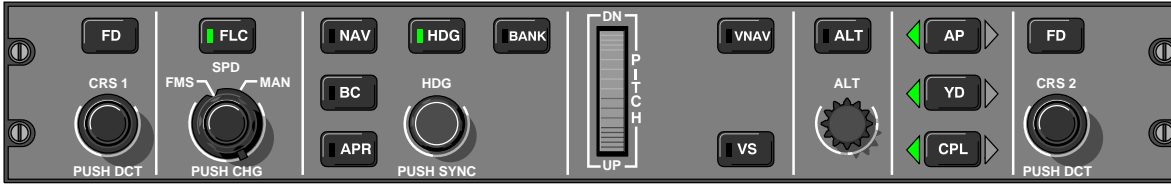
If an autopilot/flight director mode is armed or engaged, the annunciator on the appropriate button is illuminated.

Indicates FLC mode is armed or engaged



Indicates HDG mode is armed or engaged

GUIDANCE PANEL



Flight Director (FD) Switch

Used to remove flight director command bars from the PFD not selected by the flight director.

Navigation (NAV) Switch

Used to arm lateral guidance for capture of selected navigation course or desired track.

Heading (HDG) Switch

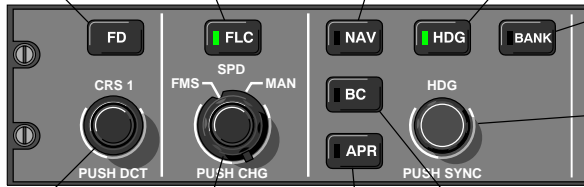
Used to activate the lateral guidance to compute steering commands, based on selected heading.

Flight Level Change (FLC) Switch

Used to select airspeed hold mode. Overrides all active vertical modes except VNAV.

Bank (BANK) Switch

Used to manually select bank angle limit in HDG, VOR, or NAV modes.



Heading (HDG) Button

Used to move the heading bug on PFD.

Push Synchronize (PUSH SYNC) Button

When pushed, causes heading bug to synchronize to airplane heading.

Course 1 (CRS 1) Button

Used to move the course pointer on selected PFD.

Push Direct (PUSH DCT) Button

When pushed, causes course pointer to indicate deviation course to tuned VOR.

Approach (APP) Switch

Used to arm the lateral guidance for localizer or VOR approach capture. When localizer capture, vertical guidance is armed for glideslope capture.

Back Course (BC) Switch

Used to select approach mode guidance for capture and tracking of back course data.

Speed (SPD) Button

Used to set speed on PFD (manually or by use of FMS).

• **MAN**

Airspeed reference set by turning inner knob.

• **FMS**

Airspeed reference set by FMS.

PUSH CHG

When inner knob pushed, changes IAS to Mach or Mach to IAS.

NOTE

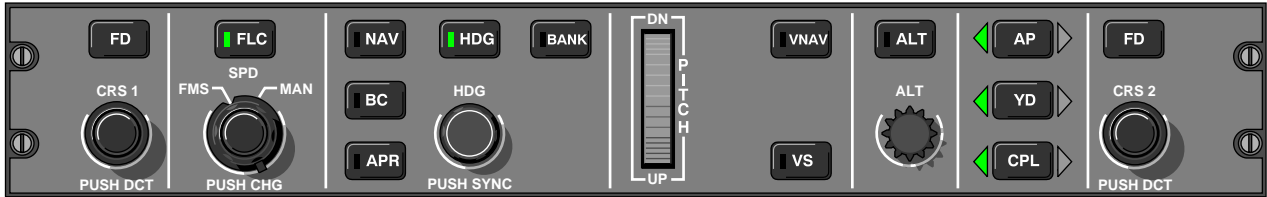
Annunciator, (on all flight director mode switches), illuminates when selected mode is armed or active.

Annunciator Light



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GUIDANCE PANEL (CONT'D)



Altitude (ALT) Switch
Used to maintain indicated altitude at time of selection.

Vertical Navigation (VNAV) Switch
Used to select the vertical navigation mode, tracking vertical flight profile from selected FMS.

Yaw Damper (YD) Switch
Used to engage and disengage the yaw damper. Disengaging the yaw damper, disengages the autopilot.

Autopilot (AP) Switch
Used to engage and disengage autopilot. When autopilot engaged, the yaw damper is engaged simultaneously. Disengaging the autopilot does not disengage the yaw damper.

AP and YD Pointers
Illuminates to indicate which AP FGC or YD is engaged. Whichever AP or YD pointer was active on the last landing becomes the standby FGC on next power-up.

Flight Director (FD) Switch
Used to remove flight director command bars from the PFD not selected by the flight director.

Course 2 (CRS 2) Button
Used to move the course pointer on selected PFD.

Push Direct (PUSH DCT) Button
When pushed, causes course pointer to indicate deviation course to tuned VOR.

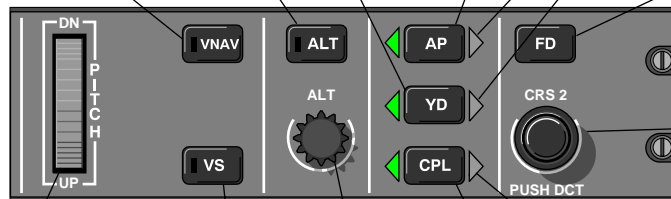
Speed/Pitch Wheel
Used to change vertical reference value being used by vertical speed (VS) mode. Functional only when AP engaged, or flight director active.
• **DN** – Rotate the wheel forward to select pitch down and speed increase.
• **UP** – Rotate the wheel backwards to select pitch up and speed decrease.

Vertical Speed (VS) Switch
Used to hold a vertical speed. When pushed, the vertical speed reference is synchronized to current vertical speed, displayed on PFD. Use speed/pitch wheel to change vertical value.

Altitude (ALT) Preselect Button
Used to preselect altitude, displayed on PFD.

Coupled (CPL) Switch (lateral and vertical flight guidance)
Used to couple either pilot's or copilot's PFD and associated ADC data to FGC1 and FGC2.

CPL Pointer
Illuminates to indicate whether the associated AP is coupled to FGC1 or to FGC2. Both pointers will illuminate during an ILS approach.



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AUTOPILOT

The autopilot (AP) system automatically controls the airplane in pitch and roll attitude via servo control of ailerons, elevator and aircraft trim system. The two autopilot computer channels operate in a high priority/low priority (active/standby) configuration.

Assignment of priority channel is alternated on power-up. The high priority channel provides control functions, while the low priority channel operates in a back-up mode. The autopilot/yaw damper actuators and pitch trim interface can only be driven by the priority channel.

In the event of a channel failure, the priority will automatically switch to the other channel.

Each FGC shall determine which symbol generator is driving the selected PFD, as selected on the reversion control panel located on the pedestal. The following guidance data is received from the appropriate symbol generator, via the Avionics Standard Communications Bus (ASCB), for use in the FGC:

Air data source identification	Lateral and vertical path deviations
Attitude source identification	Distance to station
NAV source identification	Tuned-to-NAV and To/From status
Course error	Inner, Middle and Outer marker data
Heading error	Radio Altitude

The source of other guidance information is selected via the source identifier received from selected PFD symbol generator. The data received includes:

- **IRS:**

Roll Angle	Normal acceleration
Pitch Angle	Ground speed
Roll rate	True track angle
Pitch rate	Flight path angle
Yaw rate	Magnetic heading
Longitudinal acceleration	True heading
Lateral acceleration	Inertial vertical speed
- **ADC:**

Baro-corrected altitude	True airspeed (TAS)
Pressure altitude	Dynamic pressure
Vertical speed	V_{MO}
Mach	M_{MO}
Calibrated airspeed (CAS)	
- **FMS:**

Lateral steering command	VNAV sub-mode selection flags
VNAV targets	
- **FWC:**
 - Pre-selected altitude
- **Display Controller (DC):**
 - Speed references

Manual selection of the master AFCS channel is accomplished via the pop-up menu on either multi-functional display (MFD), in conjunction with the MFD control panel located on the pedestal.

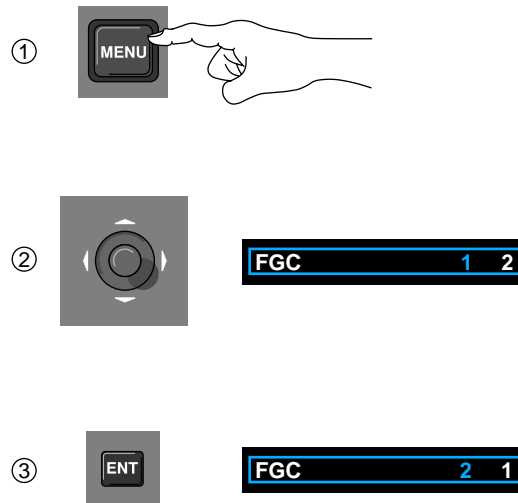
AUTOPILOT (CONT'D)



MFD



MFD Control Panel



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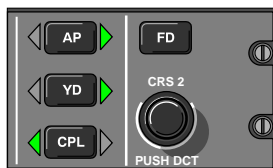
YAW DAMPER

The yaw damper provides stability augmentation and turn coordination for the airplane yaw axis, via 2 linear actuators, in series with the rudder control system.

The yaw damper function will automatically engage on the ground, within 3 seconds after successful completion of AFCS power-up test. As with the autopilot, the yaw damper operates in an active/standby configuration. When engaged, the active yaw damper will center both linear actuators.

The YD will not automatically engage once the airplane is airborne. The YD button, located on the guidance panel may be used to re-engage the YD. When YD is engaged, the associated arrow on the guidance panel is illuminated.

One valid yaw damper must be engaged for autopilot operation. Autopilot engagement without YD will occur only when YD has failed in flight.

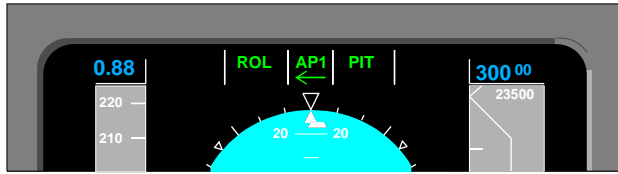


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For more information on yaw damper see Chapter 10, FLIGHT CONTROLS.

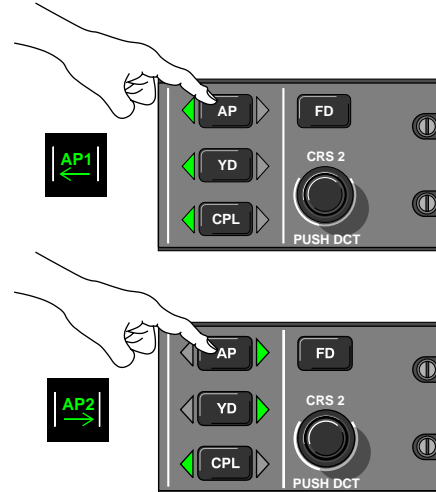
AUTOPILOT ENGAGE

The autopilot cannot be engaged without flight director guidance modes active. When no vertical or lateral mode is active, the autopilot will engage the pitch and roll FD modes. Autopilot is engaged via the AP button on the guidance panel.



PFD

When selected, **AP1** or **AP2** will flash for approximately 5 seconds, then steady



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Autopilot control authority:

- • Roll rate is limited to $\pm 7.5^\circ/\text{sec}$.
- • Pitch rate is ± 0.3 G in straight and level flight and maximum 0.7 G pitch up in a turn.

The autopilot can engage throughout the range:


- • Pitch = $\pm 50^\circ$
- • Roll = $\pm 75^\circ$
- Once engaged, the autopilot will reduce the pitch and roll angles below control limits.

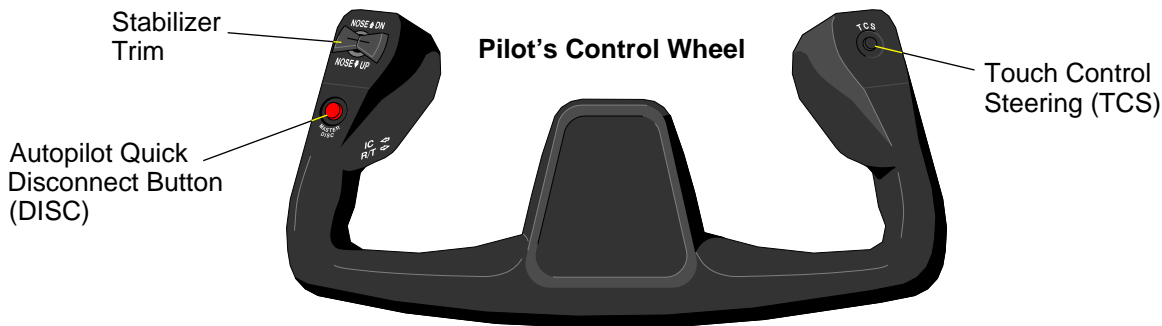
Autopilot control limits:

- • Roll = $\pm 35^\circ$ except in Approach Track (APPT) mode. When in APPT mode, the roll limits are reduced linearly from $\pm 25^\circ$, above 200 feet radio altitude, to $\pm 5^\circ$ at 0 feet radio altitude.
- • Pitch = $\pm 20^\circ$. In APPT mode, the nose-down pitch limit is reduced below 300 feet programmed by vertical rate and radio altitude.

AUTOPILOT DISENGAGE

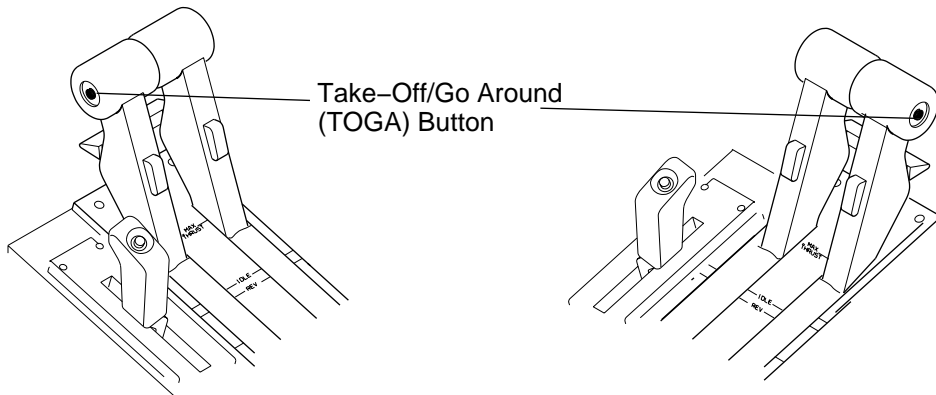
Normal disengagement of the autopilot is accomplished by activating any of the following:

- AP button on guidance panel. 
- Autopilot quick disconnect (DISC) button on either control wheel.
- Manual stabilizer trim when touch control steering (TCS) not active.
- YD button on FGC panel.
- TCS button on either control wheel (while depressed). When the TCS button on either control wheel is activated, the aileron and elevator servo clutches are released, the autopilot is disengaged and the flight director is re-synchronized. Releasing the TCS button re-engages the servo clutches and autopilot is engaged, if within normal pitch and roll limits. Where applicable, the flight director modes will react as if the autopilot had just been engaged.



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- Take-Off/Go Around (TOGA) buttons on thrust levers.



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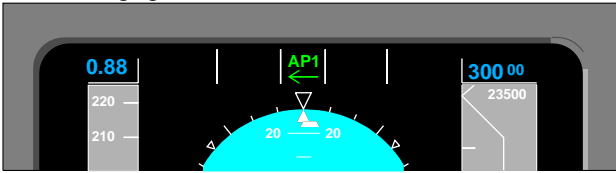
For a normal autopilot disengagement, **AP1** or **AP2** annunciator will change to a steady **AP1** or **AP2** for 2 seconds, then flash continuously and an aural “cavalry charge” will sound once. The annunciation and aural can only be cancelled by depressing DISC button on either control wheel.

For an abnormal autopilot disengagement, (motor trip/failure or AFCS failure), **AP1** or **AP2** will flash continuously and an aural “cavalry charge” will sound repeatedly. The annunciation and aural can only be cancelled by depressing DISC button on either control wheel.

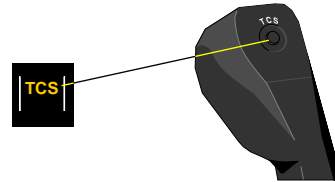
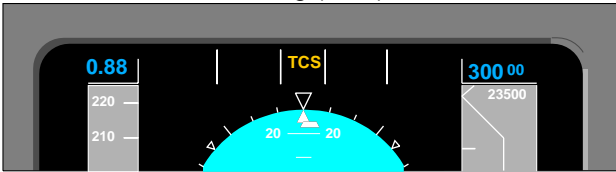
PFD ANNUNCIATION

The PFD will display the following AFCS information:

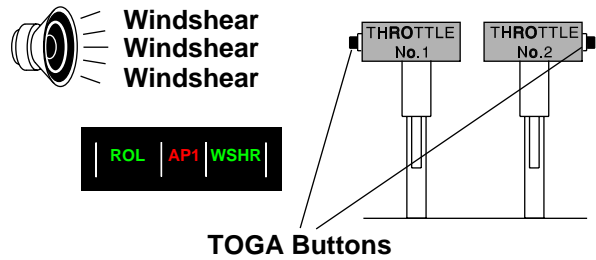
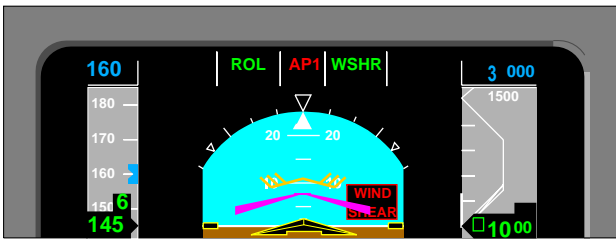
- AP engage status



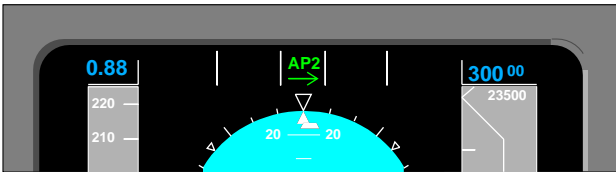
- Touch control steering (TCS) status



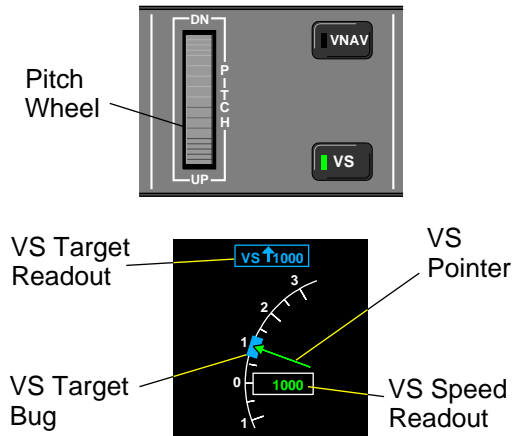
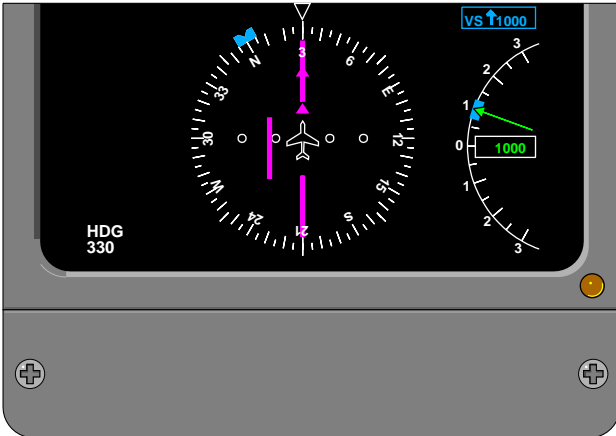
- Flight director commands and status



- Flight director data source (CPL)



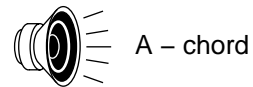
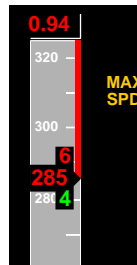
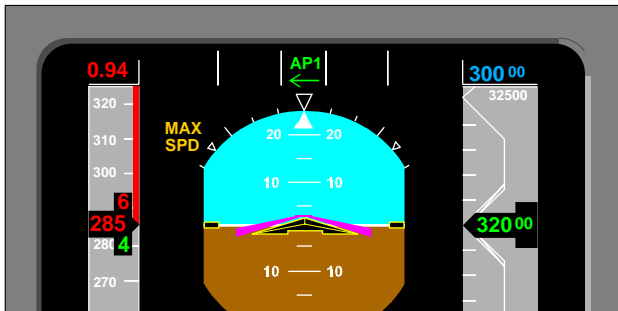
- Vertical speed reference



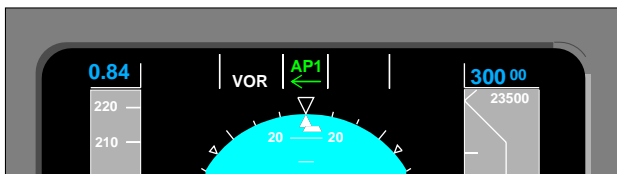
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PFD ANNUNCIATION (CONT'D)

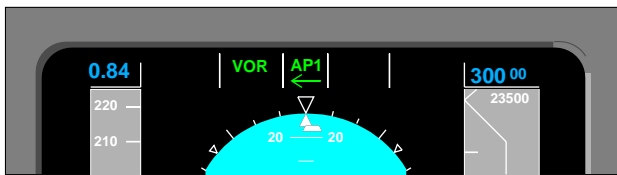
- Overspeed warning



- Armed lateral mode



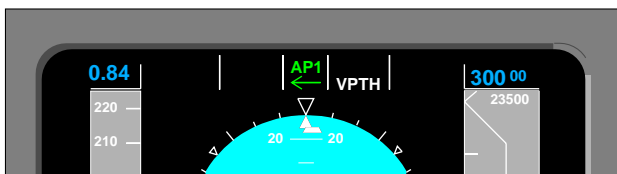
- Active lateral mode



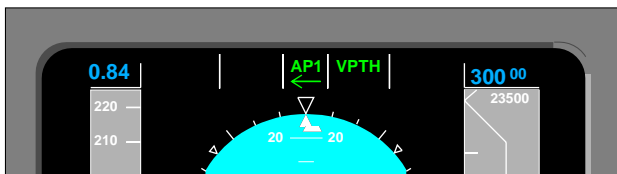
Active mode flashes for 5 seconds upon automatic mode capture.



- Armed vertical mode



- Active vertical mode



Active mode flashes for 5 seconds upon automatic mode capture.

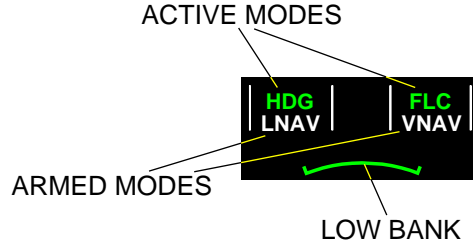
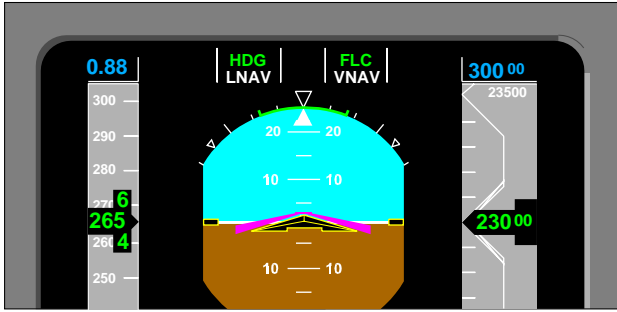


GF0410_022

FLIGHT DIRECTOR (FD)

There are two modes of operation, one vertical and one lateral. Only one vertical mode and one lateral mode may be active at any time, however up to 2 vertical arm modes and one lateral arm mode may be selected simultaneously.

The armed and active modes are annunciated on both PFDs. Armed modes are displayed in white below active modes, which are displayed in green. The lateral modes are annunciated on the left side of the displays and the vertical modes on the right side, above the attitude sphere. Low bank mode is annunciated via green eyebrow on top of the attitude sphere.



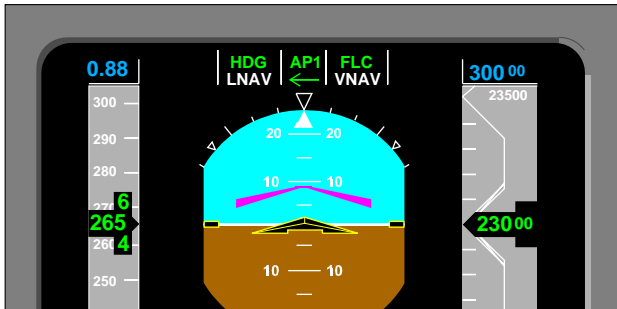
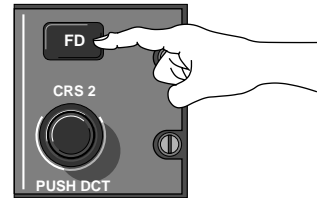
GF0410_027

Flight director command bars appear on the PFD whenever an FD mode is selected. The flight director command bars can be removed from the off-side PFD that is not selected for use by the flight director by pressing the off-side FD button, while still retaining the active mode status on both PFDs (either autopilot ON or OFF). The flight director command bars can be removed from both PFDs and all flight director modes canceled by pressing the on-side FD button (autopilot OFF, only; on-side FD button inactive with autopilot ON). The off-side flight director command bars may not be deselected when Go-Around (GA) or Take-Off (TO) mode is active. The flight director command bars may not be deselected on either PFD when Windshear (WSHR) is the active mode.

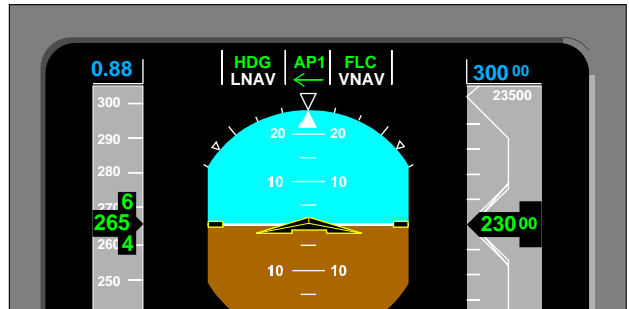


FD Switch:

Used to remove Flight Director command bars from the PFD not selected by the Flight Director.



PILOT'S PFD



COPILOT'S PFD

GF0410_028

FLIGHT DIRECTOR MODES

LATERAL MODES		
Switch (guidance panel)	Mode	Annunciation
HDG	Heading Select	HDG
NAV	Lateral Navigation Modes: Based on displayed navigation source (VOR, FMS, Localizer)	VOR LNAV LOC
APR	Lateral Approach mode (VOR displayed)	VAPP
BC	Back Course	BC
BANK	High/Low Bank (HDG, VOR AND VAPP modes only)	Eyebrow on attitude sphere (low bank only)

VERTICAL MODES		
Switch (guidance panel)	Mode	Annunciation
FLC	Flight Level Change	FLC
None	Automatic Altitude Preselect	ASEL
ALT	Altitude Hold	ALT
VS	Vertical Speed Hold	VS
VNAV	Vertical Navigation Modes Requested by FMS	VFLC VASEL VALT VPTH

MULTI-AXIS MODES		
Switch (guidance panel)	Mode	Annunciation
APR	Approach (ILS)	LOC / GS
TOGA	Go-Around	ROL / GA
TOGA	Take-Off	ROL / TO
TOGA	Windshear Guidance	ROL / WSHR

BASIC MODES		
Switch (guidance panel)	Mode	Annunciation
None	Roll Hold	ROL
	Roll Hold Sub-mode (wings level)	ROL
	Roll Hold Sub-Mode (heading hold)	ROL
None	Pitch Hold	PIT

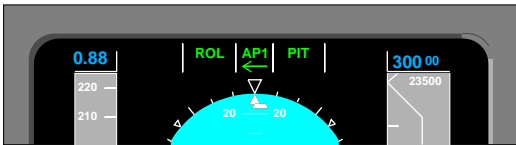
MODES OF OPERATION: (LATERAL)

The following are the lateral modes of operation:

Roll (ROL) Mode

Roll mode is automatically selected, when no other lateral mode is active and the autopilot is engaged. Roll mode generates commands to hold the heading that exists when the mode is initiated, unless the roll angle upon initiation is over 6° (commands are then generated to hold the roll angle). The roll mode reference is reset to the current heading, or current roll angle, upon AP engagement. The maximum bank angle in roll mode is 35°.

ROL mode is annunciated in the lateral capture field on the PFD. Roll mode is cleared by selecting another lateral mode. **ROL** will flash for 5 seconds, when active.

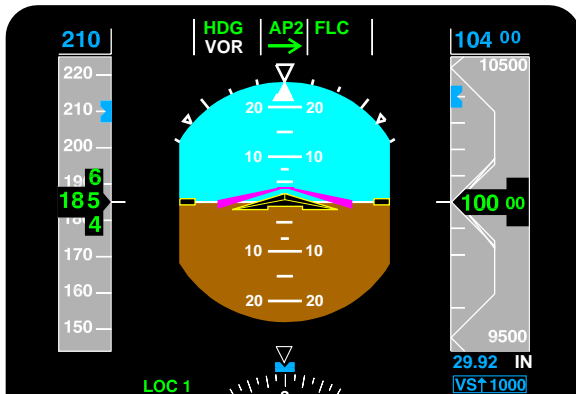


GF0410_033

Heading Select (HDG) Mode

The heading select mode is activated via the HDG button on the guidance panel. The heading select mode is automatically activated whenever a navigation (NAV) mode, approach (APR) mode or back course (BC) is armed. While in HDG mode, all armed roll flight director modes are available, but a capture of any armed roll mode will cancel the heading select mode.

HDG Active. "HDG" will flash for approximately 5 seconds, when active.

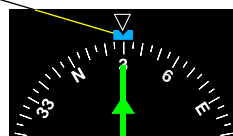
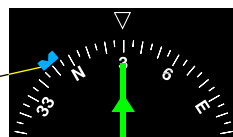


HDG Switch:
When selected, activates heading mode.



HDG Knob:
Turn to set the heading bug on the HSI.

PUSH SYNC:
Used to synchronize heading bug to present heading.



GF0410_035

MODES OF OPERATION: (LATERAL) (CONT'D)

Heading Select (HDG) Mode (Cont'd)

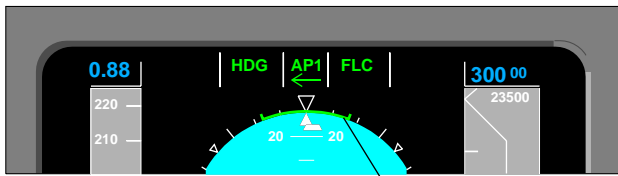
If the heading bug is turned through more than 180° but less than 360° (airborne), the FGC will follow the bug all the way around to the target and not turn in the shortest arc. The FGC provides guidance to the selected target using the shortest arc when on the ground. The on-ground logic will prevent the airplane from turning in the wrong direction following take-off, due to maneuvering the airplane may have done on the ground.

While in BANK mode, roll rate commanded by the heading mode is limited to 4°/sec. If the roll angle is less than or equal to 6° when ascending through an altitude of 35,050 feet, the FGC shall automatically transition to the low bank limit of 17°. If the roll angle is greater than 6°, an automatic bank limit transition will not occur until the roll angle is reduced to less than or equal to 6°.

When descending through 34,950 feet, the bank limit shall revert to the high bank limit of 27°, if the roll angle is less than or equal to 6°. If the roll angle is greater than 6°, high bank limit reversion will not occur until the roll angle is reduced to less than or equal to 6°.

The bank angle can also be toggled between high and low bank limits by means of the BANK switch on the guidance panel.

When heading select mode is active with the low bank limit, an “eyebrow” is displayed between ± 17° on top of the attitude sphere on the PFD.




"EYEBROW"



BANK Switch:
Used to limit bank angle.

GF0410_036

LATERAL NAVIGATION MODES

Lateral navigation mode is activated by selecting the NAV button on the guidance panel . The following navigation sources may be activated:

- Very high frequency Omni-directional Range (VOR).
- Localizer (LOC).
- FMS Lateral Navigation (LNAV).

When any NAV mode is armed, HDG is automatically active. 

HDG will be de-activated when NAV mode is active. 

Lateral navigation guidance and automatic transitions are computed based on the following data, received from the selected PFD:

- Lateral path deviation (VOR and LOC).
- Course or heading error.
- NAV source identification (VOR, LOC, FMS).
- VOR radio frequency re-tuned flag.
- To-From flag.
- Distance to station (DME) and tuned-to-NAV flag.
- Radio altitude.

LATERAL NAVIGATION MODES (CONT'D)

Very High Frequency Omni-Directional Range (VOR) Mode

VOR mode provides for automatic intercept, capture and tracking of a selected VOR radial.

If Distance Measuring Equipment (DME) information is not available, the FGC estimates a distance of 30 NM. If an Inertial Reference System (IRS) is installed and in NAV mode, the distance estimate is updated based on ground speed and track error. If IRS navigation information is not available, the estimate is updated based on true airspeed and course error.

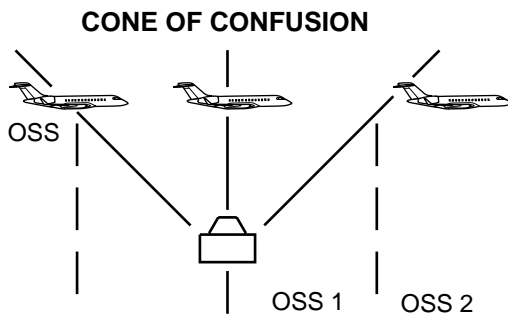
Capture and tracking will occur, provided that:

- The intercept angle is less than 60°. The optimum intercept angle should be less than 45°. If greater than 45°, course cut limiting may occur to limit steering commands to 45° which forces flight path to get to radial sooner to prevent overshooting beam center, and
 - the bank angles required do not exceed the roll limits.
- █ FD roll commands are limited to ± 24° when in VOR capture and roll rate commands are 5.5°/sec.
- █ When VOR track is active, FD roll commands are ± 14° and roll rate commands 4°/sec.

If selected VOR is re-tuned to another VOR frequency while in VOR capture, track or over station, VOR mode cancels and re-arms automatically.

When the airplane is passing over the VOR transmitter (cone of confusion), VOR mode will fly towards selected course reference (over-station passage). If selected course is unchanged prior to entry into cone of confusion, previously computed wind correction is applied and VOR mode will not command a turn towards selected course pointer. Changes of course pointer setting when over-station will cause a change in course hold reference.

- If DME is available, the cone of confusion entry boundary is estimated based on distance to transmitter and altitude or VOR TO/FROM transition. When over the VOR station, VOR will follow a course change of up to 120°. The cone of confusion exit boundary is based on altitude, airspeed and time. If DME information is not available, the cone of confusion boundaries are determined by level of beam noise or VOR TO/FROM transition. When in VOR over station, the flight director roll commands are limited to ± 24° and roll rate commands are 7°/sec. The over station sensor (OSS) monitors entry into zone of confusion and removes radio deviation from the roll command.
- █



OSS – is used to detect erratic radio signals encountered in the area above VOR transmitter.

OSS1 monitors beam deviation and will occur when:

- OSS has occurred.
- A calculated period of time has elapsed since last TO/FROM transition.
- The period of time elapsed is calculated using true speed and altitude.
- The higher the altitude, the longer it takes to get through cone of diffusion.
- The higher the airspeed, the faster the airplane will be through the cone.
- VOR track has occurred, plus 3 seconds of elapsed time.
- Distance to station is less than 1/4 of the altitude and DME present, or lateral deviation is greater than 1 dot and rate of deviation is greater than 25 feet/sec and DME is not present.

OSS2 – ensures beam deviation is useable and will occur when:

- OSS1 has occurred, plus 3 seconds.
- Beam deviation is less than 1 dot.
- Beam rate is less than 25 feet/sec.

GF0410_040



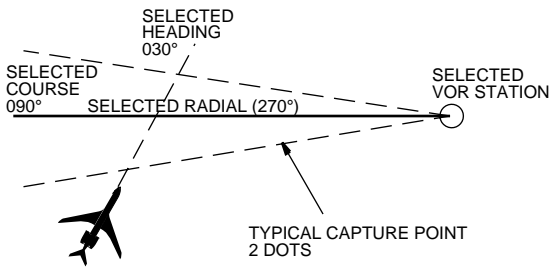
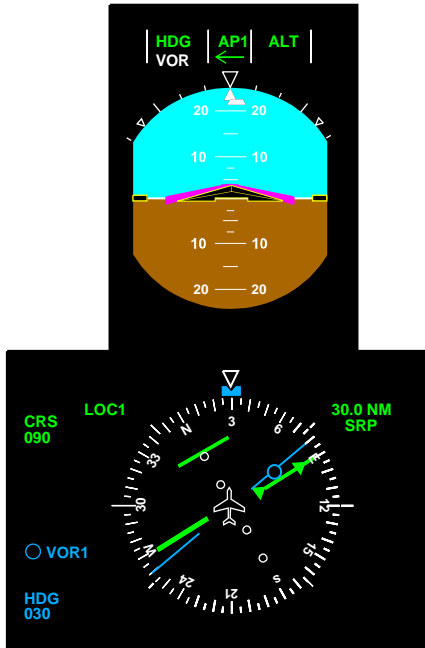
Armed.



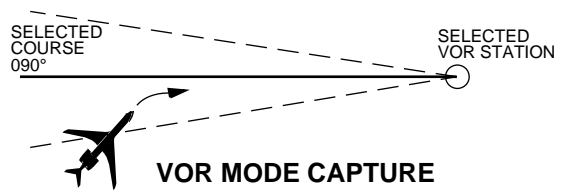
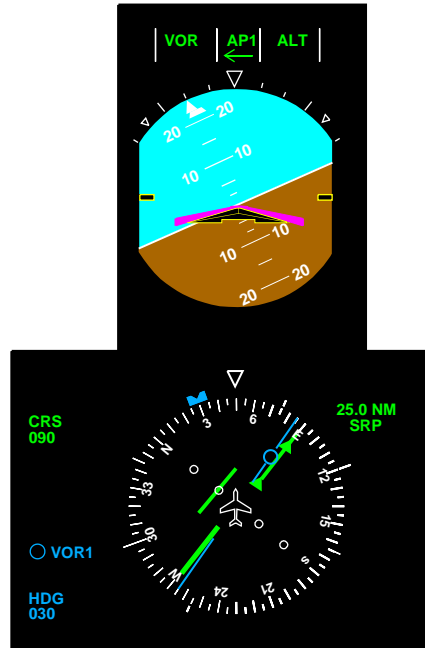
Active. "VOR" will flash for approximately 5 seconds, when active.

LATERAL NAVIGATION MODES (CONT'D)

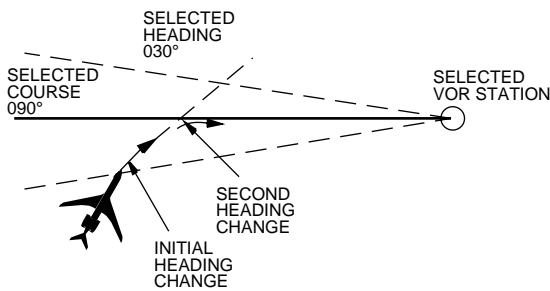
Very High Frequency Omni-Directional Range (VOR) Mode (Cont'd)



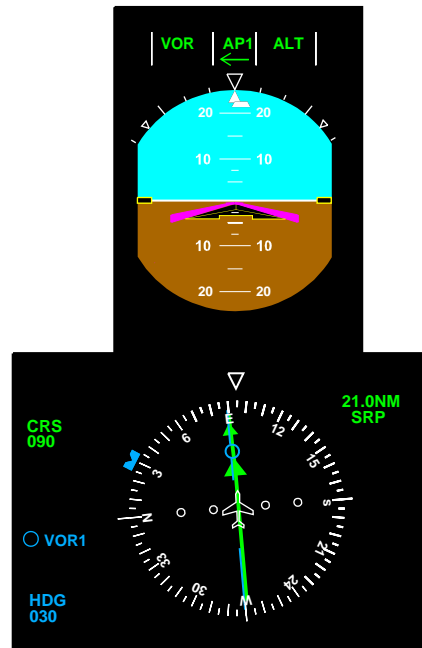
VOR MODE INTERCEPT



VOR MODE CAPTURE



VOR MODE TRACK



NOTE
During course cut limiting, typically the roll command will make an initial heading change, level out and fly towards the beam, then make a second heading change to line up on the centre of the radial.

GF0410_043

LATERAL NAVIGATION MODES (CONT'D)**Localizer (LOC) Mode**

Localizer mode provides for automatic intercept, capture and tracking of the front course localizer beam, to line up on the centreline of the runway in use.

Localizer capture and tracking commands are based on the distance-to-transmitter. The FMS will output the distance to tuned navaid or distance to destination, based on the following conditions:

- If the FMS is used to autotune the LOC, the FMS will output the distance-to-station the tuned LOC transmitter.
- If the FMS is tuned manually by LOC-frequency on the CDU, the FMS will output the distance to the tuned LOC transmitter, regardless of approach or flightplan.
- If the LOC frequency is manually tuned with a LOC-frequency on the CDU, or if tuned on the RMU, and the FMS will output distance to destination selected in the flight plan.
- If the LOC frequency is manually tuned with a LOC-frequency on the CDU, or if tuned on the RMU, and the FMS does not have a destination selected, no distance information will be output by the FMS. In this case, the AFCS will use estimated distance.

The AFCS priority for determining distance to LOC transmitter is:

- Distance-to-station (DME) information, if the DME is valid and co-located with the locator transmitter.
- If DME information is not available, or not co-located, the distance to localizer is based on radio altitude, true airspeed, glideslope deviation and an assumed flight path angle of 3°.
- If, in addition to invalid DME, the radio altitude is invalid, the AFCS will use FMS distance information.

If a destination other than the one designated in the FMS flight plan is used and the LOC-frequency is manually tuned with a LOC-frequency on the CDU, or on the RMU, and DME and RAD ALT are not available, the FMS will output erroneous distance to destination data. To prevent potential problems in this circumstance, a limit was placed on the value the AFCS will accept from the FMS for distance (30 nm). Testing showed that when performing a close-in capture (7-10 nm) using the maximum value for distance (30 nm), the LOC overshoots on initial capture were within acceptable limits and were damped out within 2 oscillations.

FD roll commands are $\pm 30^\circ$ when capturing localizer. During localizer track mode, the roll commands are $\pm 24^\circ$.

Roll rate commands are 7°/sec during capture and 5.5°/sec during track modes.

The optimum intercept angle is 45°. If intercept angle is greater than 45°, course cut limiting may occur. As LOC moves from ARMED to ACTIVE, the LOC will flash for approximately 5 seconds, when active.



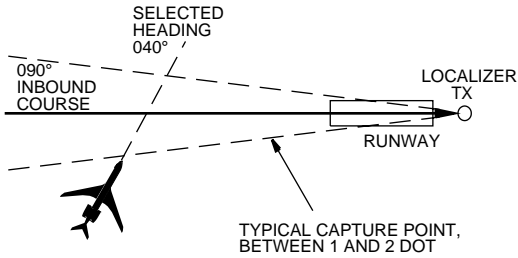
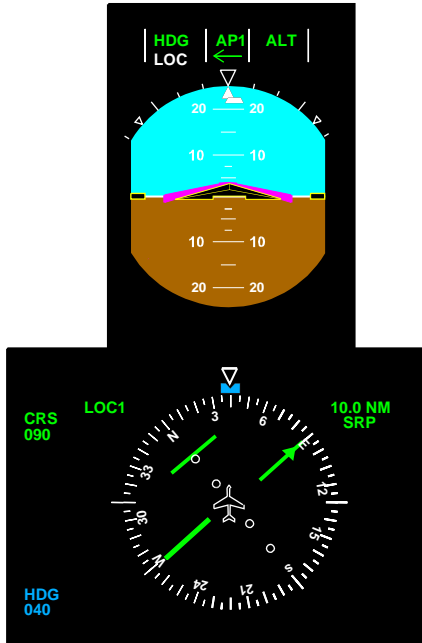
Armed.



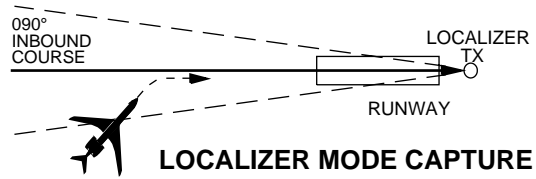
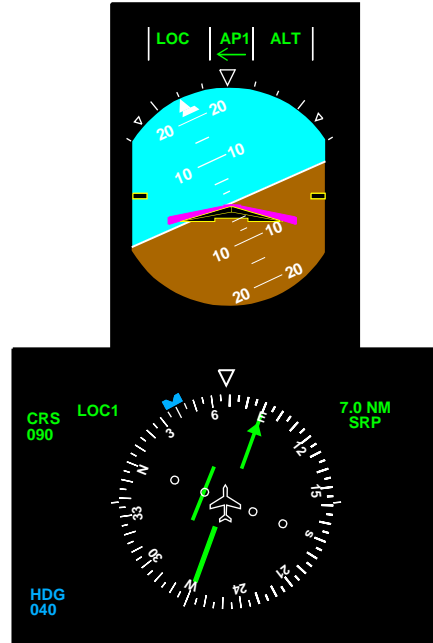
Active. "LOC" will flash for approximately 5 seconds, when active.

LATERAL NAVIGATION MODES (CONT'D)

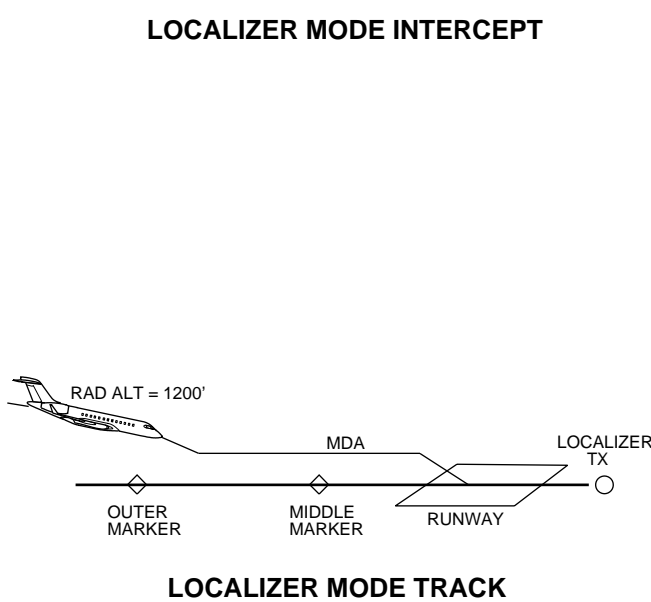
Localizer (LOC) Mode (Cont'd)



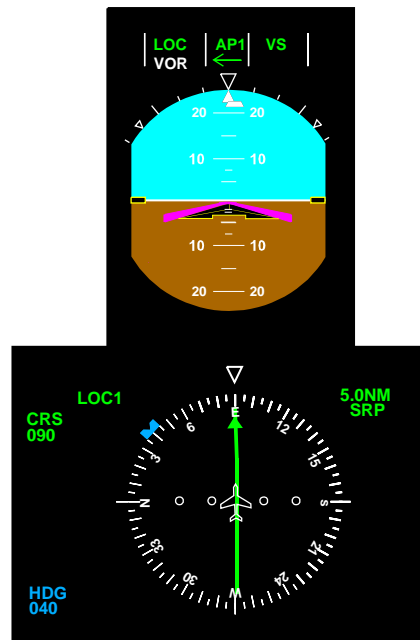
LOCALIZER MODE INTERCEPT



LOCALIZER MODE CAPTURE



LOCALIZER MODE TRACK











GF0410_046







LATERAL NAVIGATION MODES (CONT'D)







FMS Lateral Navigation (LNAV) Mode


The FMS lateral steering command is a roll command which aligns the airplane with the flight plan in the FMS. The FGC limits the FMS roll commands to 30° and roll rate to 5.5°/sec.

The FD will transition automatically from FMS navigation to an approach or back course mode, via the approach preview mode. The selected NAV source must be FMS and NAV radio must be tuned to a localizer frequency, to select an approach preview.

The previewed approach is armed by pushing  or  switch on guidance panel and the NAV radio must be tuned to a localizer frequency. When    LOC or BC captures, it replaces LNAV.   

If the active vertical mode was not VNAV prior to capture, the vertical mode remains unchanged. If the active vertical mode was VNAV prior to capture   , then ALT mode will replace the vertical mode.   

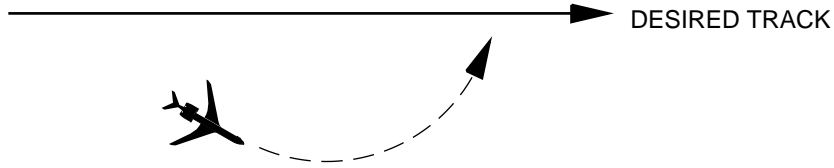
If armed approach mode was APR (ILS), then GS is armed with LOC capture    and GS will capture when GS criteria is met.   

 Armed.  Active. “LNAV” will flash for approximately 5 seconds, when active.

LATERAL NAVIGATION MODES (CONT'D)

FMS Lateral Navigation (LNAV) Mode (Cont'd)

LNAV capture will occur when the airplane is within 2.5 miles of the desired track and moving away from it.

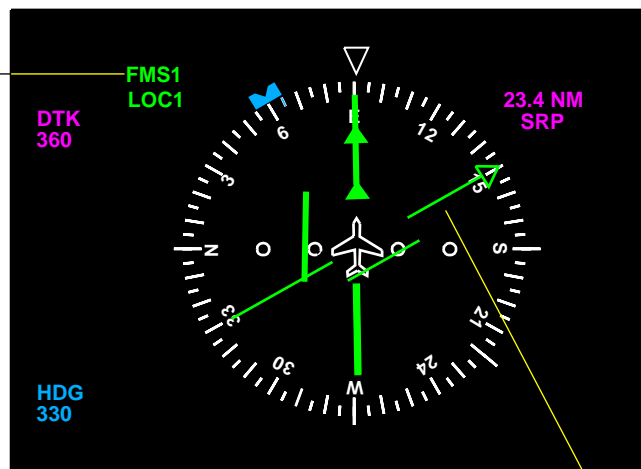


LNAV capture will occur when the airplane is at a calculated point, as a function of track error and ground speed, if the airplane is flying towards the desired track.



PREVIEWED APPROACH

Preview
Navigation
Source




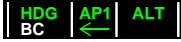
Preview
Course
Pointer

GF0410_057



LATERAL NAVIGATION MODES (CONT'D)

Back Course (BC) Mode

Back course mode provides for automatic intercept, capture and tracking of the back course localizer signal.

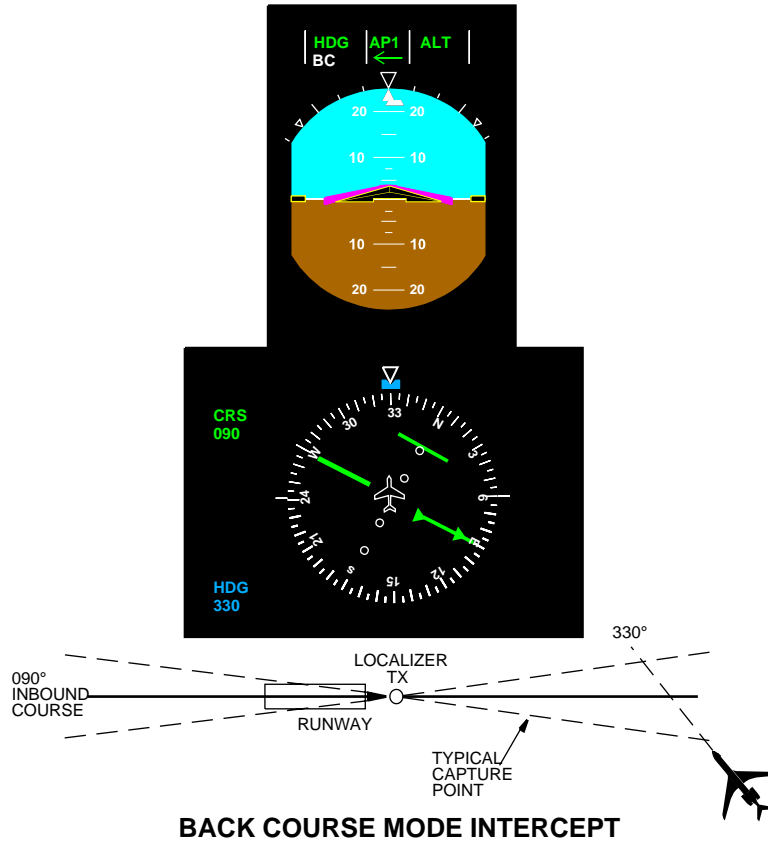
When BC is armed,  **HDG** is automatically active .

BC mode is identical to LOC mode except that the transmitter is located 2000 feet in front of the touch-down point. The course arrow must be set to the front course runway heading. The FGC will invert the course and radio deviation signals to provide correct back course steering commands.

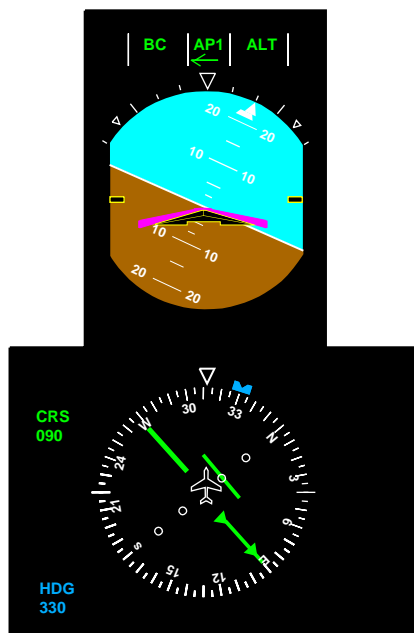
 Armed.  Active. “**BC**” will flash for approximately 5 seconds, when active.

LATERAL NAVIGATION MODES (CONT'D)

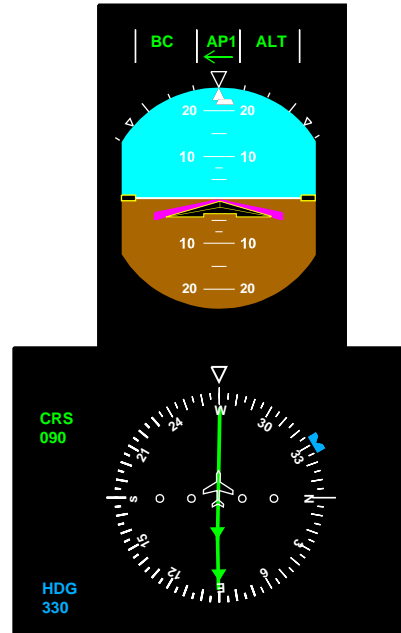
Back Course (BC) Mode (Cont'd)



BACK COURSE MODE INTERCEPT



BACK COURSE MODE CAPTURE



BACK COURSE MODE TRACK

GF0410_062

MODES OF OPERATION: (VERTICAL)

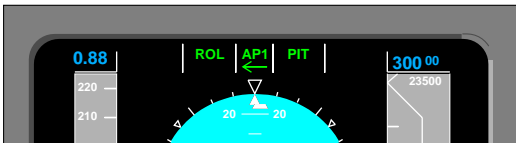
The following are vertical modes of operation:

Pitch Hold (PIT)

PIT mode is automatically selected when no other vertical mode is active and the autopilot is engaged and if **ROL** mode is active and no vertical mode is active. If the pitch angle is greater than 20°, pitch hold mode will reduce the airplane pitch angle to ± 20°. PIT reference is modifiable (within pitch limits), via pilot inputs to the pitch thumb-wheel, or by TCS. There is no speed protection in PITCH mode.

The pitch hold mode holds a flight path angle rather than a fixed pitch angle. The selected flight director pitch angle will change with altitude, configuration and/or airspeed changes, while climbing, descending or in level flight.

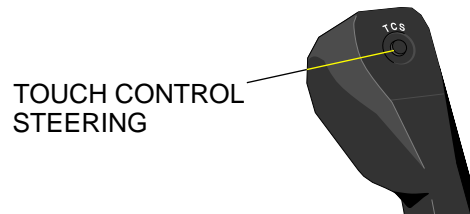
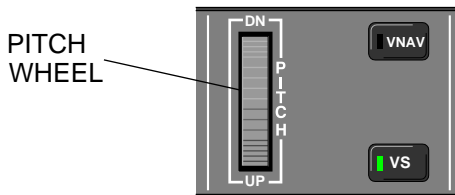
PIT mode is annunciated in the vertical capture field on the PFD. Pitch mode is cleared by selecting another vertical mode. **PIT** will flash for 5 seconds, when active.



GF0410_063

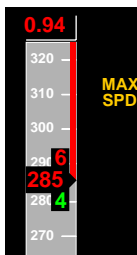
Vertical Speed (VS) Select

VS mode is used to maintain a pilot selected vertical speed reference. FGC will generate pitch commands to align the airplane vertical rate displayed on the PFD. The airplane vertical rate is adjustable via the pitch wheel. The pilot may select another vertical speed reference without cancelling VS mode by depressing the TCS button and maneuvering the airplane to another vertical speed.

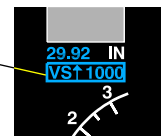


GF0410_064

FGC will not generate commands to exceed V_{mo} or M_{mo} when in VS mode. When a potential overspeed condition is detected, VS flight director pitch commands will be limited to 3 knots less than V_{mo} or M_{mo} and **MAX SPD** annunciation is displayed on the PFD and an aural warning is activated.



VERTICAL SPEED
TARGET READOUT





GF0410_065

- When VS mode is active, the pitch angle is limited to ± 20°. The vertical speed commands are from -8000 feet/minute to +6000 feet/minute.

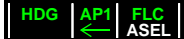
MODES OF OPERATION: (VERTICAL) (CONT'D)

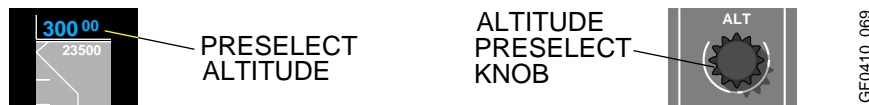
Vertical Speed (VS) Select (Cont'd)

VS mode is activated by selecting  on guidance panel. VS mode is annunciated in the vertical capture field on the PFD. VS mode is cleared by selecting another vertical mode.  will flash for 5 seconds, when active.


Altitude Select (ASEL) Mode

ASEL mode provides for automatic capture, flare and level off onto a preselected altitude.


ASEL is armed automatically  when the airplane is flying at a continuous vertical rate of greater than 60 feet/minute towards preselected altitude displayed on PFD for 1 second. The preselected altitude is adjusted via the altitude preselect knob on the guidance panel.



ASEL will capture when ascending toward the preselect altitude and preselected altitude is within 2000 feet of current altitude and the altitude rate required to fly a constant 0.05 G capture curve is less than the current airplane internal climb rate.

ASEL will capture when descending toward the preselect altitude and the preselected altitude is within 10,000 feet of current altitude and the altitude rate required to fly a constant 0.05 G capture curve is less than the current airplane internal descent rate. 

Departure from selected altitude will be followed by an aural “ALTITUDE” and an aural “C Chord”

FGC will generate pitch commands to capture the preselect altitude displayed on the selected PFD. Pitch angle is limited to $\pm 20^\circ$. Once the reference altitude is reached, the altitude hold mode is activated. 

NOTE


When ASEL is the active (green) vertical mode, and the ALT preselector has not been changed, selection of any other vertical modes other than GS is inhibited.

Attempting to select any vertical mode on the guidance panel while ASEL is active, the ASEL annunciation on the PFDs shall flash for 5 seconds to indicate acknowledgement of the button press.

While ASEL is active, preselecting the next altitude will enable selection of FLC or VS mode.

Altitude Hold (ALT) Mode

ALT mode is used to maintain a barometric altitude reference.

ALT mode is activated automatically following preselect altitude capture, or can be activated manually via  on the guidance panel to maintain a barometric altitude at time of selection.


MODES OF OPERATION: (VERTICAL) (CONT'D)

Altitude Hold (ALT) Mode (Cont'd)

If the ALT mode is selected when the airplane is in a climb or descent, FGC will generate pitch commands to zero the vertical speed and capture the selected altitude.

The pilot may select another altitude reference without cancelling ALT mode by depressing the TCS button, and maneuvering the airplane to a new altitude.

The ALT mode will use a baro-corrected altitude and respond to baro knob changes to airplane pitch angle up to ± 20° limit.

ALT mode is annunciated in the vertical capture field on the PFD.  will flash for 5 seconds, when active.

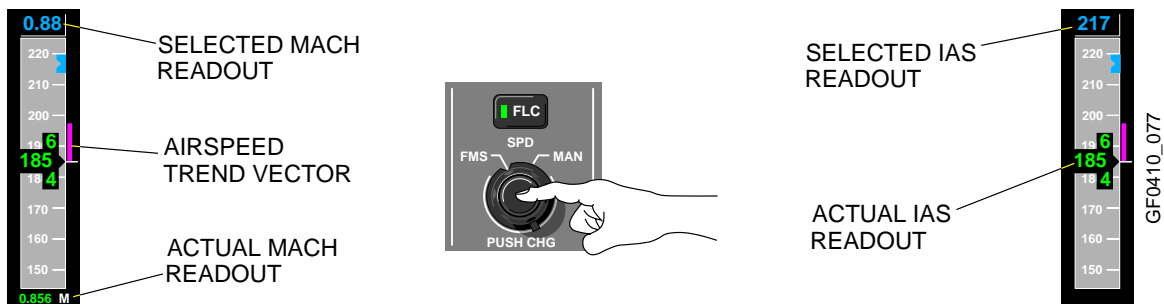
Flight Level Change (FLC) Mode

FLC mode is used to climb or descend to a new altitude reference, while maintaining an Indicated Airspeed, or Mach reference. FLC mode is selected via flight level change switch on the guidance panel and is automatically active. FLC is cleared when another armed vertical mode is capture.

FLC mode is selected on guidance panel  and is automatically active. 

FLC is cleared when another armed vertical mode is captured. 

FGC will generate pitch commands to capture and track the speed reference displayed on the selected PFD. To obtain Mach readout, Mach must be greater or equal to 0.40 M.

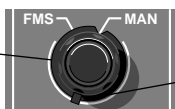


Automatic transfer from IAS to Mach speed reference will occur in climb, above 32,400 feet. Automatic transfer by pushing the SPD PUSH CHG button. There is no auto transfer between IAS and Mach in MAN speed.

MAN speed selection is accomplished by selecting MAN on the outer knob and turning the inner knob on the SPD button. A cyan airspeed bug will follow the commands from the inner knob and is located on the airspeed tape of the selected PFD. Manual transfer from IAS to Mach speed reference can be accomplished by pushing the SPD PUSH CHG button.

Inner Knob

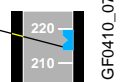
When rotated, sets speed on airspeed tape (MAN mode).



Outer Knob

When rotated, enables MAN mode or FMS mode of airspeed reference.

AIRSPEED BUG



FMS speed selection is programmed in the active flight plan in the FMS. A magenta speed bug will appear on the airspeed tape of both PFDs.

MODES OF OPERATION: (VERTICAL) (CONT'D)

Flight Level Change (FLC) Mode (Cont'd)



FMS IAS OR MACH
SPEED BUG



GF0410_079


If preselect altitude is above the airplane's present altitude and there is adequate thrust, FLC mode will climb at the speed reference until preselected altitude is captured. If thrust is inadequate, FLC mode will hold present airplane altitude until adequate thrust is applied.


If preselect altitude is below the airplane's present altitude and thrust is appropriate, FLC mode will descend at the speed reference until preselected altitude is captured. If thrust is excessive, FLC mode will decelerate the airplane at its present altitude.

FGC pitch guidance will not generate commands to exceed V_{mo} or M_{mo} . When a potential overspeed condition exists, FLC will command a pitch maneuver to maintain a speed reference 3 knots less than V_{mo} or M_{mo} .

VERTICAL NAVIGATION (VNAV) MODE

VNAV mode contains 4 vertical sub-modes that can be flown using speed and altitude targets, that are programmed in the active flight plan of the FMS. A double C-chord (aural) is activated for VNAV vertical track alerts. However, if the FD/AP active vertical mode is not a VNAV submode, the aural

vertical track alert is inhibited.  **Double C – chord**

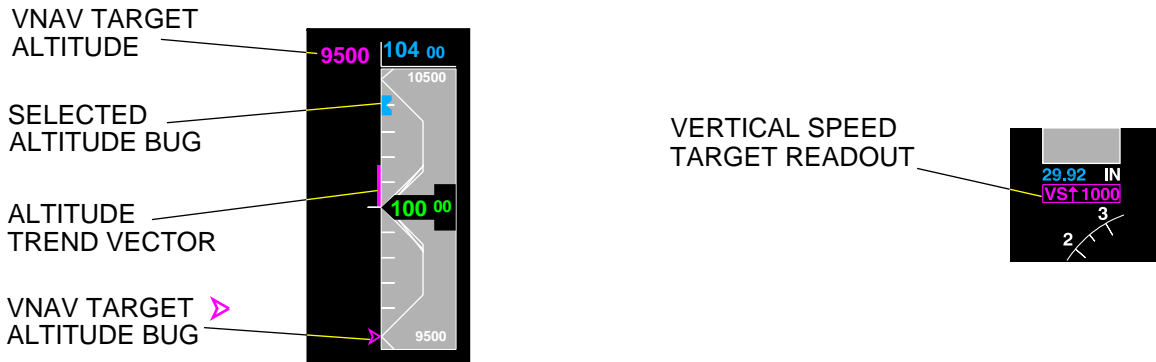
VNAV mode is activated by selecting  on guidance panel. The vertical mode active at the time shall remain engaged.

FMS sub-mode selections when in VNAV mode are as follows:




- **VFLC** – Operates identical to FLC mode, except that the target altitude from the FMS is used for climb or descent. The speed command is from the active displayed speed target (MAN or FMS) on the PFDs. VFLC will also engage if VALT is engaged and FMS initiates a climb or descent. Also if VALT or VPTH is engaged and FLC is selected on guidance
- **VPTH** – Used to fly a fixed flight path angle to a vertical waypoint during descent. VPTH will engage whenever FMS initiates a path descent which may occur while in VFLC or VALT

modes.  

A VNAV target altitude bug will appear on the altitude tape of selected PFD.




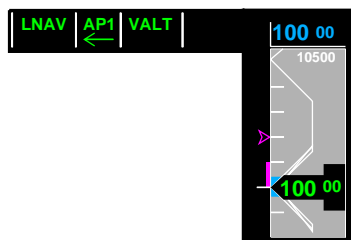
GF0410_084

- **VASEL**– Operates identical to ASEL mode. VASEL sub-mode will arm as soon as VFLC or VPTH is engaged.   

VASEL mode is cancelled whenever VALT mode engages.

- **VALT** – Operates identical to ALT mode. VALT sub-mode will engage automatically when VASEL has captured the target altitude. 

VALT will also engage whenever VNAV is activated  on guidance panel and airplane is within 250 feet of VNAV target altitude.



GF0410_088

MULTI-AXIS MODES

The following are multi-axis modes of operation:

Approach (LOC/GS, VAPP) Modes

The approach mode provides for automatic intercept, capture and tracking of the front course localizer and glideslope signals which enables the pilot to fly a fully coupled ILS approach. APR modes are based on vertical path deviation and valid glideslope on the selected PFD.

When APR mode is armed  , HDG is automatically active  .

ILS

ILS lateral/vertical capture and tracking is established, based on data from selected PFD.

The lateral beam must be captured before the vertical beam in order to prevent inadvertent descent.

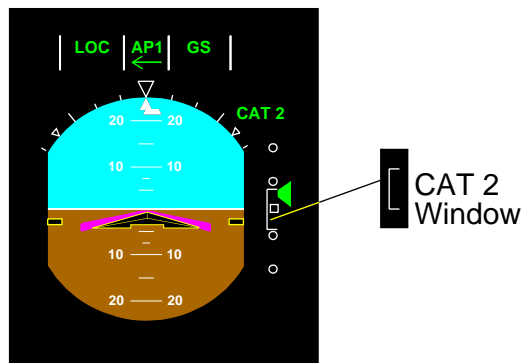
Distance and beam width estimates for the vertical axis are :

- The vertical distance is based on radio altitude information. If radio altitude information is not available, the distance estimate is based on vertical speed, middle marker beacon and an assumed initial altitude of 1500 feet. The beam width is based on the estimated distance, glideslope deviation, airspeed and an assumed glideslope angle of 3°. The beam width is fixed at $\pm 1^\circ$.

Tracking performance for glideslope mode is within ± 1 dot from 700 to 100 feet (radio altimeter).

ASEL is inhibited during glideslope capture.

During a CAT 2 approach, EFIS will monitor for excessive deviation from the beam and will provide appropriate annunciation. The outputs provided by AFCS (used by EFIS) in the determination of CAT 2 status are glideslope arm or capture and dual couple status. A valid CAT 2 status is indicated on the PFD. A CAT 2 window also appears to display deviation from the beam. The fully coupled (dual arrow) ILS approach becomes active when the aircraft is below 1200 feet AGL.



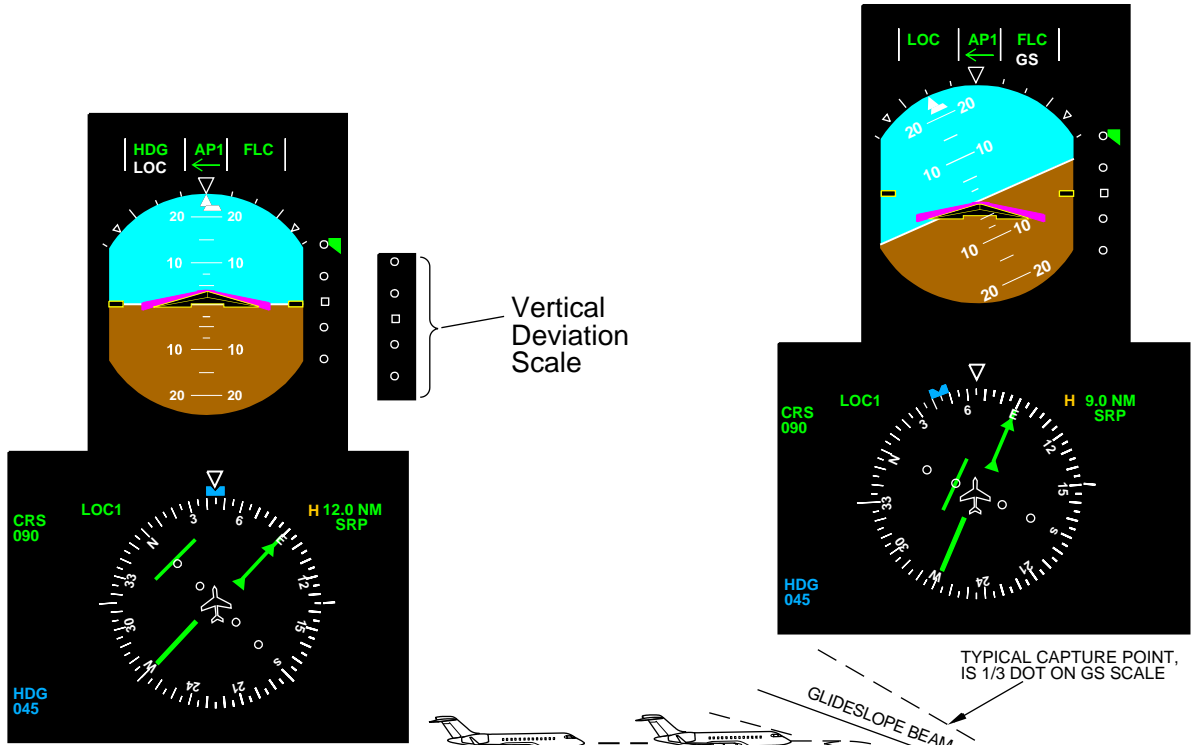
GF0410_091

VOR Approach (VAPP) Mode

VOR approach mode is identical to VOR mode except that, with flaps other than zero, the FGC sets bank limits and rate limits to ensure proper gain control and performance from VOR capture through the approach profile, to landing. FD roll commands are $\pm 30^\circ$ during VOR approach capture and roll rate commands 7°/sec. When track phase is active, FD commands are $\pm 14^\circ$ and roll rate commands 4°/sec.

MULTI-AXIS MODES (CONT'D)

Approach Mode



APPROACH MODE CAPTURE

APPROACH MODE INTERCEPT

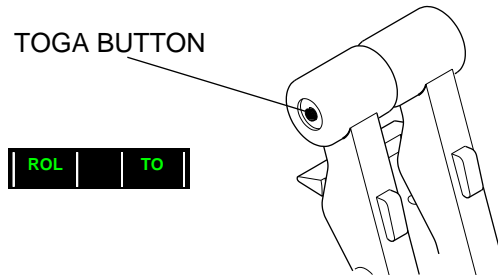
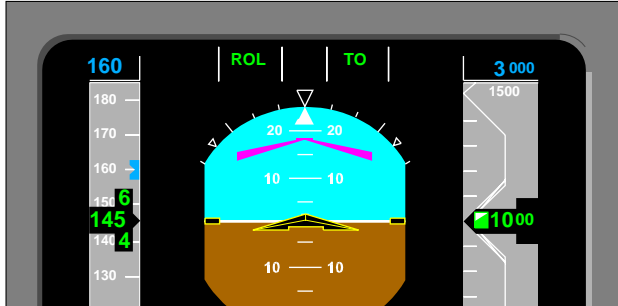
APPROACH MODE TRACK

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TAKE-OFF (TO) MODE

TO mode provides pitch and lateral commands during the take-off phase of flight.

TO mode is activated by pushing one of the throttle-mounted TOGA buttons, while on the ground. When TO mode is selected, all other lateral and vertical modes are cleared.



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TO mode is a heading submode of ROL. TO mode will track the current heading at the time the airplane passes 80 KIAS during the take-off roll.

Vertical TO mode generates a fixed pitch attitude of 17.5°, based on power being developed by the engines. In the event of a loss of an engine, ($N_1 < 70\%$ on either engine), the pitch command will be reduced to 13°.

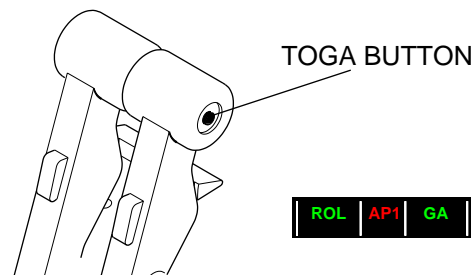
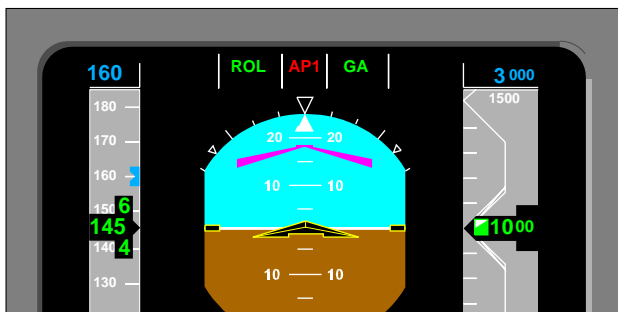
- The autothrottles will provide full takeoff thrust until TO mode is cleared.

TO mode can be cleared by selecting the AP on, or by selecting another vertical mode.

GO AROUND (GA) MODE

GA mode provides pitch and lateral commands for a transition from an approach to climb out condition, when a missed approach has occurred.

GA mode is activated by pushing one of the throttle-mounted TOGA buttons, while airborne. When GA mode is selected, autopilot is disengaged and all other lateral and vertical modes are cleared. The resultant AP disengage warning may be cancelled by pressing the AP DISC switch.



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The GA mode is a heading submode of ROL. GA mode will track the current heading at the time of GA selection.

GA mode will capture the preselected altitude under the following circumstances:

- If a BARO minimum was not set on the coupled PFD, GA will transition to ASEL and capture the altitude preselector;

GO AROUND (GA) MODE (CONT'D)

- If a BARO minimum was set on the coupled PFD and the altitude preselector is at least 500 ft higher than the BARO minimum, GA will transition to ASEL and capture the altitude preselector.

Vertical GA mode generates a fixed pitch attitude of 10° whether dual or single engine.

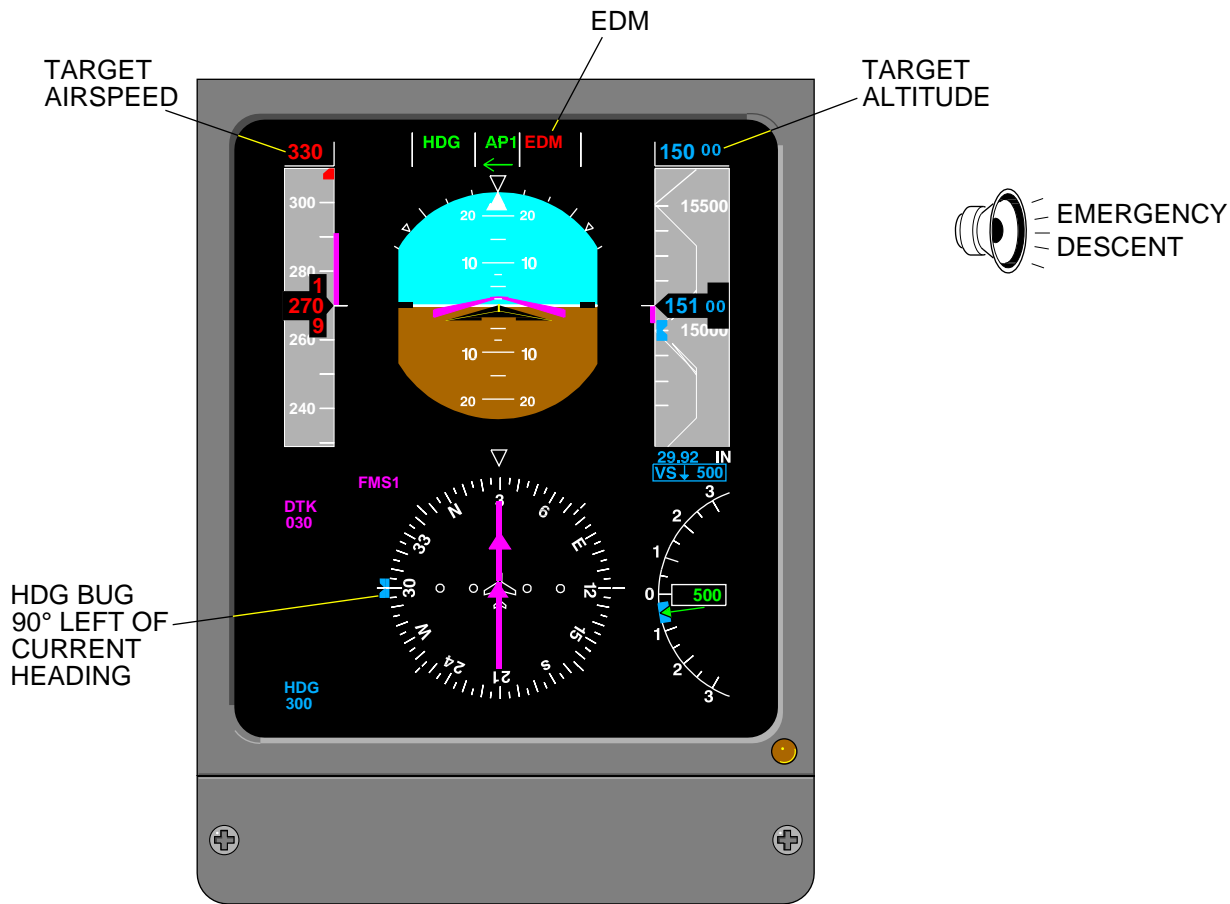
GA mode can be cleared by selecting the AP on, or by selecting another vertical mode.

AUTOMATIC EMERGENCY DESCENT MODE (EDM) (OPTIONAL)

■ The EDM mode provides vertical and lateral commands to the AFCS to descend and level the airplane in the case of flight crew incapacitation due to loss of cabin pressurization.

The EDM mode will be automatically activated when the following conditions are met:

- The autopilot is engaged
- The airplane pressure altitude is above 25,000 feet
- The cabin altitude exceeds 14,500 feet.



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■ In EDM mode the aural warning EMERGENCY DESCENT will be generated and an **EMERGENCY DESCENT** warning message will be posted on EICAS. Pressing the Master Warning/ Caution pushbutton will mute the aural warning. The aural warning CABIN ALTITUDE will be generated if the cabin altitude exceeds 9,000 feet. Pressing the Master Warning/ Caution pushbutton will mute the aural warning. If both the EMERGENCY DESCENT and CABIN ALTITUDE aural warnings are being generated a single press of the Master Warning/ Caution pushbutton will mute both aural warnings.

EDM will show as the flight director (FD) vertical mode and **HDG** will show as the FD lateral mode on the PFDs.

The preselected altitude will be automatically set to 15,000 feet or 4500 meters. The HDG bug will be automatically set to 90° left of the current heading. Both the HDG bug and the preselected altitude may be changed by the flight crew during emergency descent mode.

AUTOMATIC EMERGENCY DESCENT MODE (EDM) (OPTIONAL) (CONT'D)

The digital readout of the IAS/Mach will be displayed in red on the PFDs. The target airspeed will follow $V_{mo}-10$. A target speed of 250 KIAS will be selected when the ASEL FD mode becomes active.

- The FD will fly a HDG/FLC descent to 15,000 feet. The FD will transition to ASEL mode and then ALT when levelling off at 15,000 feet. The EDM annunciation will flash for 5 seconds when transitioning between modes.

The FD will remain in EDM mode until the autopilot is disengaged. The only way to cancel EDM mode is to disengage the autopilot. The autopilot can be disengaged at anytime while in EDM mode. Pressing the TCS switches longer than one second will be considered as disengaging the autopilot. When the autopilot is disengaged, the FD modes will be the lateral and vertical modes that were active at the time.

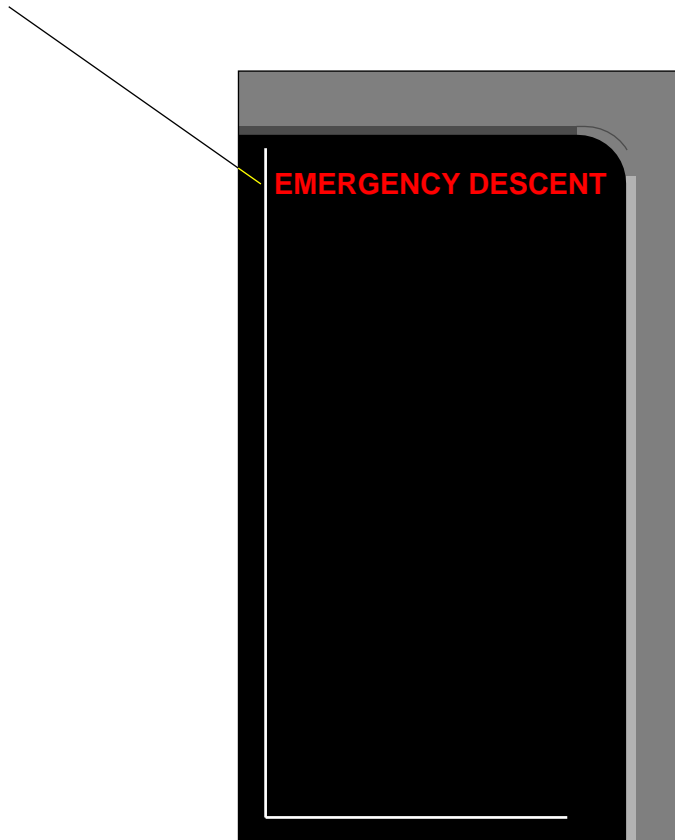
- Autothrottle automatic engagement will only occur upon initiation of EDM. Autothrottle can be manually disengaged and re-engaged while in EDM. Autothrottle will not be re-engaged automatically if disengaged.

The **EMERGENCY DESCENT** CAS message will be recorded by the FDR when posted.

AUTOPILOT - FLIGHT DIRECTOR EICAS MESSAGES

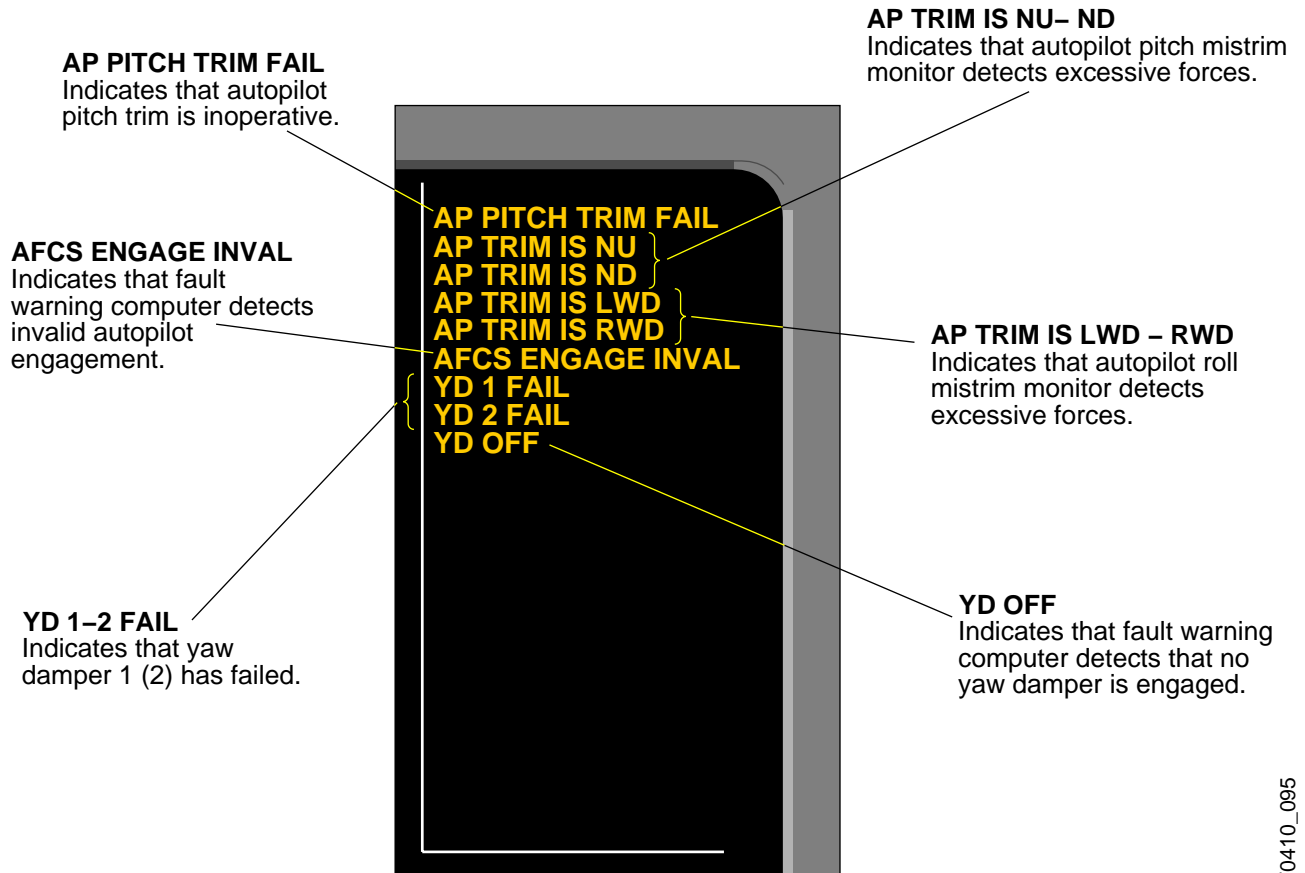
EMERGENCY DESCENT

Indicates that the AFCS is in automatic emergency descent mode.



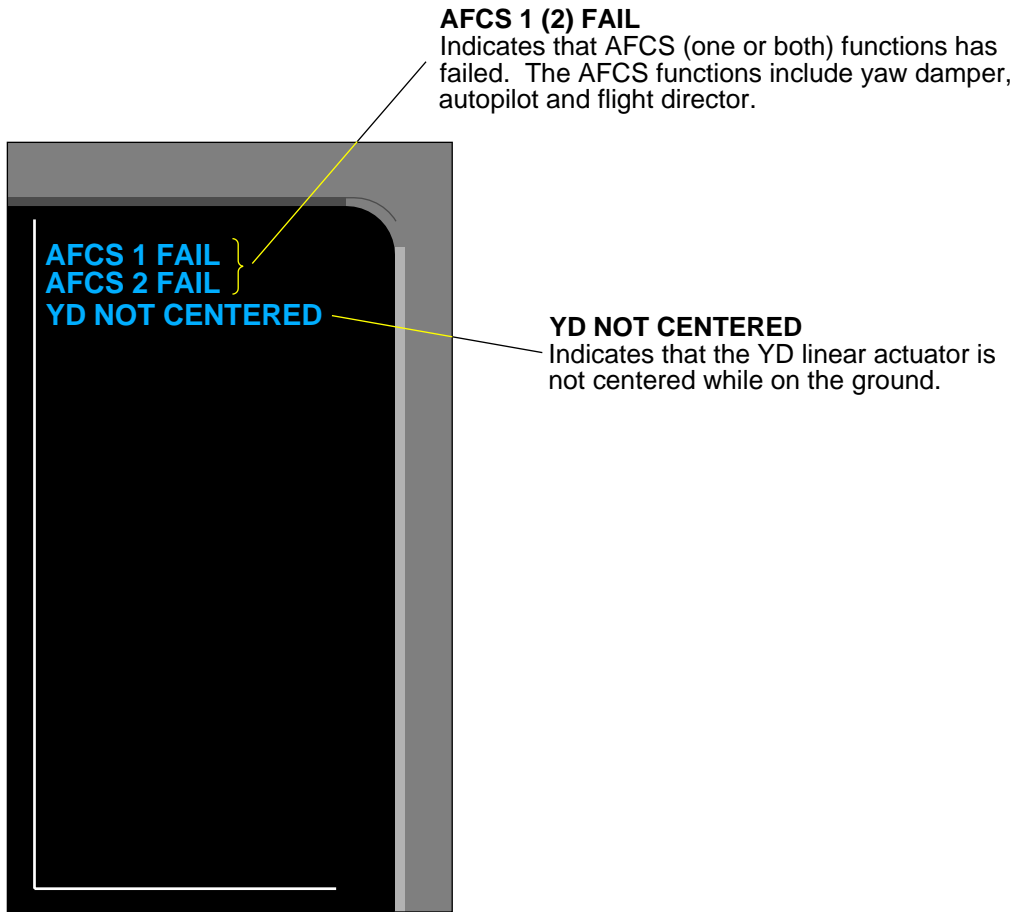
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AUTOPILOT - FLIGHT DIRECTOR EICAS MESSAGES (CONT'D)



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AUTOPILOT - FLIGHT DIRECTOR EICAS MESSAGES (CONT'D)

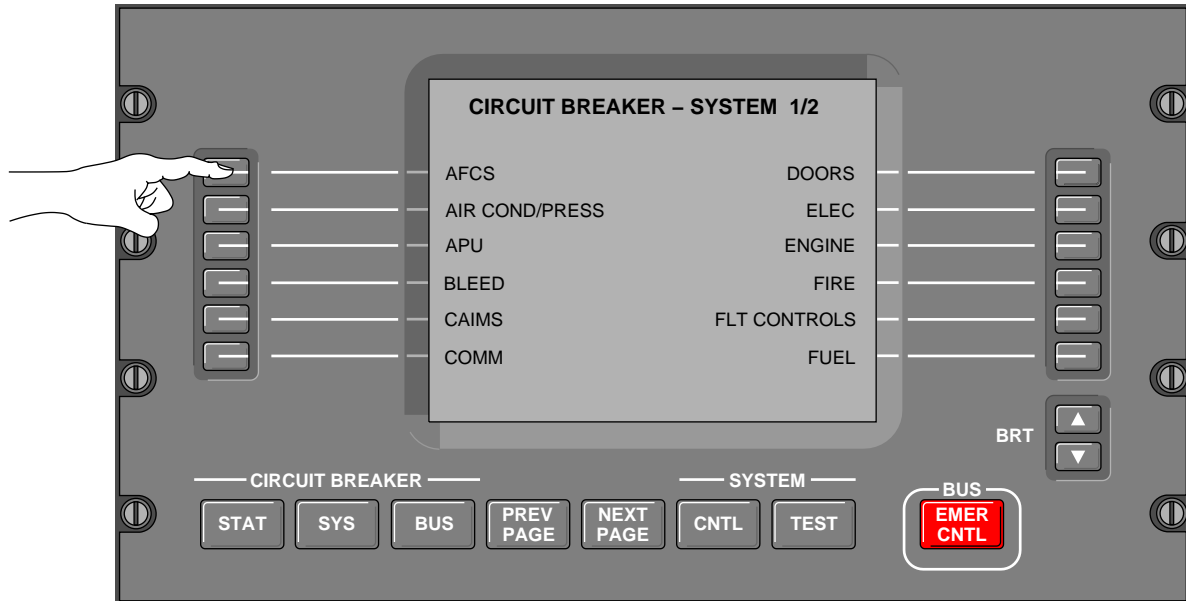


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AUTOMATIC FLIGHT CONTROL SYSTEM

EMS CIRCUIT PROTECTION

CB - AFCS SYSTEM



CB - AFCS SYSTEM		1/3	
A/T CTLR	AC 1	CCBP	IN
A/T SERVOS	DC 1		IN
AP 1 SERVOS	DC 1		IN
AP 2 SERVOS	DC 2		IN
GUID PANEL CH 1	BATT		IN
GUID PANEL CH 2	DC ESS		IN

CB - AFCS SYSTEM		2/3	
IAC 1	BATT		IN
IAC 2	DC ESS		IN
IAC 3	BATT		IN
YD 1	BATT		IN
YD 2	DC ESS		IN
YD HEAT 1	DC 1		IN

CB - AFCS SYSTEM		3/3	
YD HEAT 2	DC 2		IN

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**AUTOMATIC FLIGHT CONTROL SYSTEM
EMS CIRCUIT PROTECTION**

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