

SECTION 4

AUTOMATIC FLIGHT CONTROL SYSTEM

TABLE OF CONTENTS

	Page
1. GENERAL	1
A. Flight Director Function	1
B. Autopilot Function	4
C. Advisory Display	4

LIST OF ILLUSTRATIONS

Figure Number	Title	Page
1	Automatic Flight Control System - Simplified Block Diagram	5
2	Flight Director Function Related Controls - Flight Guidance Controller (3 sheets)	6
3	Flight Director Function Related Controls - Instrument Remote Controllers	9
4	Flight Director Function Related Displays - EFIS EADI	10
5	Flight Director Function Related Failure Displays - EFIS EADI	11
6	Flight Director Function Related Displays - EFIS EHSI	12
7	Autopilot Function Related Controls - Flight Guidance Controller (2 Sheets)	13
8	Autopilot Function Related Controls - Turn and Pitch Controller	15
9	Autopilot Function Related Controls - Remote Switches and Annunciators (2 Sheets)	16
10	Autopilot Function Related Display - EFIS EADI	18
11	AFCS - Advisory Display	19
12	Advisory Display - Display Format	20

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OPERATING MANUAL
PSP 601A-6

Figure Number	Title	Page
13	Advisory Display - Flight Director Lateral and Vertical Arm Modes	21
14	Advisory Display - Flight Director Lateral and Vertical Active Modes	21
15	Advisory Display - SAT/TAT/TAS Displays	22
16	Advisory Display - Warning Disengage Messages (Amber Flashing)	22
17	Advisory Display - Caution Disengage Messages (Amber Steady)	23
18	Advisory Display - Primary Caution Messages (Amber Steady)	23
19	Advisory Display - Advisory Caution Messages (Amber Steady)	24
20	Advisory Display - Sensor Failure Messages (Amber Steady)	25
21	Advisory Display - AFCS Status Messages	25
22	Advisory Display - Invalid Operation Messages (Amber Steady)	26

SECTION 4

AUTOMATIC FLIGHT CONTROL SYSTEM

1. GENERAL

The automatic flight control system (AFCS) processes actual aircraft attitude versus desired aircraft attitude to provide control of the aircraft's control surfaces and to provide command signals for display on the electrical flight instrument system (EFIS).

The AFCS provides flight director guidance, autopilot and stability augmentation functions.

The AFCS consists of the flight guidance computer, the flight guidance controller, the turn and pitch controller and the following associated systems:

Digital air data system (DADS), refer to Section 11

Radio altimeter system, refer to Section 16

Inertial reference system (IRS), refer to Section 16

Electronic flight instrument system (EFIS), refer to Section 11

Flight management system (FMS), refer to Section 16

A. Flight Director Function (Figures 1 through 6)

The flight director function produces lateral and vertical control command signals for the autopilot function roll and pitch axis and also for display on the EFIS. All flight director modes are selectable on the flight guidance controller, with the exception of the go around (GA) mode, which is selected from the GA switches on the throttle actuating levers.

The flight director roll (lateral) modes consist of the following:

- Heading select mode (HDG)
- VOR mode (NAV)
- Lateral navigation mode (NAV)
- Localizer mode (NAV)
- Localizer approach mode (APP)
- Back course mode (BC)
- Preselect course approach mode
- Category 2 mode (CAT 2)

The flight director pitch (vertical) modes consist of the following:

- Pitch attitude hold mode
- Vertical speed hold mode (VS)
- Flight level change mode (FLC)
- Attitude hold mode (ALT)
- Altitude preselect mode (ALT SEL)
- Glideslope mode (APP)
- Dual couple approach mode
- Vertical navigation mode (VNAV)

The flight director command signals are indicated on the pilot's and copilot's EFIS electronic attitude director indicators (EADI) by the flight director command bars. When the autopilot function is not engaged, the command bars indicate to the pilot, the maneuvers required to maintain the aircraft attitude for the selected flight director mode. When the autopilot function is engaged, the command bars indicate the commands followed by the autopilot function to maintain the aircraft attitude for the selected flight director mode.

The pilot's and copilot's EADIs and the advisory display provide an indication of the selected flight director mode(s). The modes are displayed in green when active and in white when armed. Modes without armed submodes are displayed in green only.

On the pilot's and copilot's EADIs, the flight director lateral and vertical modes are annunciated as follows:

<u>Lateral modes</u>	<u>Vertical Modes</u>
HDG (captured only)	ASEL (captured only)
VOR (armed and captured)	GS (armed and captured)
BC (armed and captured)	FLC (captured only)
LOC (armed and captured)	VFLC (captured only)
LNAV (armed and captured)	VASL (captured only)
	VALT (captured only)
	VPTH (captured only)
	VS (captured only)
	ALT (captured only)
	GA (captured only)
	MACH (captured only)

When a flight director mode changes from armed to captured, the green mode annunciation flashes for 5 seconds to indicate the submode transition.

The advisory display also provides an indication of the flight director mode(s) selected (refer to paragraph 1.C.).

The pilot's and copilot's electronic horizontal situation indicators (EHSI) provide for lateral flight director mode set-ups, and the pilot's and copilot's EADIs provide for vertical flight director mode set-ups. The pilot's and copilot's EFIS instrument remote controllers provide the controls for both the lateral and vertical flight director mode set-ups.

The lateral navigation (LNAV) and vertical navigation (VNAV) flight director modes (VFLC, VASL, VALT and VPTH) are selected and set up on the flight management system (refer to Section 11).

B. Autopilot Function (Figures 1 and 7 through 10)

The autopilot system responds to command signals from the flight director function (refer to paragraph 2.), the flight guidance controller, the air data system, the attitude and heading system and the accelerometers to control the aircraft attitude in the pitch, roll and yaw axes.

When a vertical or lateral flight director mode is selected and the autopilot function is engaged, the selected flight director steering command is displayed on the EFIS and control is provided for the associated servo-drive motors and linear actuators. These servo-drive motors and linear actuators consist of two rudder linear actuators for yaw axis control, a dual aileron servo for roll axis control and a dual elevator servo for pitch axis control (refer to Section 10).

When the autopilot function is engaged without a selected flight director mode, the autopilot function provides wings level, heading hold and pitch hold mode functions, controlled from the turn and pitch controller.

The autopilot function also consists of a pitch trim function and a Mach trim function.

The pitch trim function is automatically activated when the autopilot function is engaged. The computed pitch trim command signal is applied to the pitch trim system (refer to Section 10).

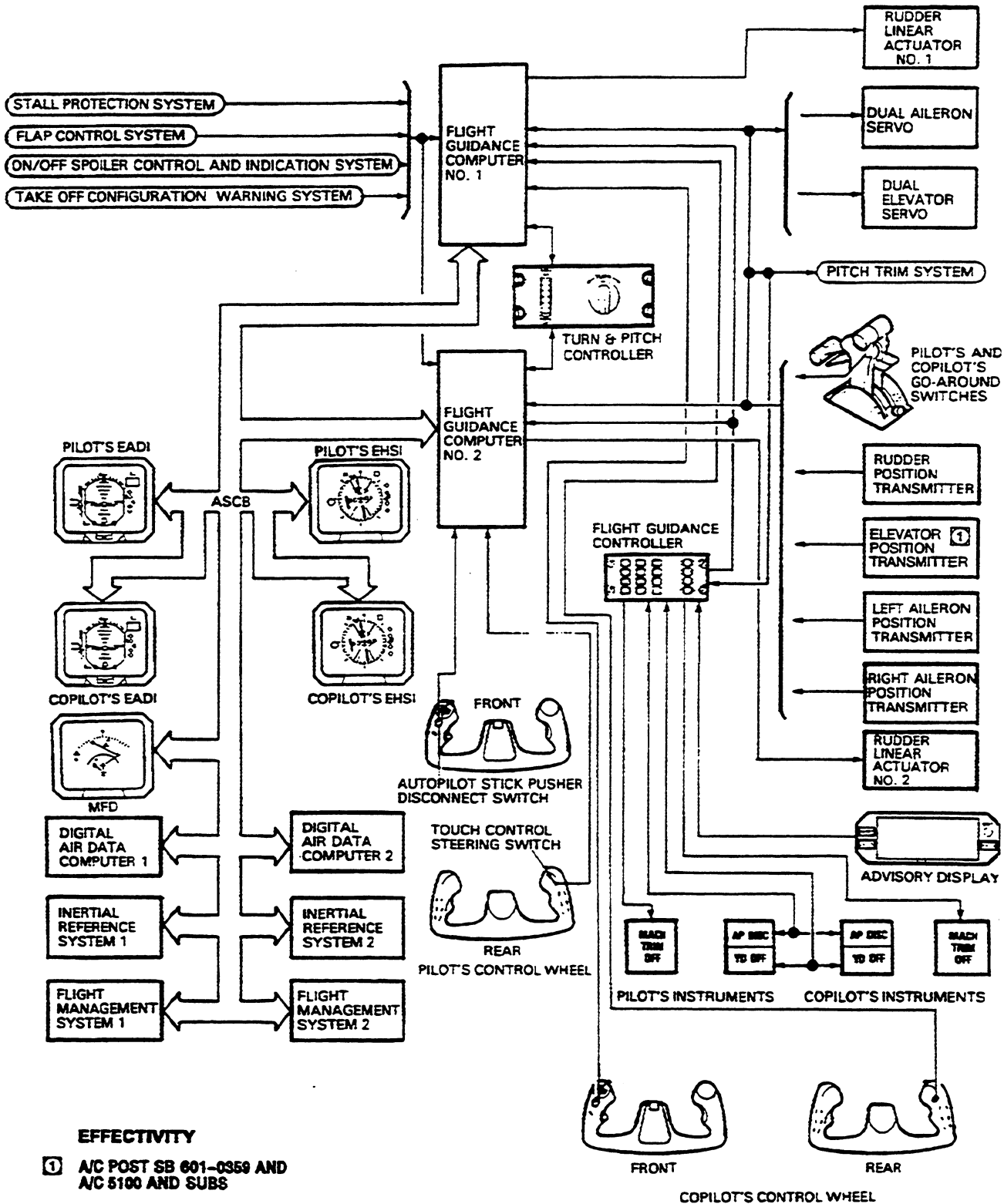
The Mach trim function is selected by pressing the M TRIM pushbutton on the flight guidance controller (refer to Figure 2 (Sheet 3)). The computed Mach trim command signal is applied to the pitch trim system (refer to Section 10).

The EFIS electronic attitude director indicator (EADI) and the advisory display (refer to paragraph 1.C.), provide an indication of the autopilot status.

C. Advisory Display (Figures 11 through 22)

The advisory display provides warning, caution, status failure and invalid operation messages, and air data and flight director mode status. Low priority messages are inhibited during heavy work load periods, such as take-offs and landings.

In addition to the display functions, the advisory display provides controls for AFCS selection, message resetting and display brightness.



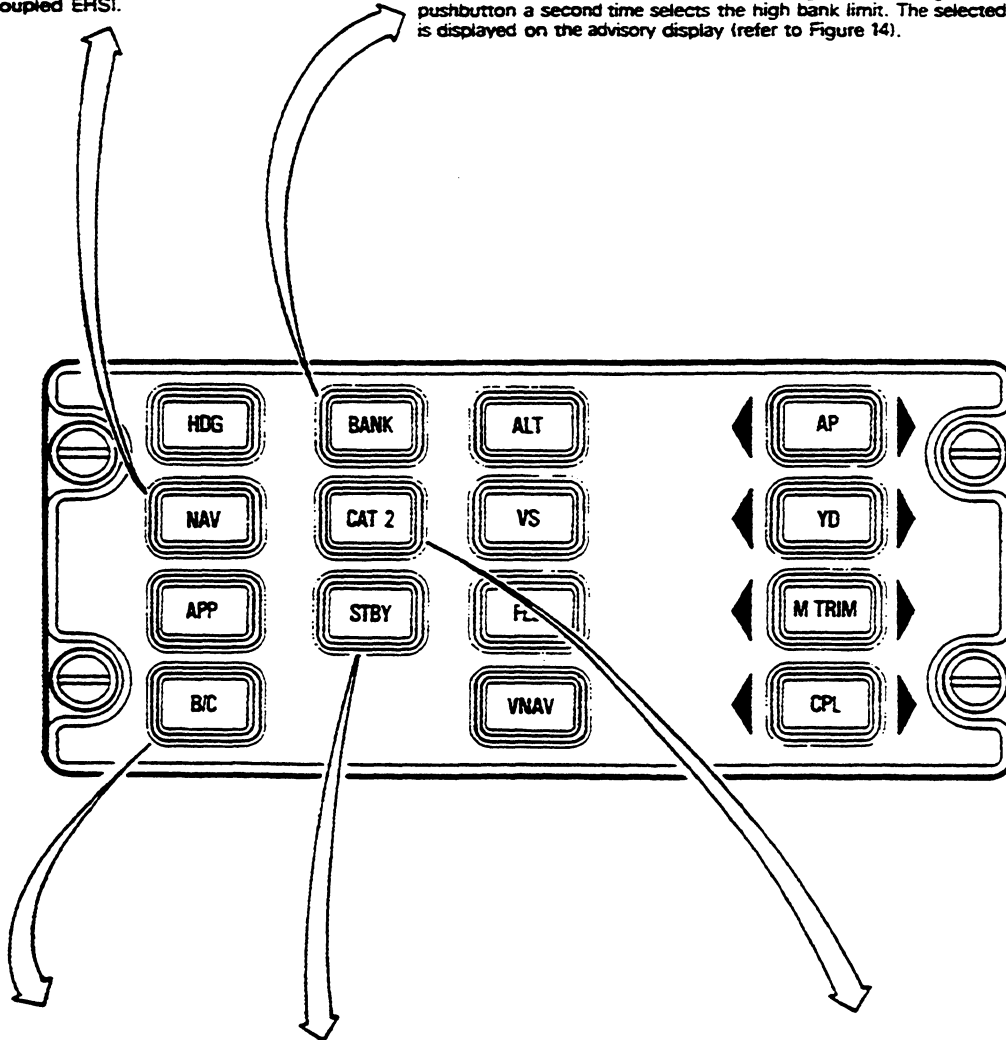
Automatic Flight Control System -
Simplified Block Diagram
Figure 1

NAV PUSHBUTTON

When pressed, arms the lateral guidance for capture of the selected navigation course displayed on the coupled EHSI.

BANK PUSHBUTTON

When pressed, selects the bank angle limit used during the HDG select mode. At power on, the high bank limit (27 degrees) is selected. Pressing the BANK pushbutton selects the low bank limit (17 degrees). Pressing the BANK pushbutton a second time selects the high bank limit. The selected bank limit is displayed on the advisory display (refer to Figure 14).



B/C PUSHBUTTON

When pressed, selects the approach mode guidance for capture and tracking of back course ILS data.

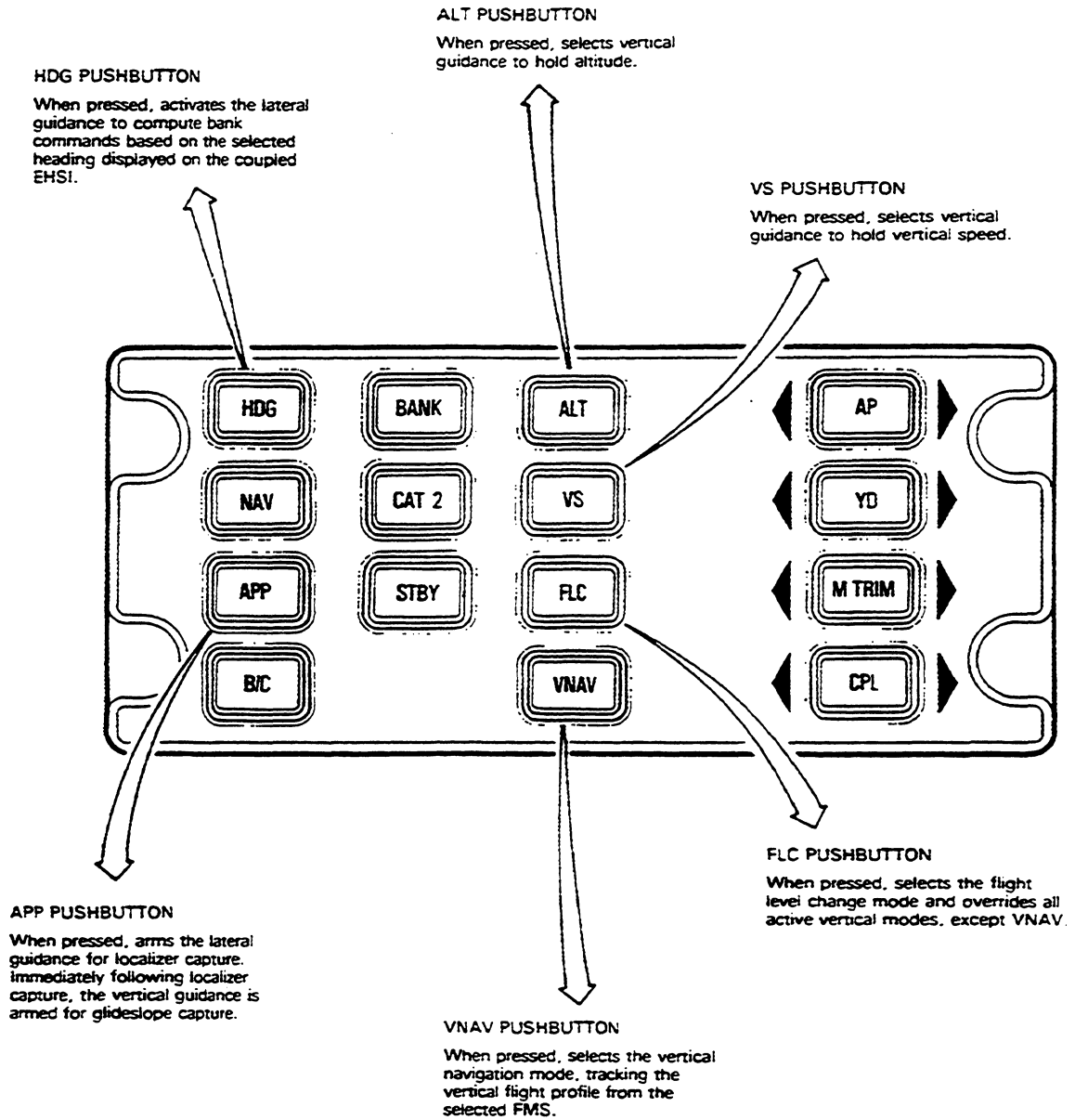
STBY PUSHBUTTON

When pressed, clears all flight director modes.

CAT 2 PUSHBUTTON

When pressed, activates the category 2 approach logic for annunciation of CAT 2 STATUS, provided that the approach (APP) mode is armed and radio altitude is greater than 800 feet.

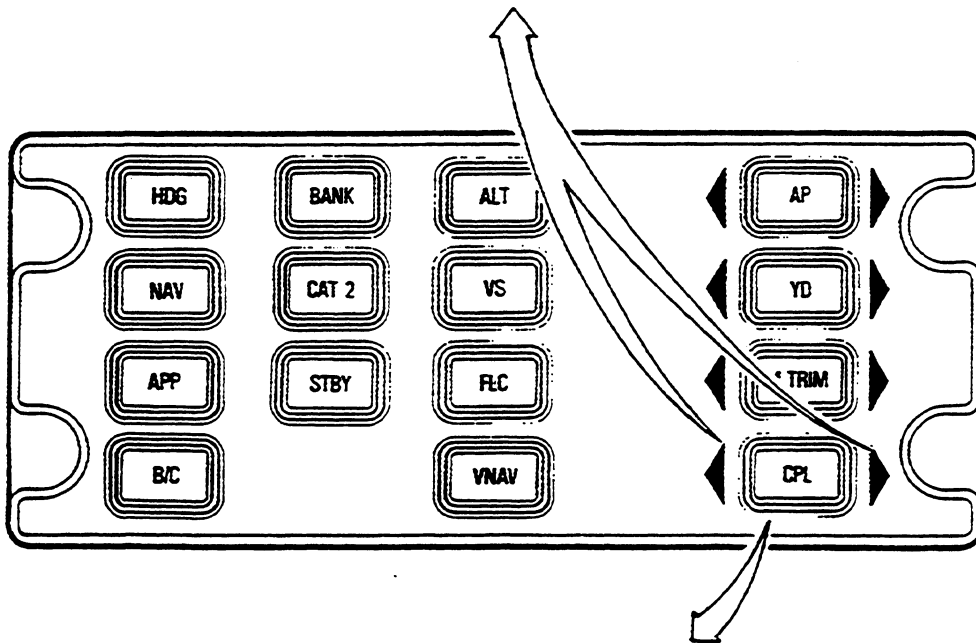
GLARESHIELD



GLARESHIELD

CPL POINTERS

Indicate whether the pilot's EHSI and DADC is coupled to the master FGC (left pointer) or the copilot's EHSI and DADC is coupled to the master FGC (right pointer). During an ILS approach, the AFCS automatically selects the data from both sides (both pointers come on). If one side fails, the remaining good side is selected.



CPL PUSHBUTTON

When pressed, selects either the pilot's or copilot's EHSI and DADC data for lateral and vertical flight guidance to the FGC 1 and FGC 2. During transfer, all flight director modes are cancelled. At power up, the pilot's data is selected. Pressing the CPL pushbutton selects the copilot's data. Pressing it a second time reselect the pilot's data.

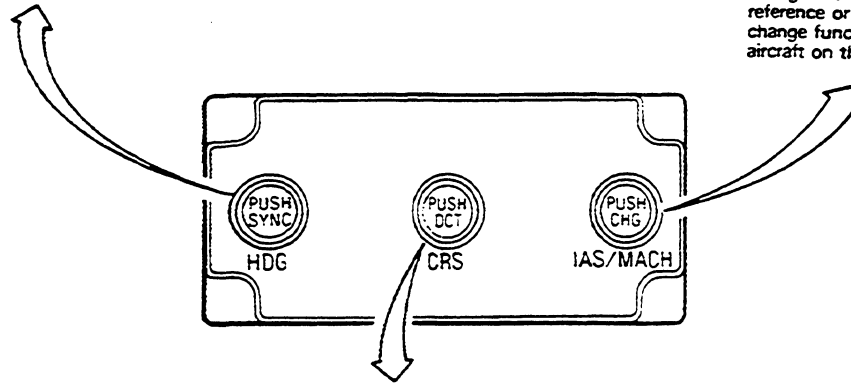
GLARESHIELD

HDG PUSH SYNC PUSHBUTTON

When rotated, moves the heading bug on the pilot's EHSI. When pressed, causes the heading bug to synchronize to the aircraft heading.

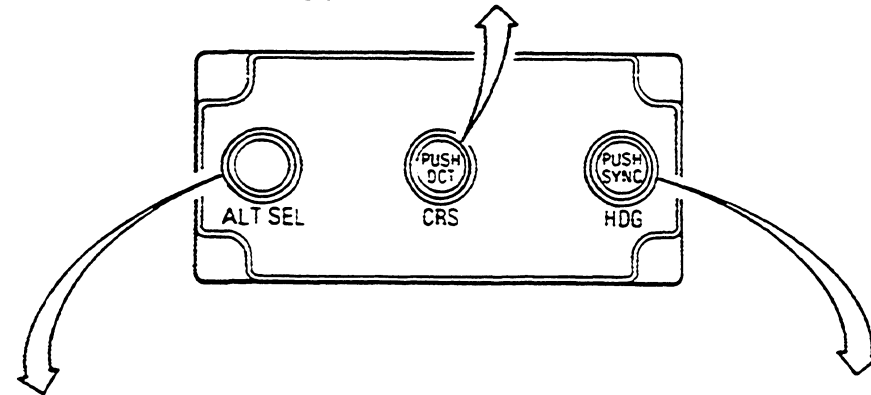
IAS/MACH PUSH CHG CONTROL/ SWITCH

When rotated, adjusts the IAS/Mach reference on the pilot's and copilot's EADIs. When pressed, change the IAS reference to Mach reference or vice versa. The push-to-change function is inhibited with the aircraft on the ground.



CRS PUSH DCT CONTROL/ SWITCH

When rotated, moves the course select pointer on the associated EHSI. When pressed, causes the course pointer to indicate the zero deviation course to the tuned VOR station. When an FMS source is selected, rotating the control causes the preselect course pointer to move.



ALT SEL CONTROL

When rotated, adjusts the ASEL display on the pilot's and copilot's EADIs.

HDG PUSH SYNC PUSHBUTTON

When rotated, moves the heading bug on the copilot's EHSI. When pressed, causes the heading bug to synchronize to the aircraft heading.

GLARESHIELD

**FLIGHT DIRECTOR COUPLE
ARROW**

Indicates whether the pilot's side or copilot's side is coupled to the AFCS. The couple arrow is displayed in green when on-side the FGC is master and yellow when the cross-side FGC is master.

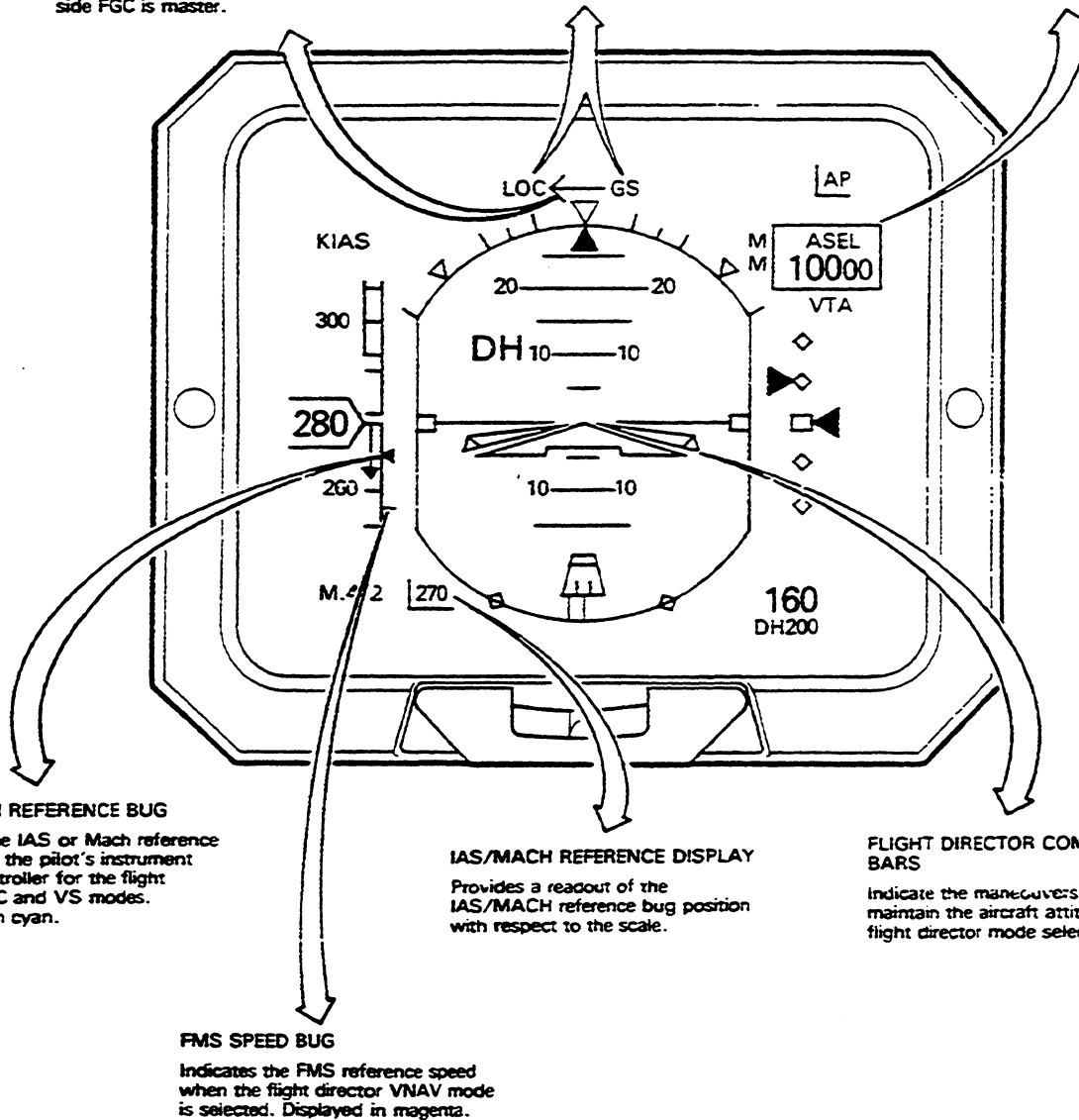
**FLIGHT DIRECTOR MODE
ANNUNCIATIONS**

Indicate the selected flight director mode(s) and the status of the mode. Armed modes are displayed in green and captured modes are displayed in white.

ASEL DISPLAY

Displays the selected altitude in the flight director ASEL mode. Range is from 0 to 60,000 feet, selectable in 100 foot increments.

When the on-side EHSI and DADC are coupled to the master FGC, the display and surrounding box are displayed in cyan. When the cross-side EHSI and DADC are coupled to the master FGC, the surrounding box is changed to yellow.



PILOTS AND COPILOTS INSTRUMENT PANELS

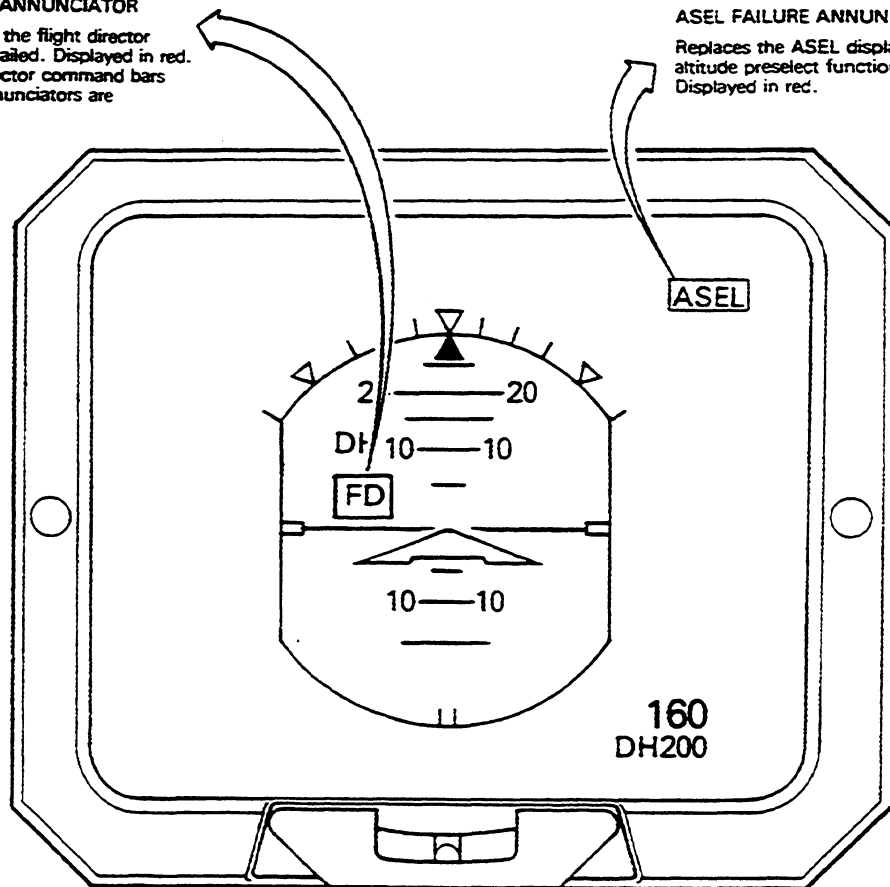
Flight Director Function Related
Displays - EFIS EADI
Figure 4

FD FAILURE ANNUNCIATOR

Indicates that the flight director function has failed. Displayed in red. The flight director command bars and mode annunciators are removed.

ASEL FAILURE ANNUNCIATION

Replaces the ASEL display when the attitude preselect function fails. Displayed in red.



PILOT'S AND COPILOT'S INSTRUMENT PANELS

CRS/DTK DISPLAY

Provides a numeric readout of the course select/desired track pointer position with respect to the heading dial. When an FMS source is selected, the CRS display replaces the DTK display for 5 seconds after the CRS PUSH DCT control is moved, in order to display the course preselect position. Displayed in green, yellow or magenta (consistent with the course select/desired track and course preselect pointers).

COURSE SELECT/DESIRED TRACK POINTER

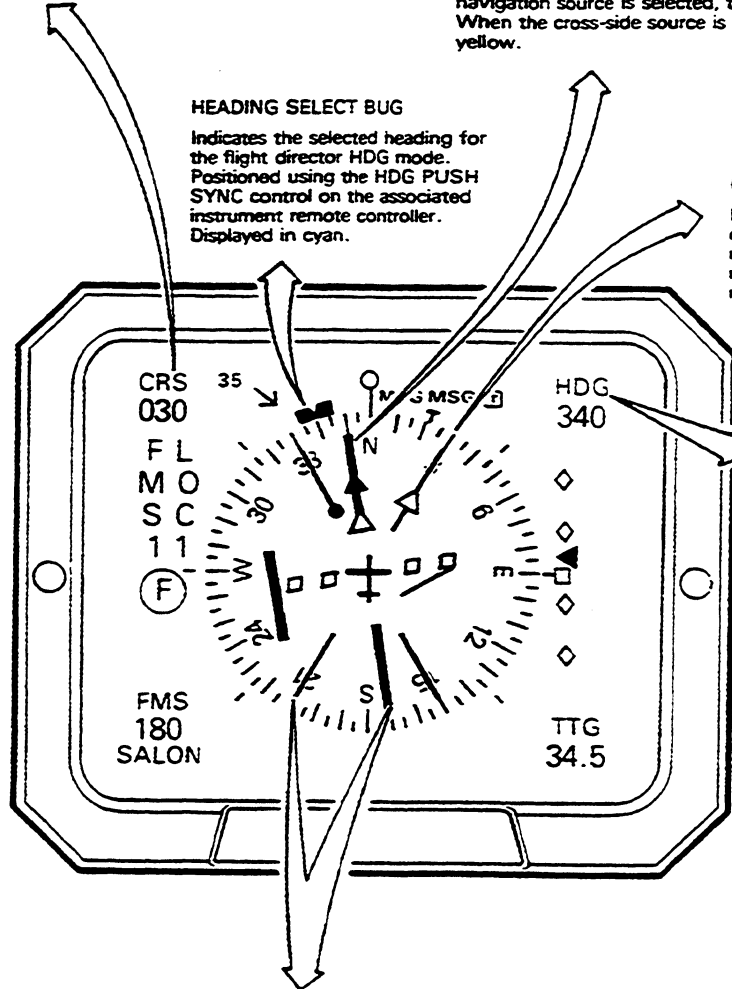
Indicates the selected course for the flight director navigation (SRN: NAV and APP flight director modes) or the desired track for the long range navigation (LRN) LNAV flight director mode. When the SRN VHF/NAV system is used, the course select pointer is positioned using the CRS PUSH DCT control on the associated remote instrument controller. When the LRN FMS source is selected the desired track pointer is positioned by the FMS. When the on-side navigation source is selected, the pointer is green. When the cross-side source is selected, the pointer is yellow.

HEADING SELECT BUG

Indicates the selected heading for the flight director HDG mode. Positioned using the HDG PUSH SYNC control on the associated instrument remote controller. Displayed in cyan.

COURSE PRESELECT POINTER

Indicates the preselected localizer course for the flight director APP mode, when the FMS is the selected navigation source. Displayed in magenta.



HEADING SELECT DISPLAY

Provides a numeric readout of the heading select bug position with respect to the heading dial. Displayed in cyan.

COURSE SELECT AND COURSE PRESELECT RECIPROCAL POINTERS

Indicate the selected back course for the flight director BC mode. Colour is consistent with the course select and course preselect pointers.

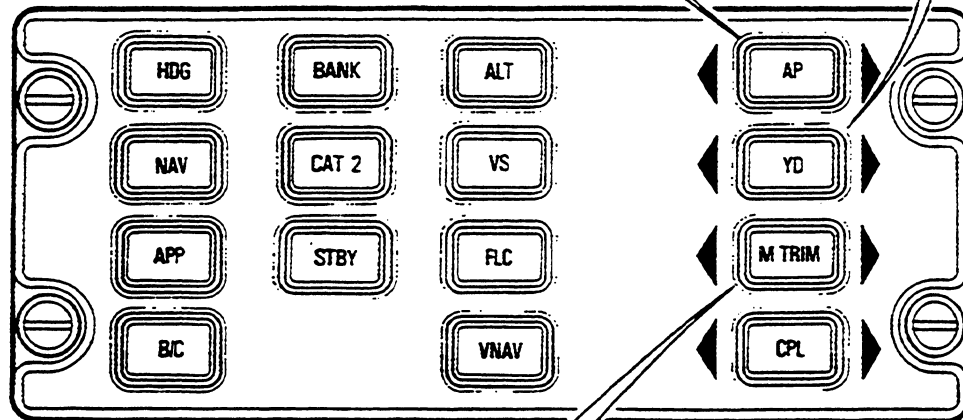
PILOT'S AND COPILOT'S INSTRUMENT PANELS

AP PUSHBUTTON

When pressed, engages the autopilot and yaw damper functions simultaneously. When pressed a second time, the autopilot is disconnected but the yaw damper function remains on.

YD PUSHBUTTON

When pressed, engages the yaw damper function. Pressing the YD pushbutton a second time disengages the YD function.



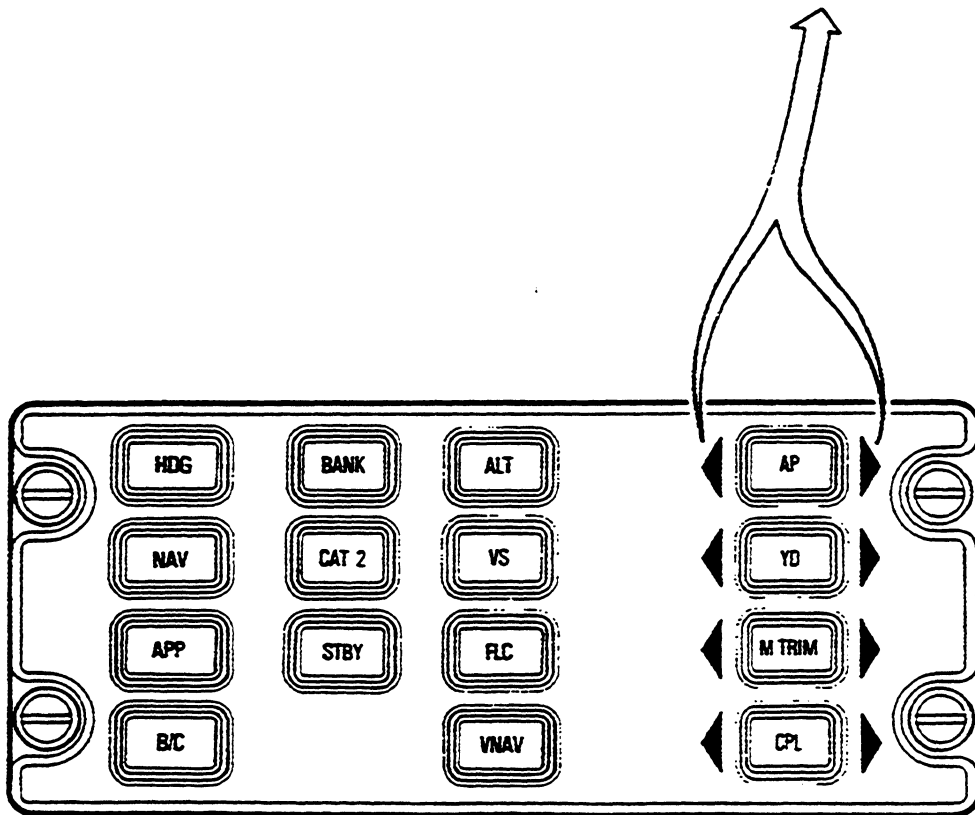
M TRIM PUSHBUTTON

When pressed, selects the Mach trim function which stays active even when the autopilot is engaged, permitting the Mach trim function to engage automatically when the autopilot is disengaged. Pressing the M TRIM pushbutton a second time disengages the Mach trim function.

GLARESHIELD

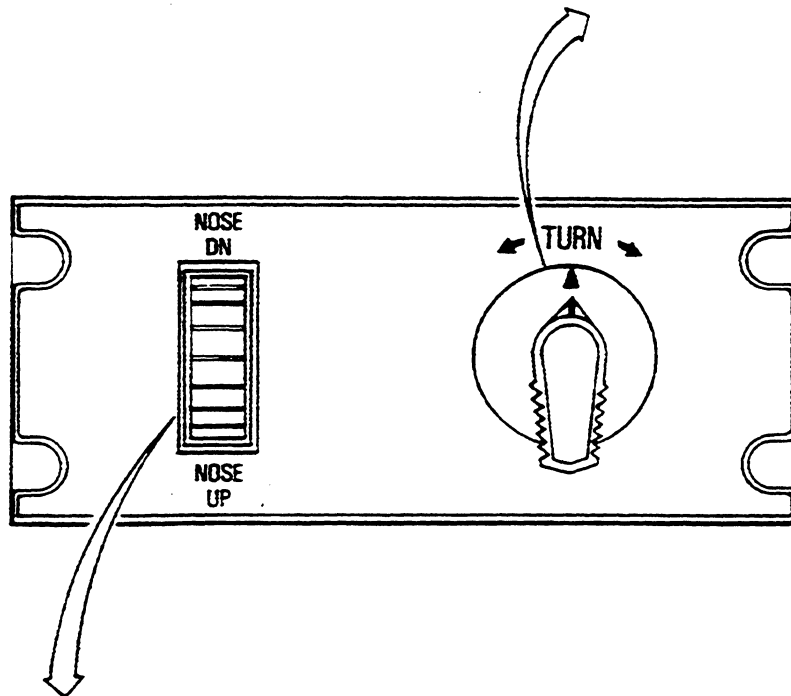
AP, YD, M TRIM AND CPL POINTERS

Left and right pointers indicate the coupled AFCS. When the selected function is operating in a normal no failure condition, the pilot's AFCS is automatically coupled and the left pointer comes on. The copilot's AFCS can be selected by pressing the R AFCS pushbutton on the advisory display. When the copilot's side is engaged, the right pointer comes on.



TURN KNOB

Provides bank commands to the autopilot (FGC 1 and FGC 2) proportional to knob displacement. When rotated out of detent (centre position), the lateral mode selected on the flight director is cancelled automatically. When returned to the detent position, a lateral mode can be reselected. The autopilot can not be engaged if the TURN knob is out of detent.



NOSE DN - NOSE UP WHEEL

Moving the NOSE DN - NOSE UP wheel (pitch wheel) changes the pitch attitude proportional to the rotation of the pitch wheel and in the direction of the rotation. When flight director VNAV and APP (glideslope captured) modes are used, the NOSE DN - NOSE UP wheel operation is cancelled.

CENTRE PEDESTAL

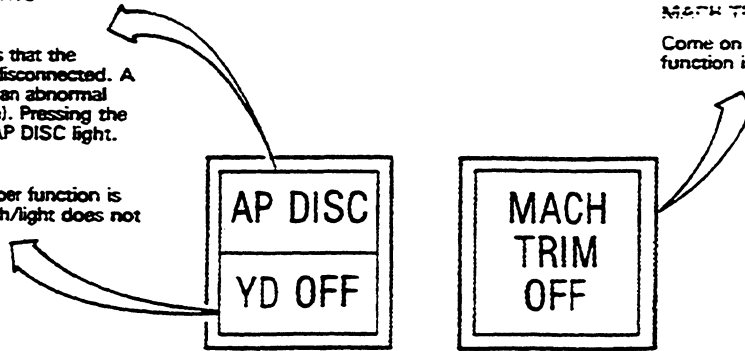
AP DISC/YD OFF SWITCH/LIGHTS

AP DISC

A steady AP DISC light indicates that the autopilot has been intentionally disconnected. A flashing AP DISC light indicates an abnormal autopilot disconnect (FGC failure). Pressing the switch/light resets the flashing AP DISC light.

YD OFF

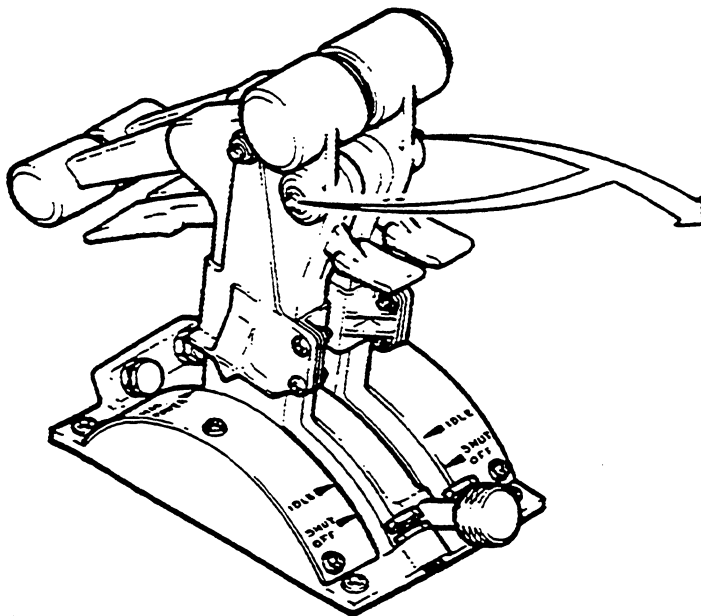
Indicates that the FGC yaw damper function is disconnected. Pressing the switch/light does not reset the YD OFF light.



MACH TRIM OFF ANNUNCIATORS

Come on to indicate that the MACH TRIM function is disengaged.

PILOT'S AND COPILOT'S INSTRUMENT PANELS



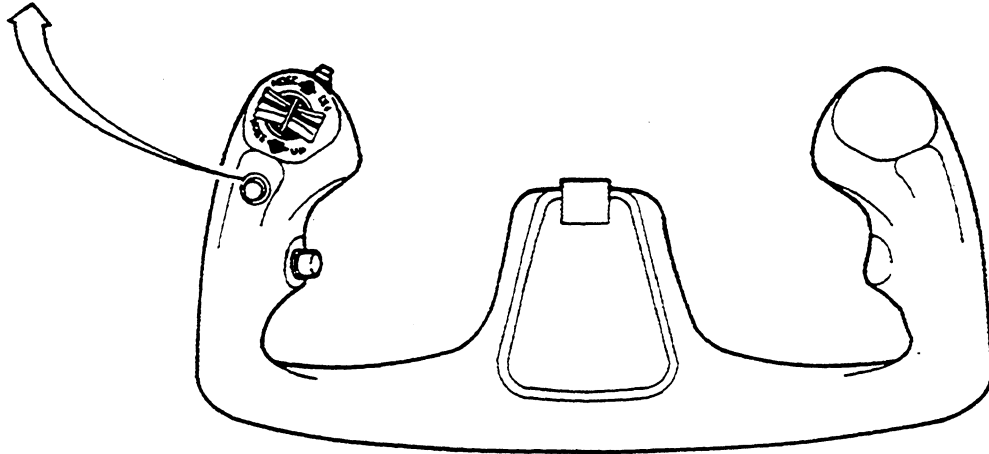
GO-AROUND SWITCHES

When pressed, the autopilot function is disengaged, all selected flight director modes are reset and wings-level and 10-degree fly-up command is displayed on the EADIs. The GA mode is cancelled by pressing the touch control steering switches or by selecting another pitch mode.

CENTRE PEDESTAL

AUTOPILOT/STICK PUSHER DISCONNECT SWITCH

When pressed, disengages autopilot and disables stick pusher system.



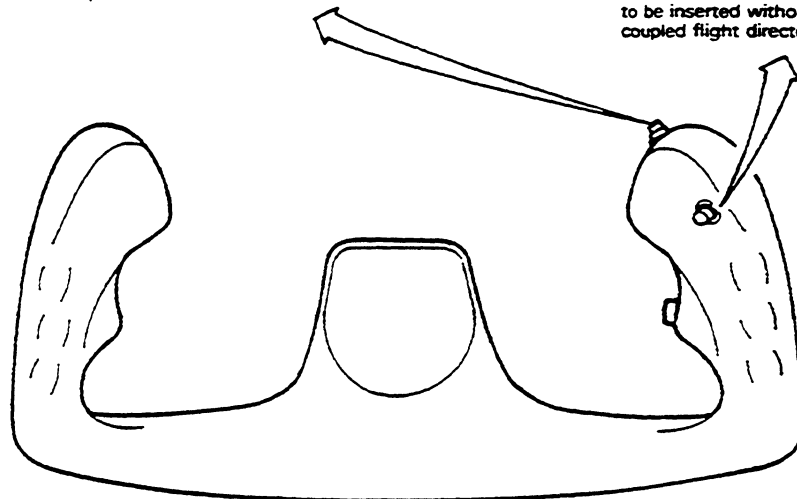
FRONT VIEW

PITCH TRIM DISCONNECT SWITCH

When pressed, disengages pitch trim system and autopilot.

TOUCH CONTROL STEERING SWITCH

When pressed, disconnects autopilot servo clutches to allow manual flight path commands to be inserted without disengaging autopilot and coupled flight director mode.



REAR VIEW

PILOT'S AND COPILOT'S CONTROL WHEELS

AUTOPILOT ANNUNCIATORS

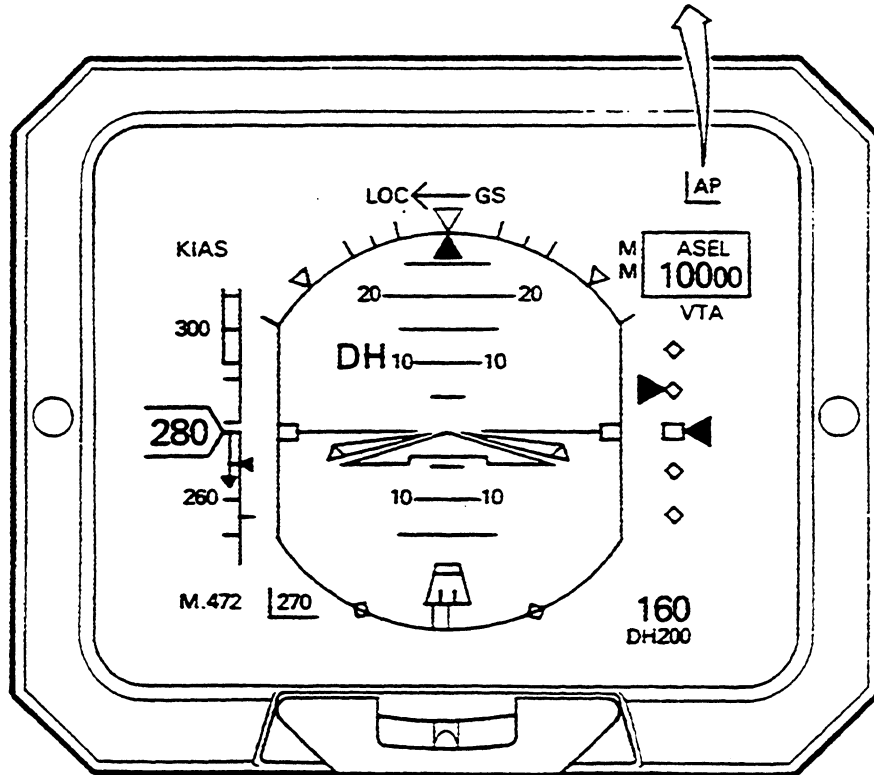
Indicates the autopilot status.

AP (green, steady) = Autopilot engaged.

AP (amber, flashing) = Autopilot disengaged.

AP (green, flashing) = Master FGC is transferred with autopilot engaged. Flashes for 5 seconds and then comes on steady.

TCS (green, steady) = Touch control steering (TCS) switch pressed with autopilot engaged.



PILOT'S AND COPILOT'S INSTRUMENT PANELS

Autopilot Function Related Display - EFIS EADI
Figure 10

RESET PUSHBUTTON

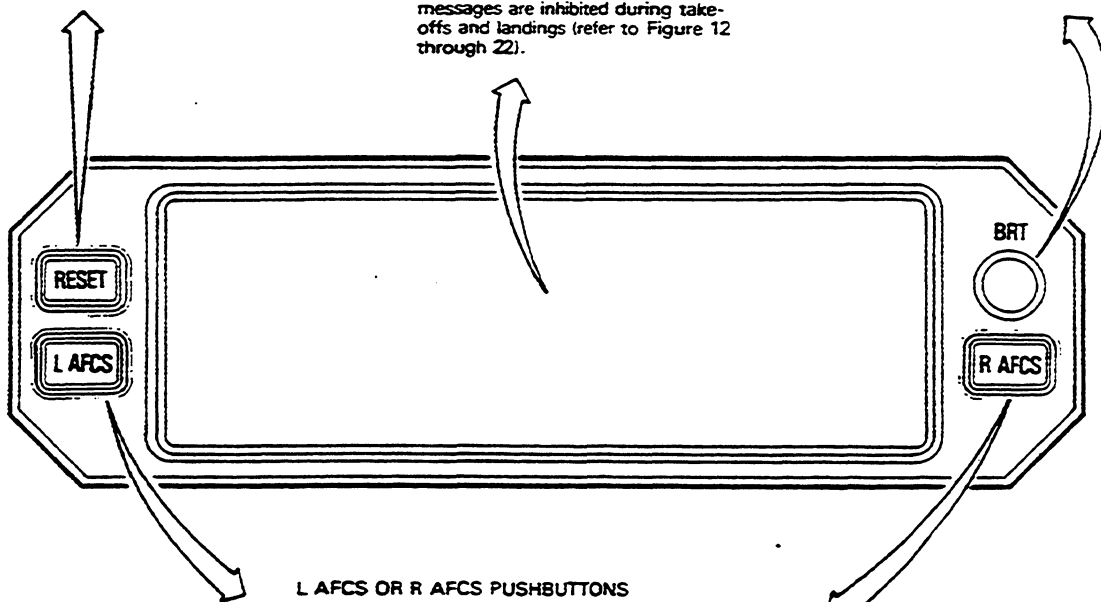
When pressed, resets failure, warning and caution messages.

DISPLAY

Provides warning, caution, status, failure and invalid operation messages, and air data and flight director mode status. Low priority messages are inhibited during take-offs and landings (refer to Figure 12 through 22).

BRT CONTROL

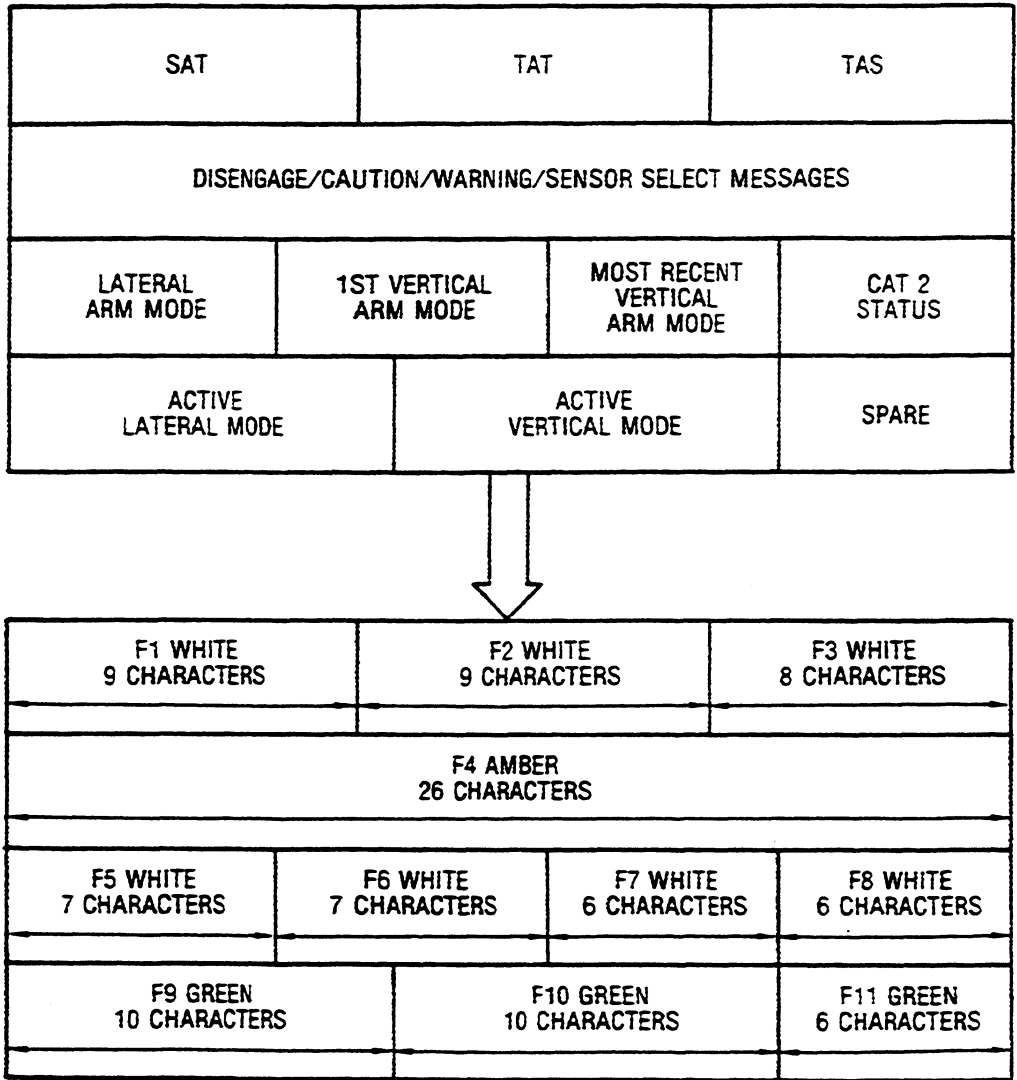
When turned on, adjusts the brightness of the advisory display.



L AFCS OR R AFCS PUSHBUTTONS

When pressed, selects either the pilot's FGC (left) or the copilot's FGC (right).

CENTRE INSTRUMENT PANEL



Advisory Display - Display Format
Figure 12

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PSP 601A-6

Message	Reverse Video (5 sec)	Field/Color	Comments
LOC	No	5/WHITE	Message used for all armed VNAV modes (VNPTH, and VNSEL) CAT 2 is displayed as long as status is valid
VOR	No	5/WHITE	
BC	No	5/WHITE	
LNAV	No	5/WHITE	
ALTSEL	No	6 or 7/WHITE	
GS	No	6 or 7/WHITE	
EL	No	6 or 7/WHITE	
VNAV	No	6 or 7/WHITE	
CAT 2	No	8/WHITE	

Advisory Display - Flight Director Lateral and Vertical Arm Modes
Figure 13

Message	Reverse Video (5 sec)	Field/Color	Comments
HDG	No	9/GREEN	HI Bank mode
HDG/LO	No	9/GREEN	LO Bank mode
VOR	Yes	9/GREEN	Indicates capture mode
LOC	Yes	9/GREEN	Indicates capture mode
BC	Yes	9/GREEN	Indicates capture mode
LNAV	Yes	9/GREEN	
VOR OS	No	9/GREEN	Overstation passage
ALT	Yes	10/GREEN	Indicates capture mode
EL	Yes	10/GREEN	Indicates capture mode
GS	Yes	10/GREEN	Indicates capture mode
VS ±dddd FPM	No	10/GREEN	Updated at 10 Hz rate
FLC	No	10/GREEN	
GO AROUND	No	10/GREEN	
VNFLC	No	10/GREEN	
VNALT	Yes	10/GREEN	Indicates capture mode
VNALT	No	10/GREEN	
VNPTH	Yes	10/GREEN	

Advisory Display - Flight Director Lateral and Vertical Active Modes
Figure 14

Message	Field/ Color	Range	Resolution	Comments
±dd °C SAT	1/WHITE	±99°C	1°C	Continuously updated at 1 Hz rate
±dd °C TAT	2/WHITE	±99°C	1°C	Digits replaced by dashes if invalid data
ddd KTAS	3/WHITE	0 to 999	1 Knot	Data originated from the coupled side (CPL)

Advisory Display - SAT/TAT/TAS Displays
Figure 15

Message	Timed-Out (5 sec)	RESET P/B On	Comments
AP/YD/M-TRIM DISENGAGED	No	Yes	For these messages, pushing either the RESET pushbutton, quick disconnect, or Go-Around clears the message and switches off the RESET pushbutton light.
AP/YD DISENGAGED	No	Yes	
AP/M-TRIM DISENGAGED	No	Yes	
YD/M-TRIM DISENGAGED	No	Yes	
AP DISENGAGED	No	Yes	
YD DISENGAGED	No	Yes	
M-TRIM DISENGAGED	No	Yes	

Advisory Display - Warning Disengage Messages (Amber Flashing)
Figure 16

Message	Timed-Out (5 sec)	RESET P/B On	Comments
AP/YD/M-TRIM DISENGAGED	No	Yes	
AP/YD DISENGAGED	No	Yes	
AP/M-TRIM DISENGAGED	No	Yes	
YD/M-TRIM DISENGAGED	No	Yes	
AP DISENGAGED	No	Yes	
YD DISENGAGED	No	Yes	
M-TRIM DISENGAGED	No	Yes	

Advisory Display - Caution Disengage Messages (Amber Steady)
Figure 17

Message	Timed-Out (5 sec)	RESET P/B On	Comments
PITCH TRIM FAIL	No	No	The pilot must manually disconnect AP. This action also clears the message.
ROLL TRIM FAIL	No	No	
MISTRIM (TRIM NOSE UP)	No	No	Message is present only while the trim hold limit is exceeded.
MISTRIM (TRIM NOSE DN)	No	No	
MISTRIM (TRIM R WING DN)	No	No	
MISTRIM (TRIM L WING DN)	No	No	
EXCESSIVE DEV	No	No	Message clears when the aircraft is within CAT II lateral and vertical thresholds.

Advisory Display - Primary Caution Messages
(Amber Steady)
Figure 18

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OPERATING MANUAL
PSP 601A-6

Message	Timed-Out (5 sec)	RESET P/B On	Comments
AMBER DASHED LINE	--	--	The dashed line is generated within the advisory display after an ASCB failure.
DISENGAGE ANNUN DATA FAULT	No	Yes	Message appears if the advisory display cannot verify the AP/YD engage/disengage status.
L AFCS OFF	No	Yes	Message appears when either the active or standby AFCS fails.
R AFCS OFF	No	Yes	
ALT OFF	Yes	No	Message appears when the flight director ALT mode is cancelled due to ASEL knob motion or by pitch wheel motion.
CAT 2 INVALID	No	Yes	Message appears when CAT 2 status becomes invalid.
NO GND TEST - NO WOW	No	Yes	Messages occur when attempting to enter maintenance test and the conditions are not met.
NO GND TEST - IAS HIGH	No	Yes	
NO GND TEST - AFCS ENG	No	Yes	
AP FAIL/YD AVAIL	No	Yes	Indicates that only the autopilot has failed, but not the yaw damper.
NAV MISMATCH (L NAV)	No	Yes	Indicates a mismatch between navigation sources. The FGC automatically selects the reasonable navigation source.
L YD NOT CENTERED R YD NOT CENTERED	No	Yes	Indicates a yaw damper recentering failure on the ground or in the air.
PUSHBUTTON ACTIVE	No	Yes	Indicates a stuck pushbutton on either the display controller or the flight guidance controller.

Message	Timed-Out (5 sec)	RESET P/B On	Comments
CPL DATA INVALID	Yes	No	Message is displayed for 5 seconds if an attempt is made to manually select a mode when the corresponding sensor data is invalid.
CPL NAV DATA INVALID	Yes	No	
IRS DATA INVALID	Yes	No	
DADC DATA INVALID	Yes	No	
CPL DATA INVALID	No	Yes	Message appears if an automatic mode cancellation occurs - due to invalid sensor data.
CPL NAV DATA INVALID	No	Yes	
IRS DATA INVALID	No	Yes	The message is cleared by a RESET pushbutton activation.
DADC DATA INVALID	No	Yes	

Advisory Display - Sensor Failure Messages (Amber Steady)
Figure 20

Message	Timed-Out (5 sec)	Field/ Color	Comments
L AFCS MASTER	Yes	4/AMBER	Message occurs if manual or automatic switchover of priority channel occurs (duration of 5 seconds).
R AFCS MASTER	Yes	4/AMBER	

Advisory Display - AFCS Status Messages
Figure 21

Message	Timed-Out (5 sec)	RESET P/B On	Comments
CHECK NAV SOURCE	Yes	No	Message indicates that the mode cannot engage because of an improper Nav source selection on the active EHSI.
NO ENGAGEMENT ON GROUND	Yes	No	Autopilot cannot be engaged while the aircraft is on the ground.
L AFCS OFF R AFCS OFF	Yes Yes	No No	Message appears at L AFCS or R AFCS activation and indicates that the corresponding AFCS has failed.
ENGAGE INHIBIT	Yes	No	Indicates that engagement of autopilot, yaw damper or Mach trim is inhibited.
CAT 2 INVALID	Yes	No	CAT 2 status is invalid when selected on the flight guidance controller.
TURN KNOB ACTIVE	Yes	No	- Indicates that engagement of autopilot is inhibited because of turn knob motion. - Indicates that engagement of a lateral mode is inhibited because the turn knob is out-of-detent and the autopilot is engaged.
SELECT INHIBIT	Yes	No	Indicates that manual FGC transfer is inhibited during a dual ILS approach.

Advisory Display - Invalid Operation Messages
(Amber Steady)
Figure 22