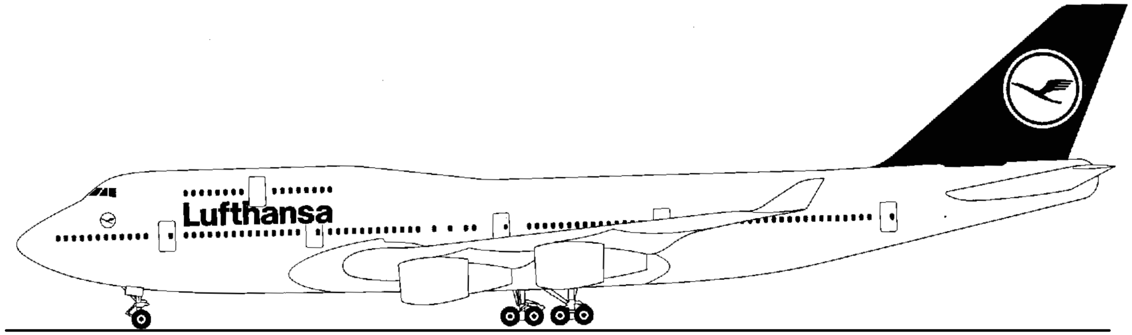
Lufthansa Technical Training

Training Manual B 747-400



ATA 22-10 AFDS GENERAL

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ATA 22-10 AFDS GENERAL FUNCTION

AUTOPILOT FLIGHT DIRECTOR SYSTEM INTRODUCTION

General
The autopilot flight director system (AFDS) controls or gives commands to the flight crew to control the flight of the airplane. These functions are supplied during all phases of flight.

Autopilot
The autopilot controls the attitude of the airplane with control surface movement. The control function in the pitch, roll and yaw axes is based on the mode of operation. In pitch, the autopilot can control:

- Airspeed
- Altitude
- Vertical speed
- VNAV
- Glide slope

In roll, the autopilot can control:

- Heading.
- Track
- LNAV
- Localizer
- Attitude

In yaw, the autopilot can control:

- Adverse yaw (engine out)
- Crab angle
- Localizer

Flight Director
All control functions are the same for the flight director (F/D) but the AFDS gives attitude commands to the flight crew. If the flight crew follows the flight director commands, the airplane control is the same as the autopilot.

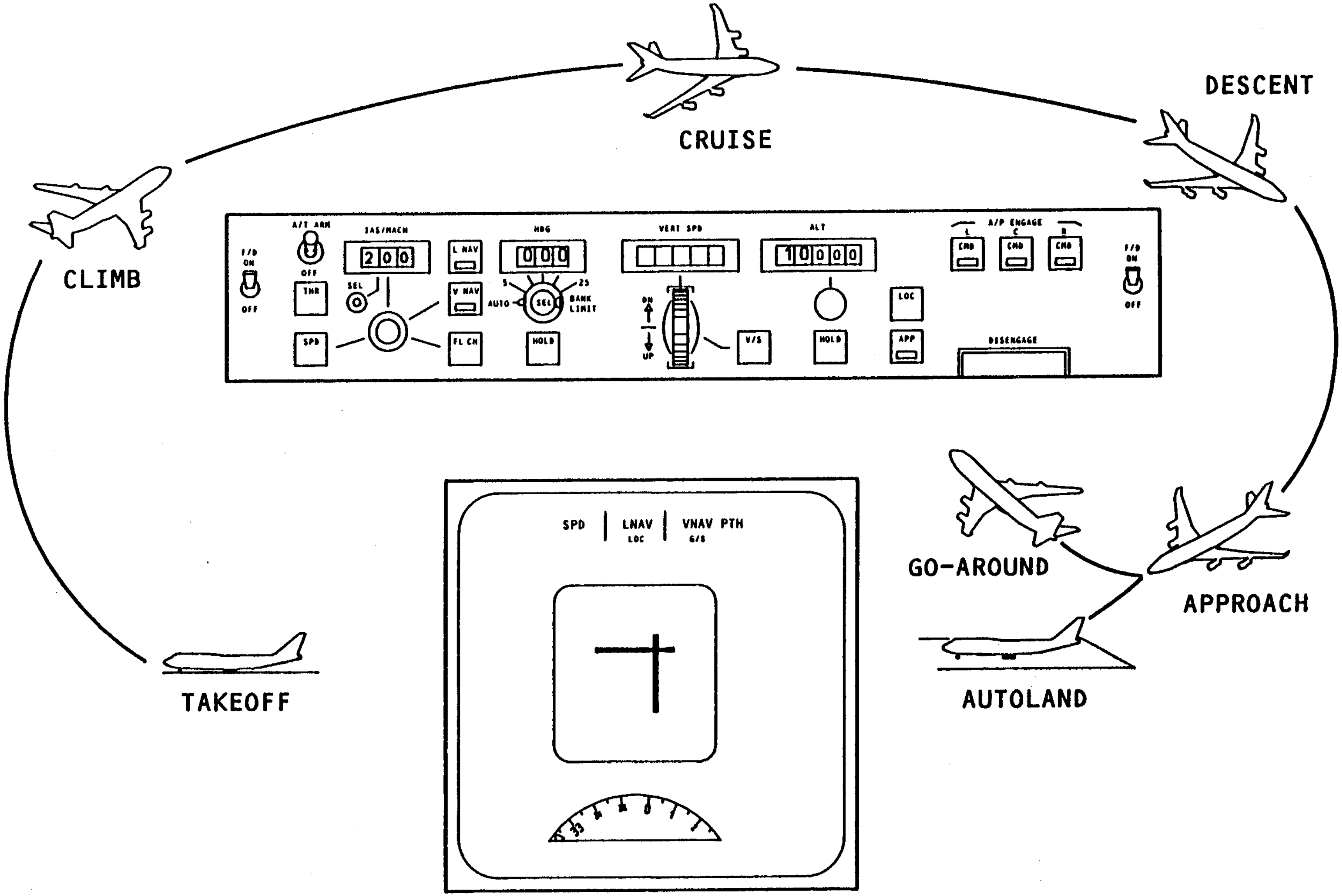

Figure 1 Autopilot Flight Director System Introduction

AUTOPILOT FLIGHT DIRECTOR SYSTEM

Pilot Interface

The automatic flight control system mode control panel (AFCS MCP) is the primary interface between the pilot and the AFDS. The MCP also has autothrottle controls for the FMC.

The pilots also have an interface with the flight control computers through disengage switches, go-around switches and heading reference switch.

Flight Control Computers

The flight control computers (FCCs) are the primary components for the AFDS. FCC operation has these functions:

- Mode management: select, engage and disengage either pilot selectable or automatic modes.
- Control laws: calculate the attitude command for automatic control or F/D guidance for the AFDS modes.
- Failure detection: detect and isolate system and internal failures.
- Configuration management: engage and disengage the AFDS and annunciate status to show system capability.
- Redundancy management: manage the redundant data and systems available to the AFDS.
- Maintenance: assess and report component failures and the interactive maintenance operation during system ground test.

Sensors

Sensors provide the AFDS with inertial, atmospheric and ground reference data. The sensors required for autoland are triple redundant. The navigation sensors are dual.

The airplane configuration sensors provide the AFDS with the necessary data to control the airplane flight characteristics.

Servos

The three FCCs each control three autopilot servos (aileron, elevator and rudder). Each of the servos operate in a similar manner. The servo actuators receive signals from the FCCs and convert these signals to mechanical movement to control the primary flight control system.

Displays

The integrated display system (IDS) is the primary display to show the AFDS flight director commands, flight mode

annunciations and status. The IDS has primary flight displays (PFDs), navigation displays (NDs), engine indication and crew alerting system displays (EICAS) and EFIS/EICAS interface units (EIUs).

Other Interfaces

The central maintenance computers (CMCs) store and report failures of the AFDS.

The modularized avionics and warning electronic assembly (MAWEA) receives warning inputs from the FCCs. The MAWEA processes crew alerting functions and controls aural alerts.

The stabilizer trim/rudder ratio module (SRM) controls the stabilizer through the stabilizer trim control module (STCM).

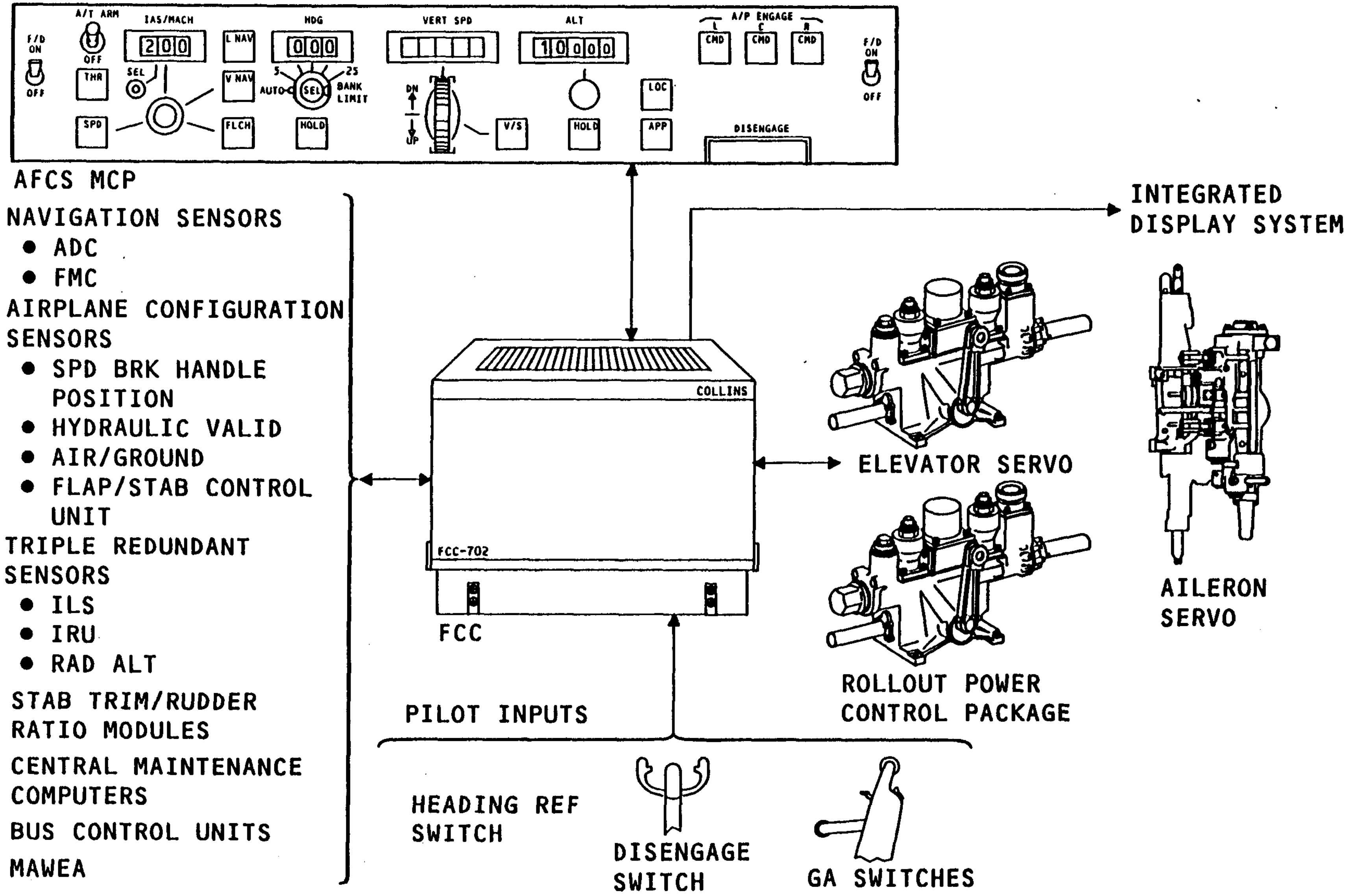

Figure 2 Autopilot Flight Director System

AFDS - COMPONENT LOCATIONS #1

The AFDS components in the flight deck are:

- AFCS mode control panel
- Autopilot disengage switches
- Go-around switches

Components that interface with the AFDS are:

- Main EICAS display
- Auxiliary EICAS display
- Primary flight display (PFD)
- Navigation display (ND)

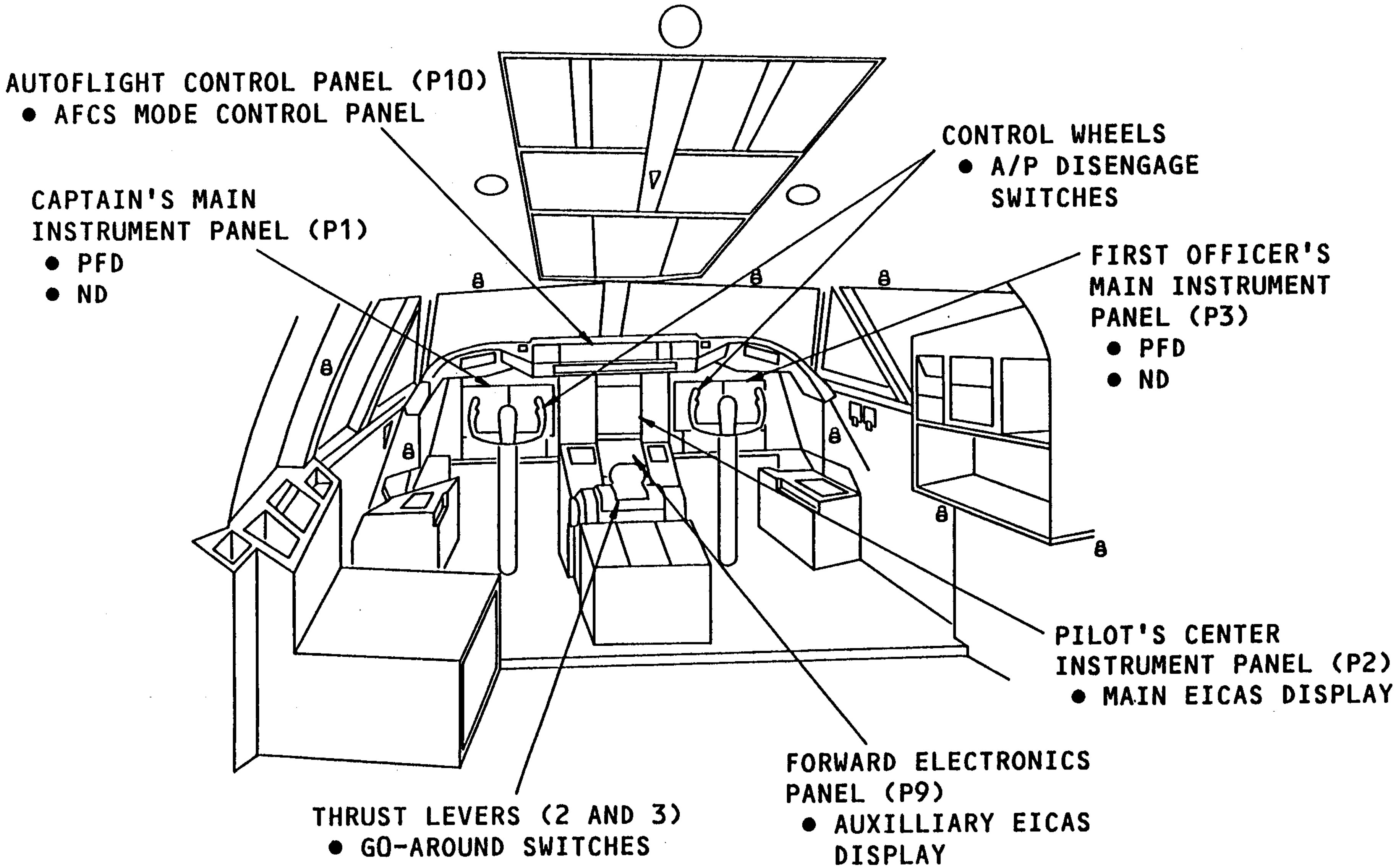

Figure 3 AFDS - Component Locations #1

AFDS - COMPONENT LOCATIONS #2

The AFDS components in the main equipment center are the flight control computers (FCCs).

The two central lateral control packages (CLCPs) are along the center keel beam in the wing gear wheel wells. The lateral autopilot servo is next to the left CLCP.

The three elevator autopilot servos are in the tail, aft of the stabilizer.

The three rollout power control packages are in the vertical stabilizer.

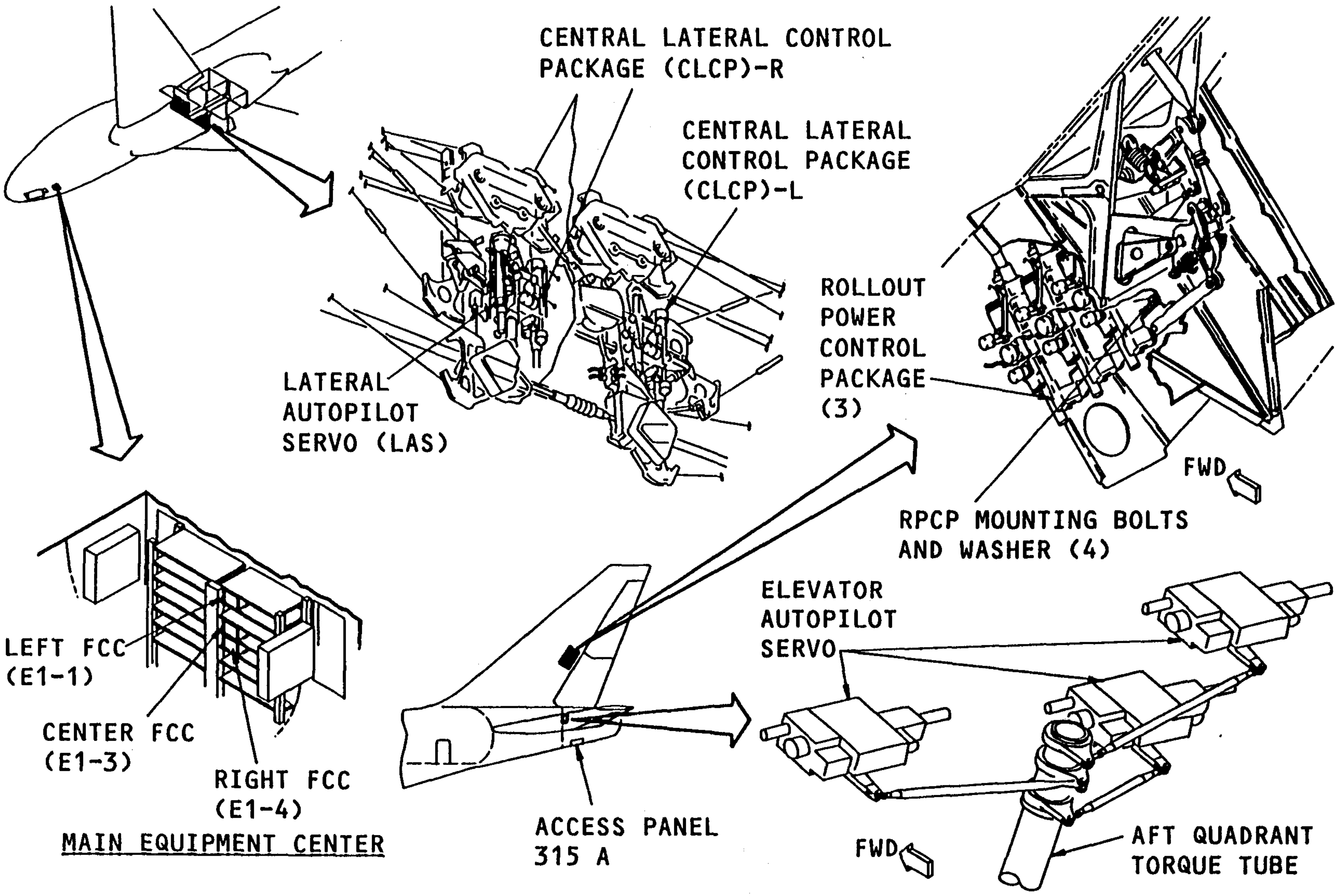

Figure 4 AFDS - Component Locations #2

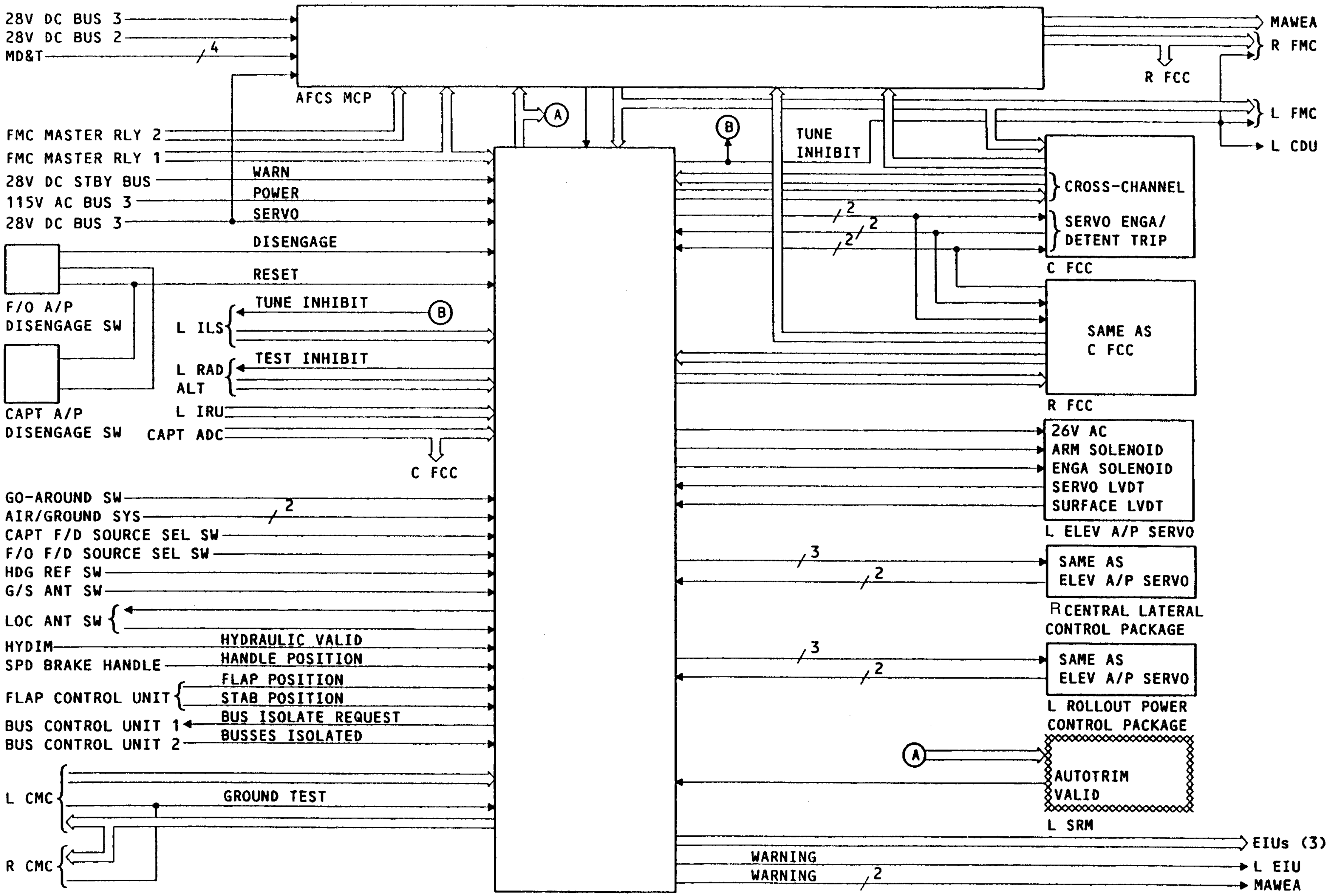

Figure 5 AFDS - Interface Diagram

AFDS - POWER DISTRIBUTION

Power distribution for the AFDS is organized around the three channel configuration of the flight control computers (FCC), the dual configuration in the mode control panel (MCP) and the dual requirements of AFDS warning logic.

Separate ac and dc busses send power to each flight control computer. The battery bus provides the second source of annunciation and warning power to each FCC.

Each FCC converts 115 ac primary power to 26 ac. The 26 ac is used for sensor excitation and reference voltage in the FCC.

Lighting power (5 ac) supplies the AFCS mode control panel for panel lights.

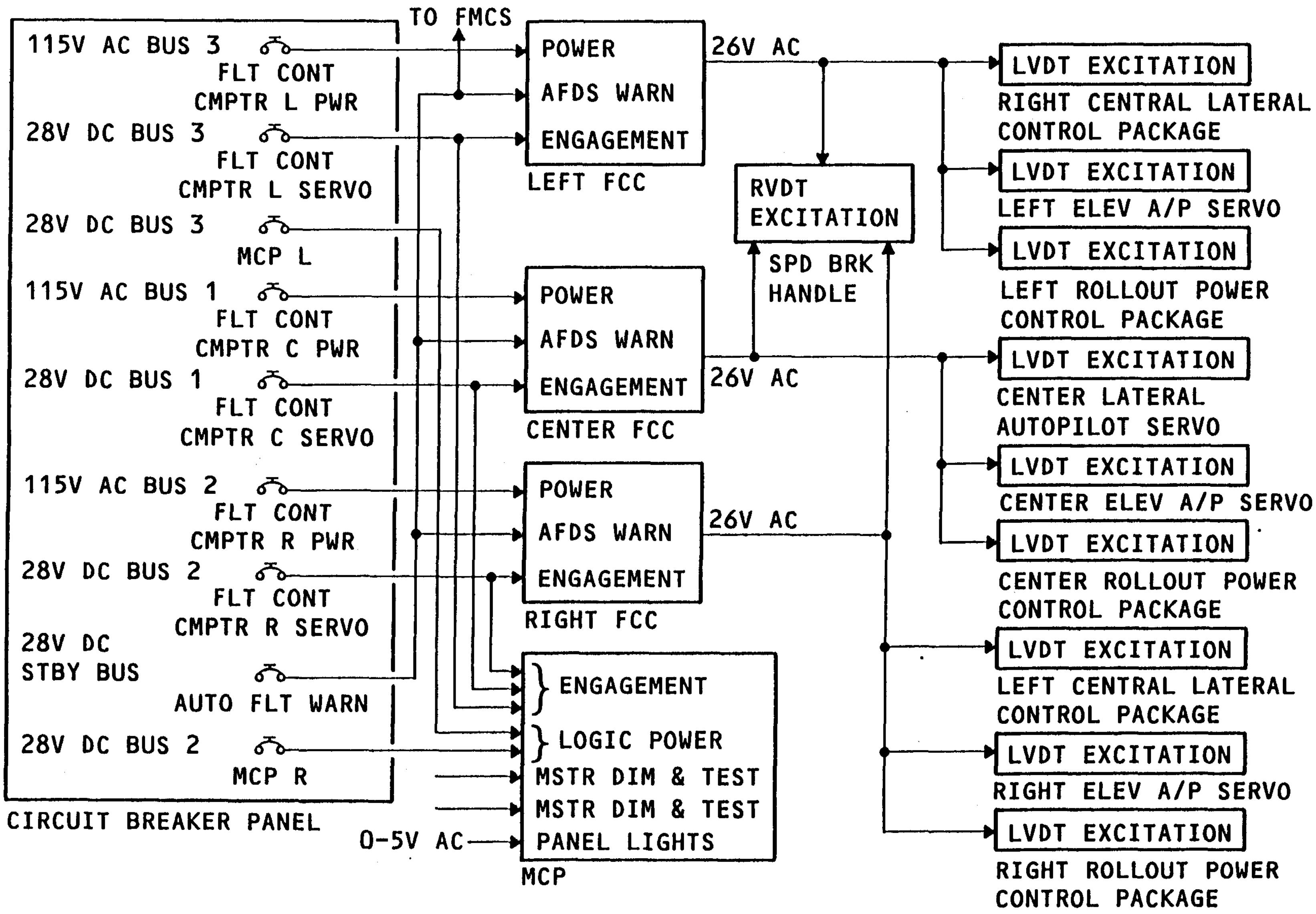

Figure 6 AFDS - Power Distribution

AFDS - FCC BUS ISOLATION LOGIC

General

During approach, triple-channel autoland requires separation of power sources for the autopilot channels.

Isolation

All FCCs send a bus isolate request to bus control unit 1 during the approach arm mode. The BCU uses bus tie breakers (BTBs) and dc isolation relays (DCIRs) on busses 1, 2 and 3 to isolate the electrical busses to the FCCs Isolation occurs within four seconds. Bus control unit 2 tells the FCCs, through the BUS ISOLATED discrete that the busses are isolated. The BUS ISOLATED logic is a necessary condition for LAND 3.

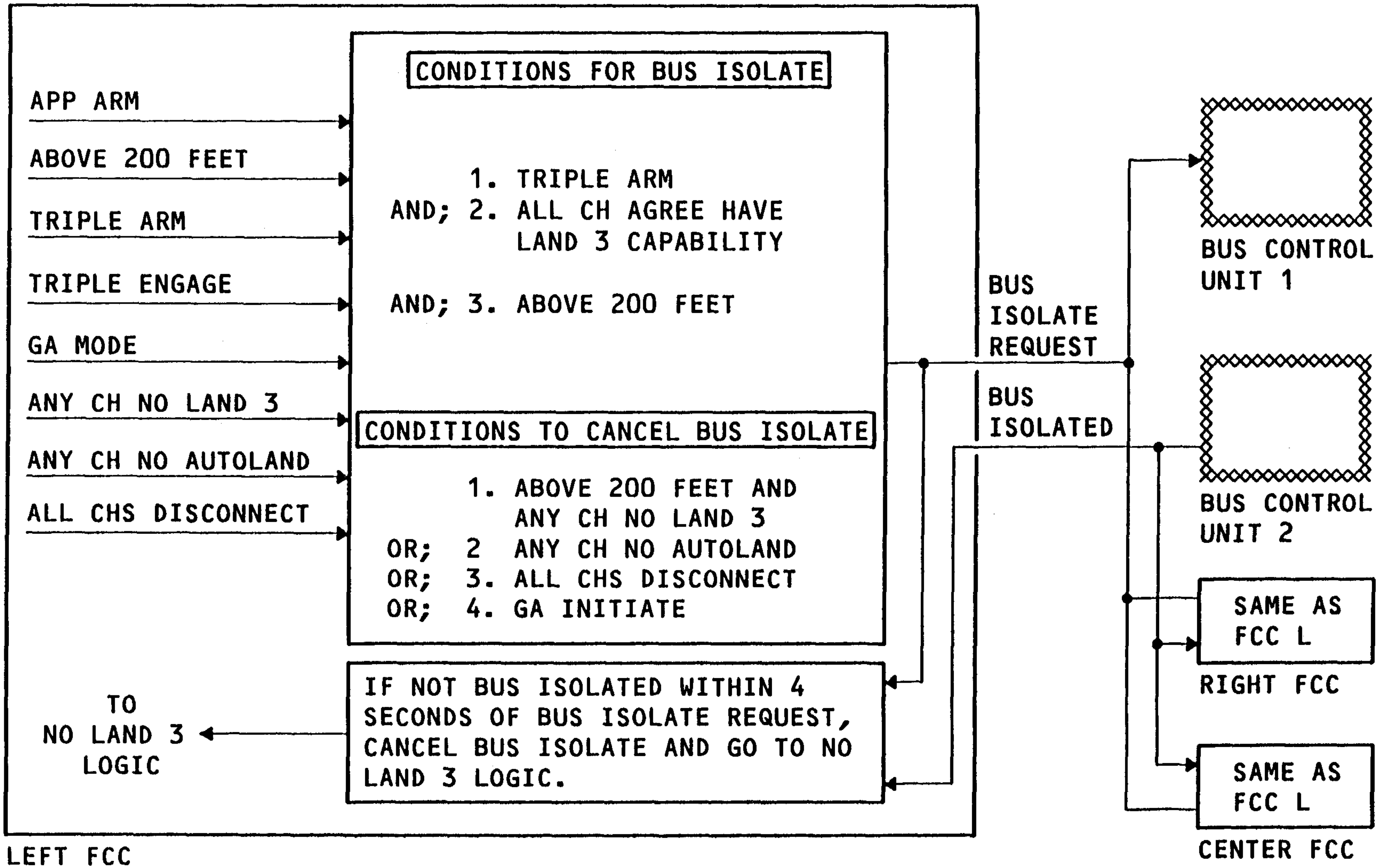

Figure 7 AFDS - FCC Bus Isolation Logic

ELECTRICAL POWER DISTRIBUTION

General

For normal operation, the four engine-driven generators provide electrical power. External power and/or APU power can be used on the ground.

Operation

Generators 1 through 4 (G1 - G4) produce 115 volts ac, 400 Hz power. Normally, generator circuit breakers (GCB) 1 through 4 are closed. This allows power to bus 1 through 4.

This power goes to the transformer/rectifiers (TRs). The TRs use this power to generate 28 volts dc power which goes to the busses.

During normal cruise operation, all BTBs, DCIR, and the split system breaker are closed. During the autoland sequence, some breakers and relays are opened to isolate the power buses. This is discussed later.

DCIR - DC ISOLATION RELAY
TR - TRANSFORMER/RECTIFIER
G - GENERATOR
GCB - GENERATOR CIRCUIT BREAKER

BTB - BUS TIE BREAKER
SSB - SPLIT SYSTEM BREAKER
XPC - EXTERNAL POWER CONTACTOR
APB - AUXILIARY POWER BREAKER

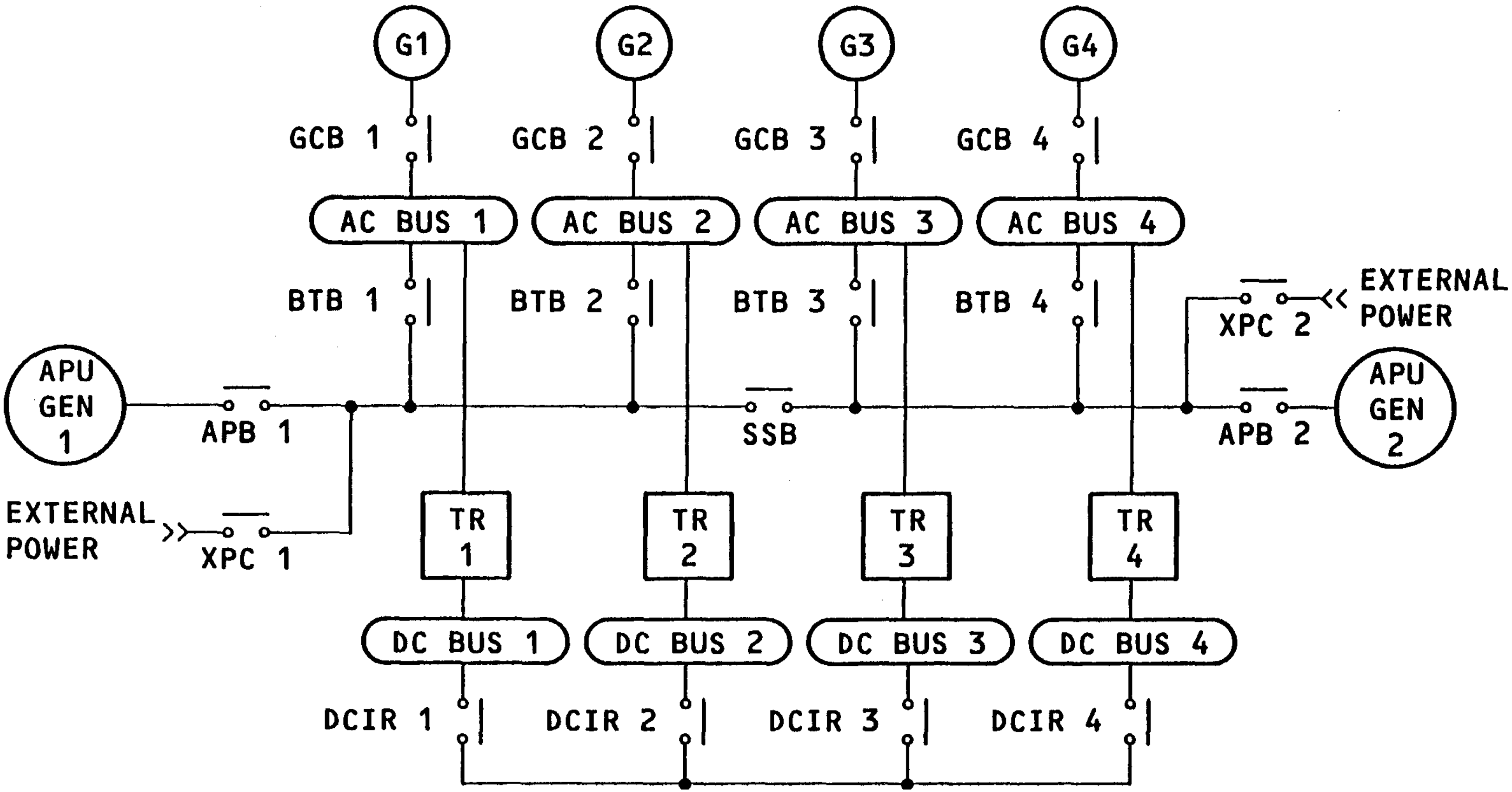

Figure 8 Electrical Power Distribution

AFDS - BCU - POWER ISOLATION LOGIC

Purpose

The purpose of the power isolation logic in the BCU is to separate the power sources for each autopilot channel during a triple-channel approach.

Operation

The BCU monitors the status of the generators, transformer rectifiers (TRs), generator circuit breakers (GCBs), bus tie breakers (BTBs), DC isolation relays (DCIRs) and the split system breaker (SSB).

When the BCU receives the bus isolation request from an FCC, the BCU examines the status of these items and opens or closes relays, as needed, to isolate the three ac and dc power sources.

Tables in the diagram show this logic. As an example, with all generators and transformer-rectifiers operating BTB 1, 2 and 3 will open and DCIR 1, 2 and 3 will open when bus isolation is requested.

Bus control unit 2 monitors bus control unit 1 to see that power is isolated for each autopilot channel. Bus control unit 2 then sends the BUS ISOLATED discrete to the FCCs.

BUS ISLN REQUEST

4 GENERATORS AND 4 TR'S OPERATING

	1	2	3	4
GCB	CLOSED	CLOSED	CLOSED	CLOSED
BTB	OPEN	OPEN	OPEN	CLOSED
DCIR	OPEN	OPEN	OPEN	CLOSED

GENERATOR 3 OR TR 3 INOP

	1	2	3	4
GCB	CLOSED	CLOSED	OPEN	CLOSED
BTB	OPEN	OPEN	CLOSED	CLOSED
DCIR	OPEN	OPEN	CLOSED	CLOSED

GENERATOR 1 OR TR 1 INOP

	1	2	3	4
GCB	OPEN	CLOSED	CLOSED	CLOSED
BTB	CLOSED	OPEN	OPEN	CLOSED
DCIR	CLOSED	OPEN	OPEN	CLOSED

GENERATOR 4 OR TR 4 INOP

	1	2	3	4
GCB	CLOSED	CLOSED	CLOSED	OPEN
BTB	OPEN	OPEN	CLOSED	CLOSED
DCIR	OPEN	OPEN	CLOSED	CLOSED

GENERATOR 2 OR TR 2 INOP

	1	2	3	4
GCB	CLOSED	OPEN	CLOSED	CLOSED
BTB	OPEN	CLOSED	OPEN	CLOSED
DCIR	OPEN	CLOSED	OPEN	CLOSED

GCB = GENERATOR CIRCUIT BREAKER
BTB = BUS TIE BREAKER
DCIR = DC ISOLATION RELAY
SSB = SPLIT SYSTEM BREAKER
TR = TRANSFORMER/RECTIFIER

GCB'S
BTB'S
DCIR'S
SSB

BUS CONTROL UNIT 1

BUS ISOLATED

BUS CONTROL UNIT 2

Figure 9 BCU - Power Isolation Logic

FCC CROSS-CHANNEL DATA INTERFACE

The FCCs exchange digital data on cross-channel busses for monitor, signal selection and synchronization functions.

The FCCs also exchange servo engage and detent trip logic as analog discretes.

The data sent on each cross channel bus is:

- Aileron surface position
- Elevator surface position
- Rudder surface position
- Test words
- Altitude reference (baro set)
- Heading reference (mag/true)
- IRS signals (19)
- ADC signals (6)
- ILS signals (3)
- FMC signals (3)
- Radio height
- Flap position
- Stab position
- Mode status
- Mode request
- VOR/LOC antenna relay status
- MCP selected data
- Software version
- Engage/arm status
- F/D selection
- Yaw damper status
- Option codes
- SRM engage status
- A/P caution
- CMD light

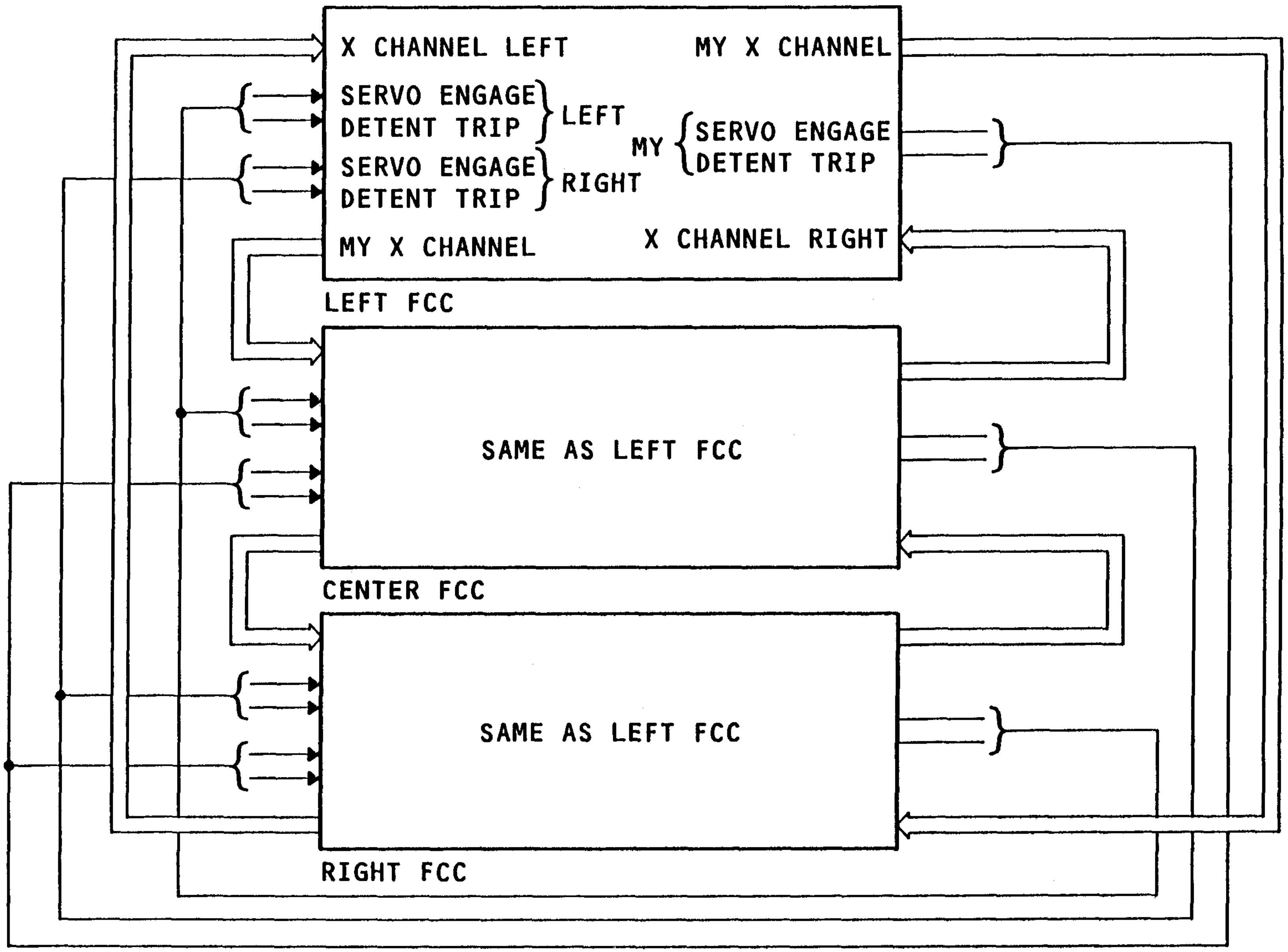

Figure 10 FCC Cross-channel Data Interface

SIGNAL SELECTION.- THREE SENSORS

General

For three sensors, one sensor of each type goes to each FCC. This is called local sensor data. The FCC receives data from the other sensors of the same type through the cross-channel data buses.

Signal Selection

The FCC uses local data at power-up and until mid-value selection starts. The three FCCs then use the same value for calculation. This reduces the command differences between autopilot channels and removes the possibility that a single sensor failure causes a hard-over control. If a single sensor fails, mid-value or zero (sensor type determines this) replaces the invalid signal.

Mid-value selection for sensors other than radio sensors (localizer, glide slope and radio altitude) starts with two sensors valid and autopilot engaged or flight director ON.

For localizer or glide slope data, midvalue selection starts with two sensors valid and localizer or glide slope capture. If glide slope capture occurs within 5 seconds after the landing gear goes down and locked, midvalue selection is inhibited until after this time. For radio altitude data, mid-value selection starts with two valid sensors, localizer and glide slope captured and radio altitude is less than 1500 feet. In addition, for localizer, glide slope or radio altitude data during a single channel or flight director only approach, if a dual failure occurs, any valid data is selected.

Signal Selection/Fault Detection (SSFD)

In addition to sensor validity determined by sign status matrix (SSM) and data bus activity, the FCC's also use a comparison of the input data with the mid-value. If a sensor input is different than the midvalue, it is considered to be a fault. This is called an SSFD fault. For heading and track data, this SSFD process is inhibited in the polar regions.

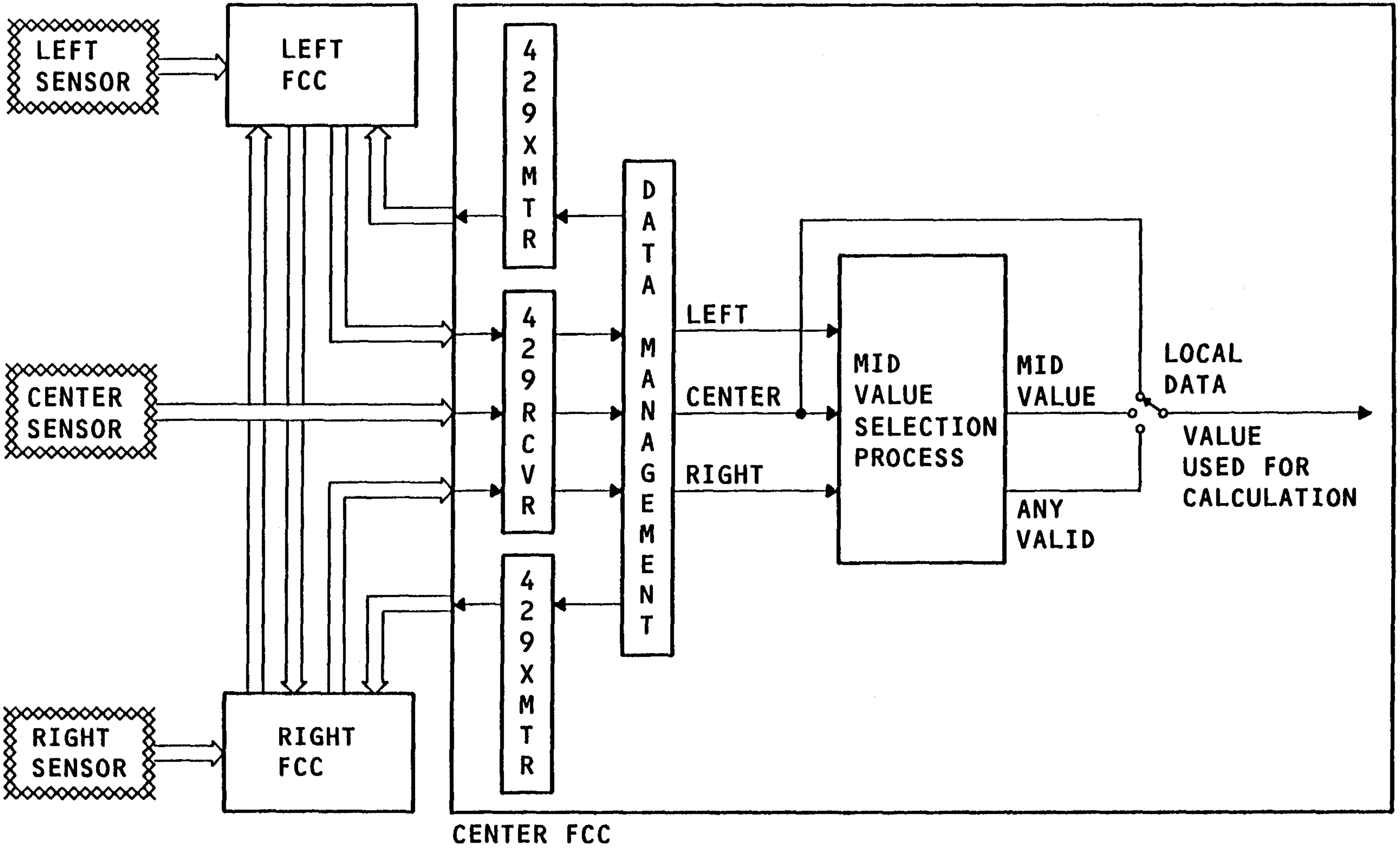

Figure 11 Signal Selection - Three Sensors

SIGNAL SELECTION - ADC AND FMC

General

For air data sensors and FMC, the FCC uses only one sensor value in control law computations. The captain's selected air data computer (ADC) goes to the left and center FCCs. The first officer's selected ADC goes to the right FCC. The FMC selected as master goes to all three FCCs.

ADC Signal Selection

All FCCs use the first officer's selected ADC data if:

- The right autopilot is first engaged or
- Only the first officer's F/D is on and no autopilot is engaged.

For all other combinations of autopilot engagement and F/D status, all FCCs use the captain's selected ADC data.

If the sensor validity of bus activity for the selected signal shows invalid, the FCCs automatically select the other ADC. The alternate source stays selected until the autopilot and F/Ds are off.

FMC Signal Selection

The FCC's use the on-side or direct FMC input. If this input is not valid, the FCC selects the FMC data from one of the cross-channel inputs. The FCC tries the relative left input first and then the relative right.

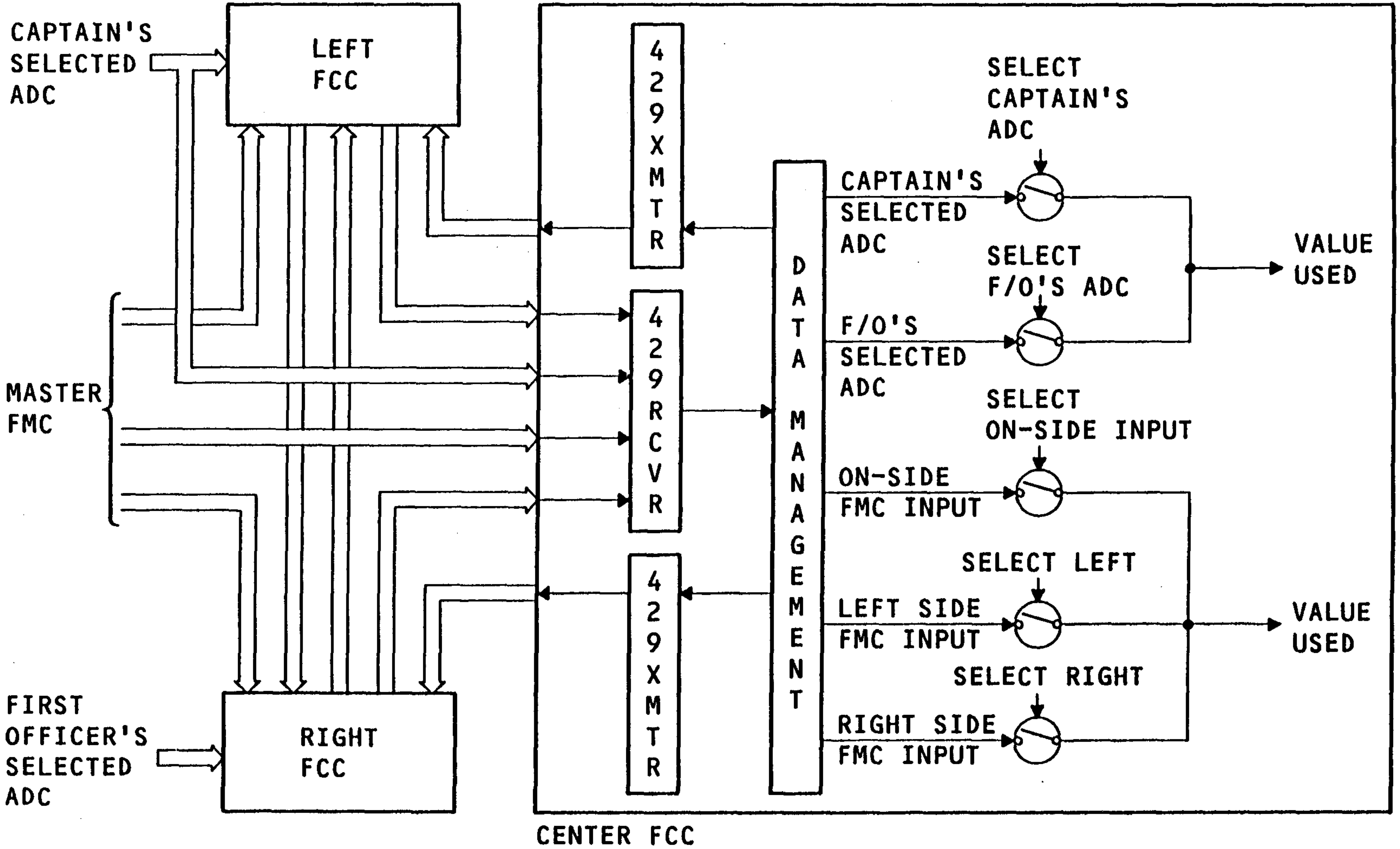

Figure 12 Signal Selection - ADC and FMC

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AFCS MODE CONTROL PANEL INTERFACE

General

The AFCS mode control panel (MCP) provides the primary interface between the flight crew and the autopilot flight director system (AFDS). It enables the crew to select operating modes, and to select parameters for airspeed, mach, heading, vertical speed, and altitude.

The MAWEA uses MCP selected altitude for altitude alert. The MCP also provides the engage control of:

- Autopilot
- Flight director
- Autothrottle

For redundancy, the MCP has two separate channels; channel A and channel B. Each channel has its own processor and receives power from a separate dc bus.

Interface

The MCP A channel receives input data from the left and center FCCs. The MCP B channel receives input data from the

right and center FCCs. Both MCP channels receive input from the FMC selected by the FMC master switch.

The MCP provides output data through two output ports to the FMCs, FCCs and MAWEA. The MCP A channel sends data to the left and center FCCs. the left FMC and the MAWEA. The MCP B channel sends data to the right FCC and to the right FMC.

If either channel A or B fails, the other processor transmits on the output buses of the failed side. This internal MCP bus switching allows the MCP to transmit if there is a failure of one MCP processor.

Data

The data sent from the FCC to the MCP is:

- Mode status
- Computed airspeed
- Elevator speed command
- Flap position
- FMC airspeed reference mach
- Selected runway heading
- Speed brake handle position
- Stabilizer position
- Test word
- Vertical speed

The data sent from the MCP to the FCC is:

- Mode status
- Mode request
- Altitude selected
- Heading selected
- Mach selected
- MCP maintenance data
- Airspeed selected
- Test word
- Vertical speed command
- Vertical speed selected

In addition, servo arm 28 volts goes to each FCC from the FCC disengage bar switches.

The data sent from the FMC to the MCP is mode, status and vertical speed command.

The data sent from the MCP to the FMC is:

- Mode status
- Mode request
- Altitude selected

Data (cont.)

- Elevator speed command
- Flap position
- Heading selected
- Mach selected
- Speed brake handle position
- Airspeed selected
- Stabilizer position
- Vertical speed selected
- MCP maintenance data

In addition, A/T servo arm 28 volts goes to the FMCs from the A/T arm switch.

The data sent from the MCP to the MAWEA is mode, status and altitude selected.

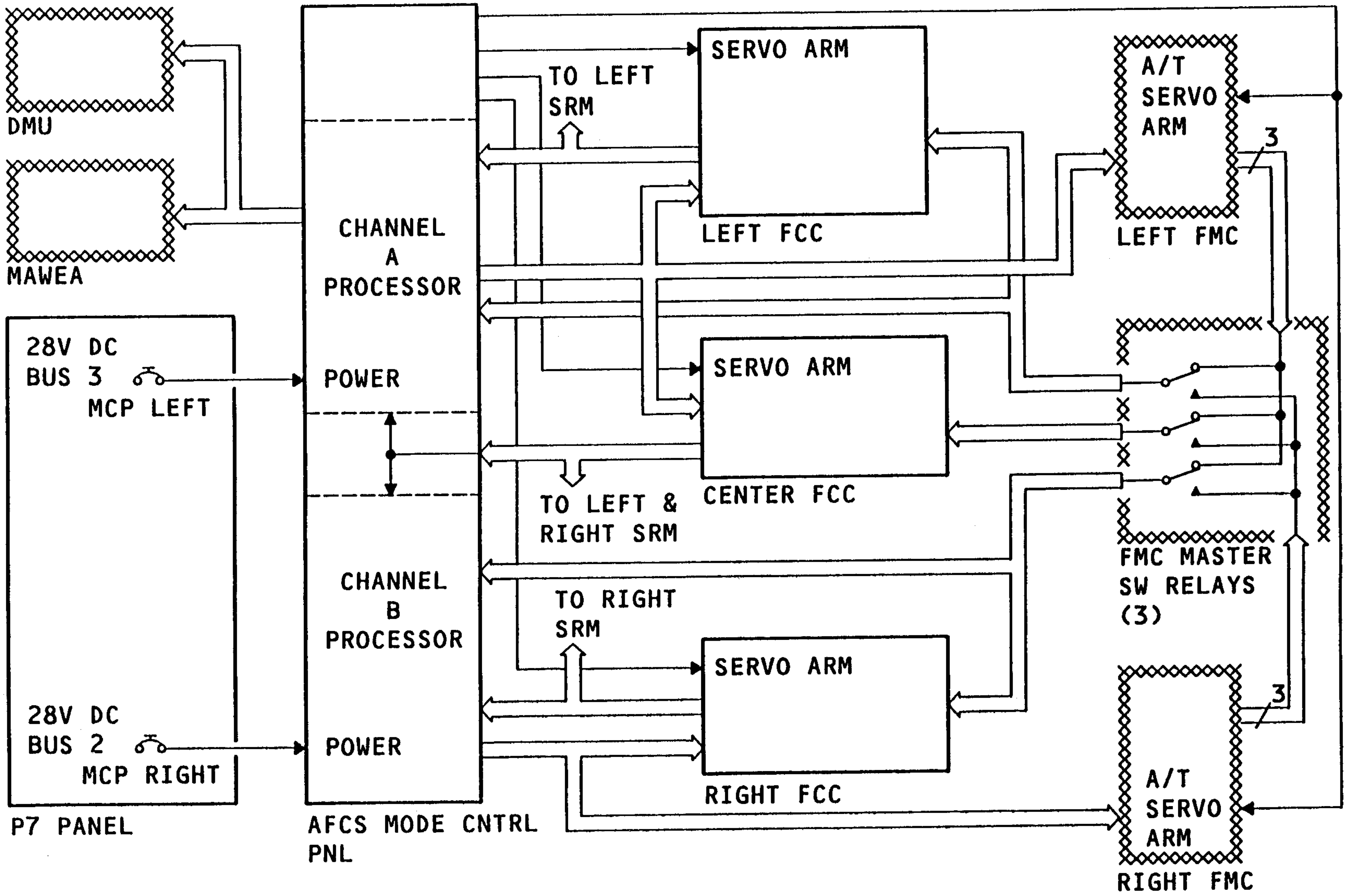


Figure 13 AFCS Mode Control Panel Interface

FCC/ADC INTERFACE

General

The air data system consists of three air data computers (ADCs). The ADCs provide air data and angle-of-attack data to the FCCs.

Interface

Normally, the left and center FCCs interface with the left ADC and the right FCC with the right ADC. The center ADC acts as an alternate to replace one that has failed. The ADC instrument source select switch controls this change.

The first officer's and captain's ADC ISSS controls ADC data to the FCCs and other FMS systems through relays Power to the ADC source select relay is removed if the other side relay has selected the center ADC. Thus, both source select relays cannot select the center ADC at the same time.

Data

The data sent from the ADC to the FCC is:

- Altitude
- Altitude rate
- Computed airspeed
- Impact pressure
- Indicated AOA
- Mach
- Maximum operating schedule
- True airspeed

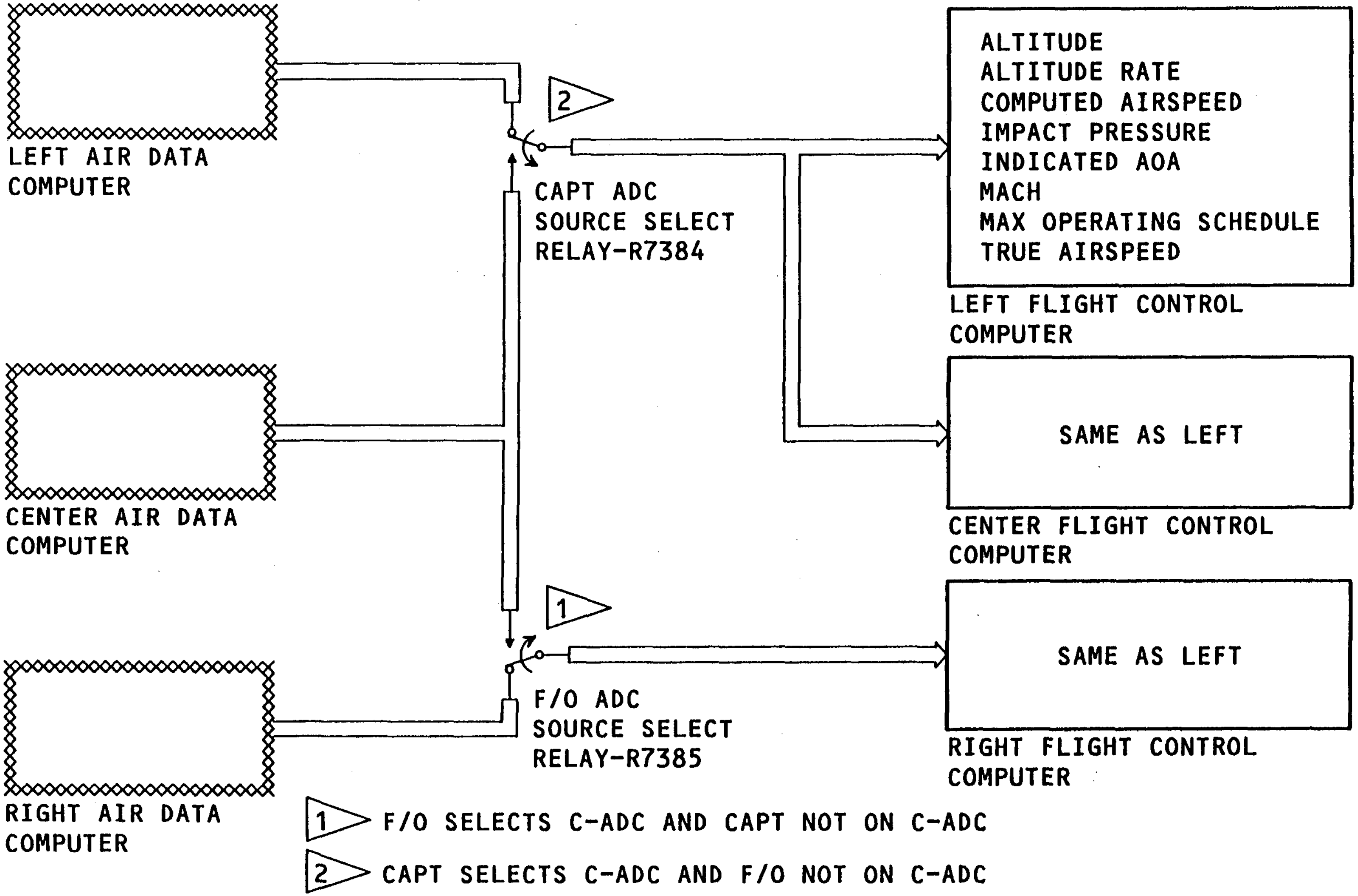


Figure 14 FCC/ADC Interface

FCC/FMC INTERFACE

General

The flight management computer (FMC) provides guidance commands to the autopilot/flight director system (AFDS).

Interface

The AFDS receives data from the FMCs through ARINC 429 data buses. All three FCCs receive data from the same FMC. Selection of this FMC is determined by the position of the FMC master switch on the EICAS control panel.

Data

The data sent from the FMC to the FCC is:

- FMC discretes
- Horizontal steering
- Target airspeed
- Target altitude
- Target mach
- Vertical steering rate
- Vertical steering
- Control maximum speed
- Control minimum speed

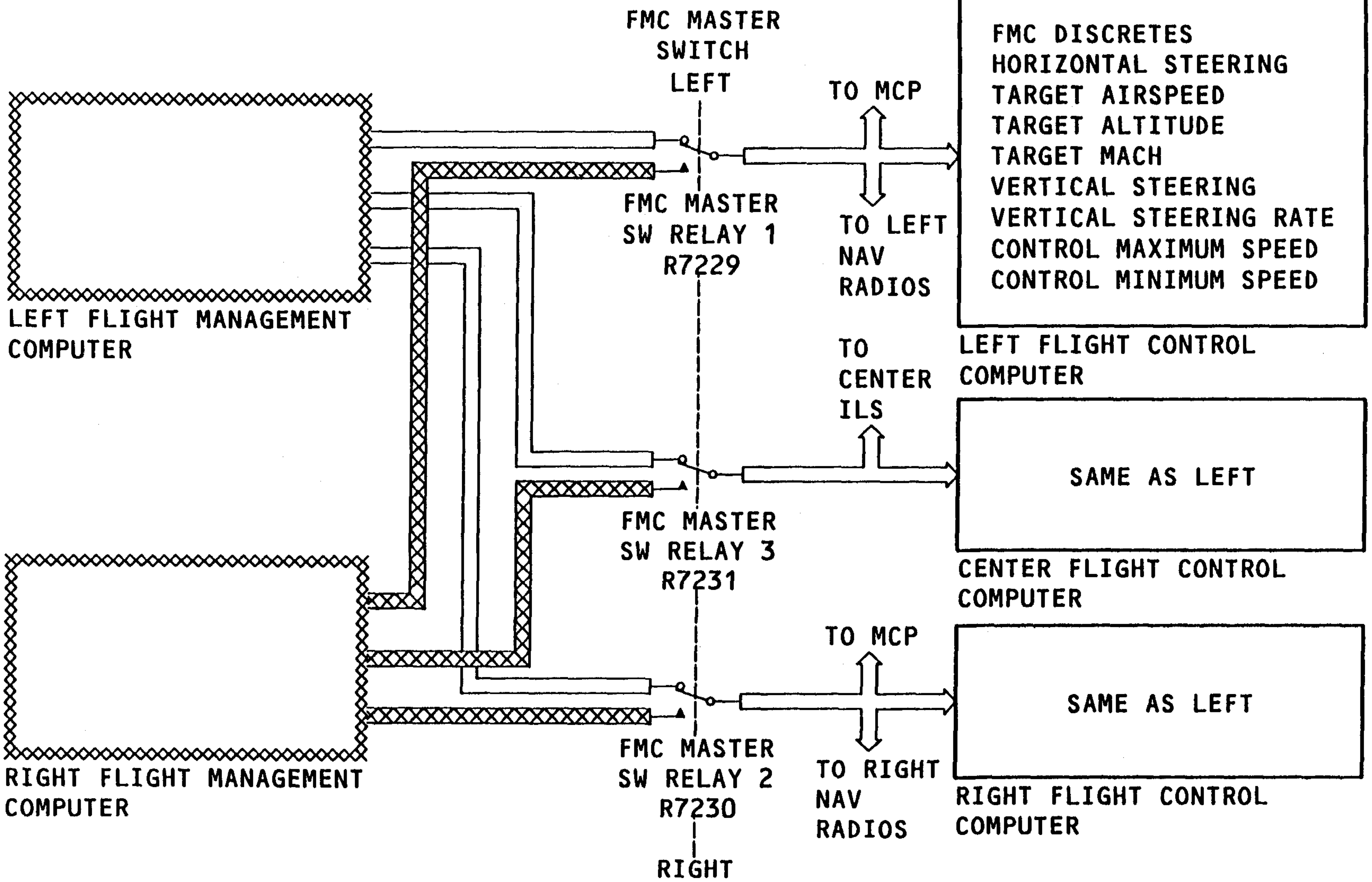


Figure 15 FCC/FMC Interface

FCC/ILS, IRU AND RA INTERFACE

General

Three radio altimeters, ILS receivers and inertial reference units (IRUs), provide data to the AFDS. Each FCC receives ARINC 429 data from a sensor and then transmits the data to the other FCCs on the cross-channel bus.

ILS Interface

The ILS provides localizer and glideslope deviation, runway heading and ILS frequency to the AFDS. Each FCC transmits the ILS TUNE INHIBIT discrete after glideslope or localizer capture if autopilot engaged or below 500 feet radio altitude if F/D only. The FCCs also transmit it when on the ground, within 45° of localizer runway heading and greater than 40 knots groundspeed if a valid localizer is tuned and LOC or APP is not selected. This discrete prevents an ILS self-test and an ILS frequency change while ILS is being used.

Radio Altitude Interface

During an autopilot approach, after localizer or glideslope capture, the FCC issues a TEST INHIBIT discrete to prevent a radio altimeter self-test. If F/D only approach, this inhibit occurs below 500 feet radio altitude.

IRU Interface

The IRU data sent to the FCC is:

- Pitch attitude
- Roll attitude
- Pitch rate
- Roll rate
- Yaw rate
- Magnetic heading
- True heading
- Magnetic track
- True track
- Ground speed
- Inertial altitude
- Inertial vertical speed
- Accelerations (7)
- IRS discretes

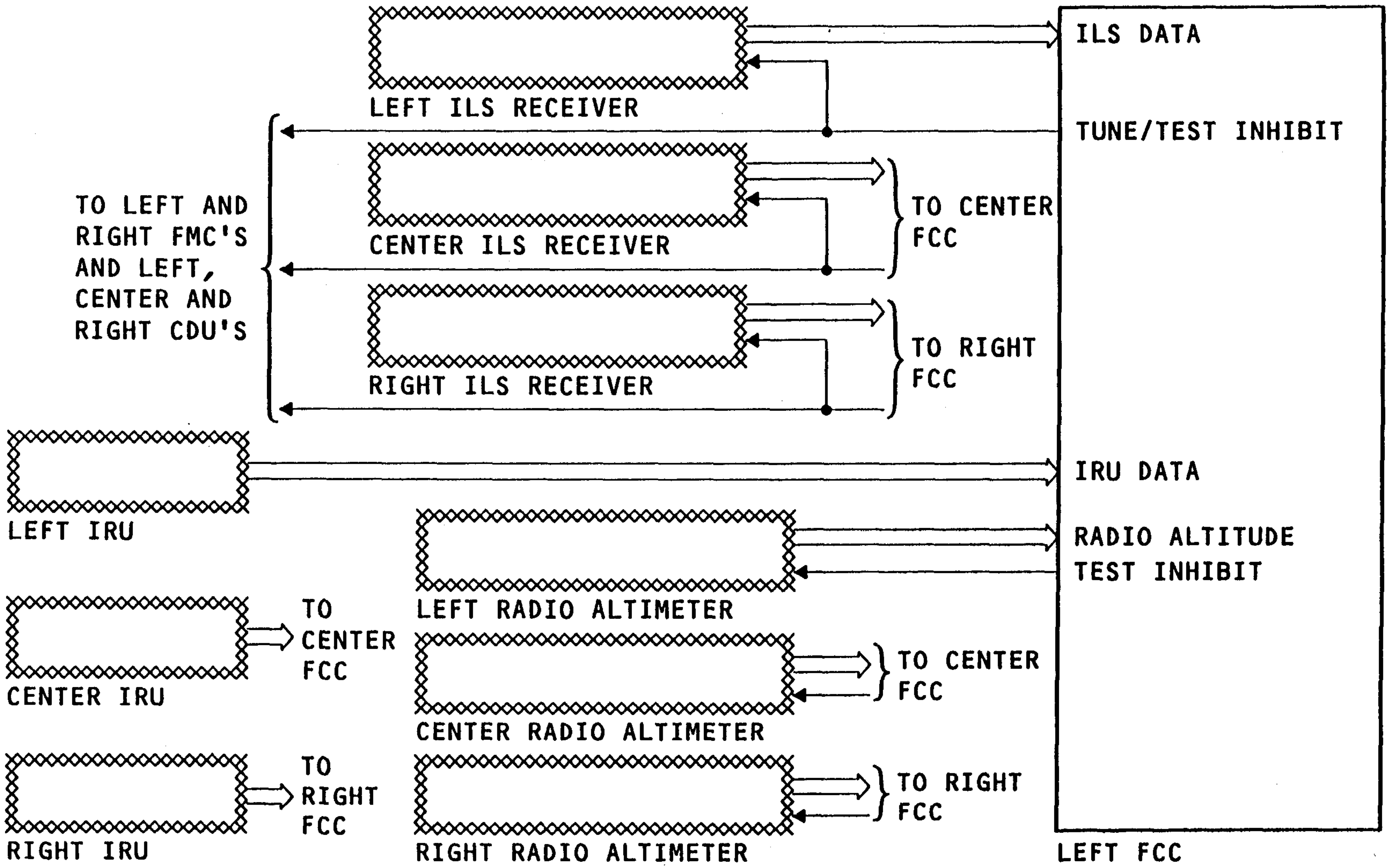


Figure 16 FCC/ILS, IRU and RA Interface

LOCALIZER ANTENNA SWITCH INTERFACE

General

The localizer antenna changes from the tail antenna to the forward antenna for an autoland. This assures a good signal when on the localizer beam.

Operation

A dual-port omni-directional VOR/localizer antenna is in the top of the vertical stabilizer. Also, localizer antennas are on the forward bulkhead inside the radome in the airplane's nose.

The FCCs control relays that change to the forward localizer antennas when:

- The airplane is on the ground, or
- The APP or LOC mode is selected

The FCCs monitor the localizer antenna switch logic to ensure the correct antenna configuration. This monitor is active when the airplane is on the ground or when the autopilot is multi-channel engaged. Antenna switch failures are detected by each FCC.

A single failure causes a NO LAND 3 annunciation. Two or more failures cause a NO AUTOLAND annunciation.

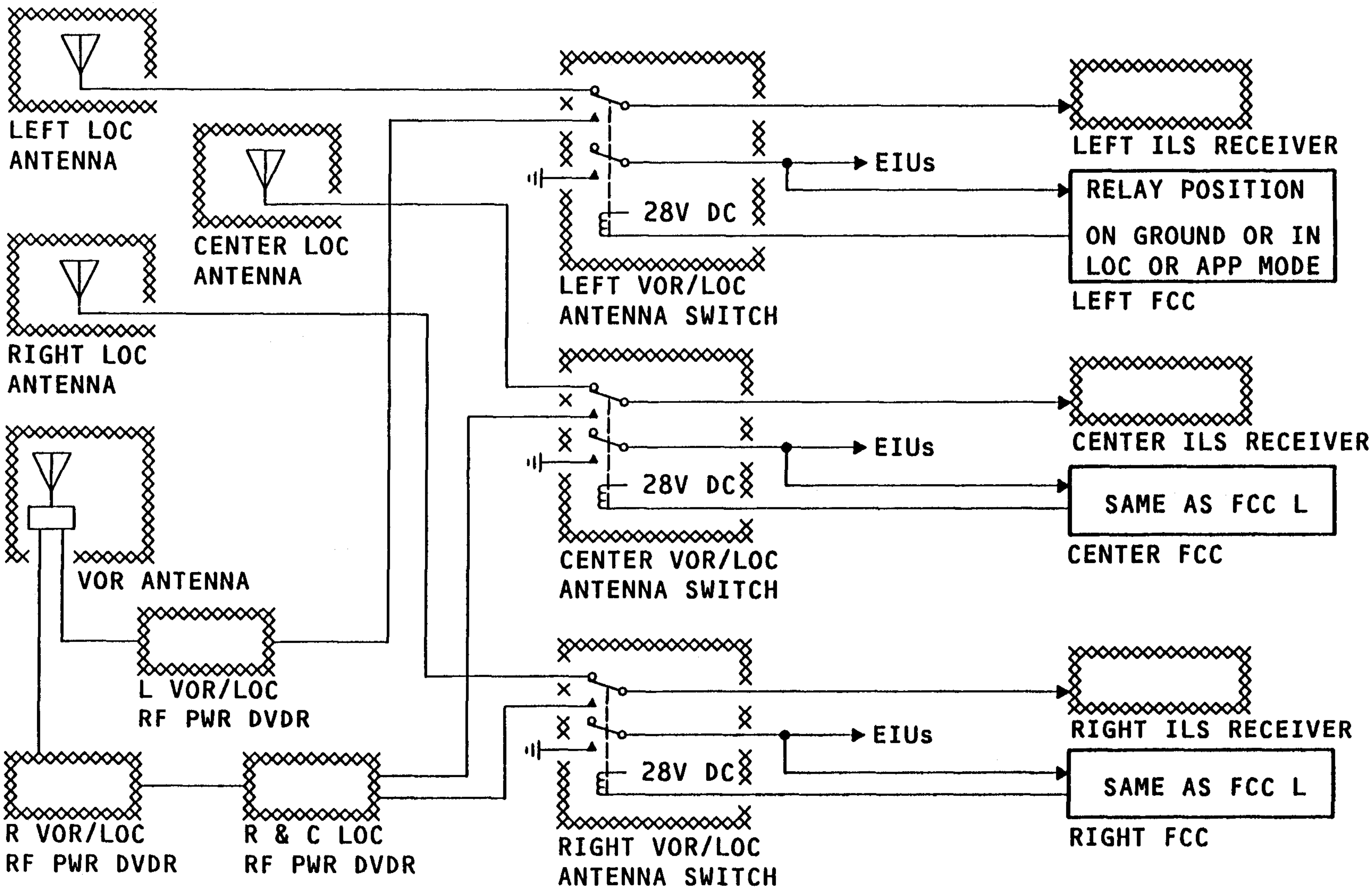


Figure 17 Localizer Antenna Switch Interface

GLIDESLOPE ANTENNA SWITCH INTERFACE

General

The switch of glideslope antennas (radome to nose wheel doors) is done during the autoland sequence. This is to assure proper gear height during landing.

Operation

The glideslope (G/S) capture antennas are in the radome (forward bulkhead) and the G/S track antennas are on the nose gear doors.

The G/S track antenna location provides a correct gear height when the runway threshold is crossed. However, reception is poor when the gear is up. The nose bulkhead antenna provides good reception for the G/S beam capture, but does not provide an acceptable G/S path.

The antenna system switches from the nose bulkhead to the nose gear door when the nose landing gear is lowered. The ILS receivers use the capture antennas when the gear is up and use the track antennas when the gear is down.

The FCC monitors the GIS antenna switch logic through a discrete from the GIS antenna switch relay (on the P31 panel). This monitor is active when the autopilot is multi-channel engaged and less than 700 feet radio altitude. Antenna switch failures are detected by each FCC. A single failure causes a NO LAND 3 status. Two or more failures cause a NO AUTOLAND status.

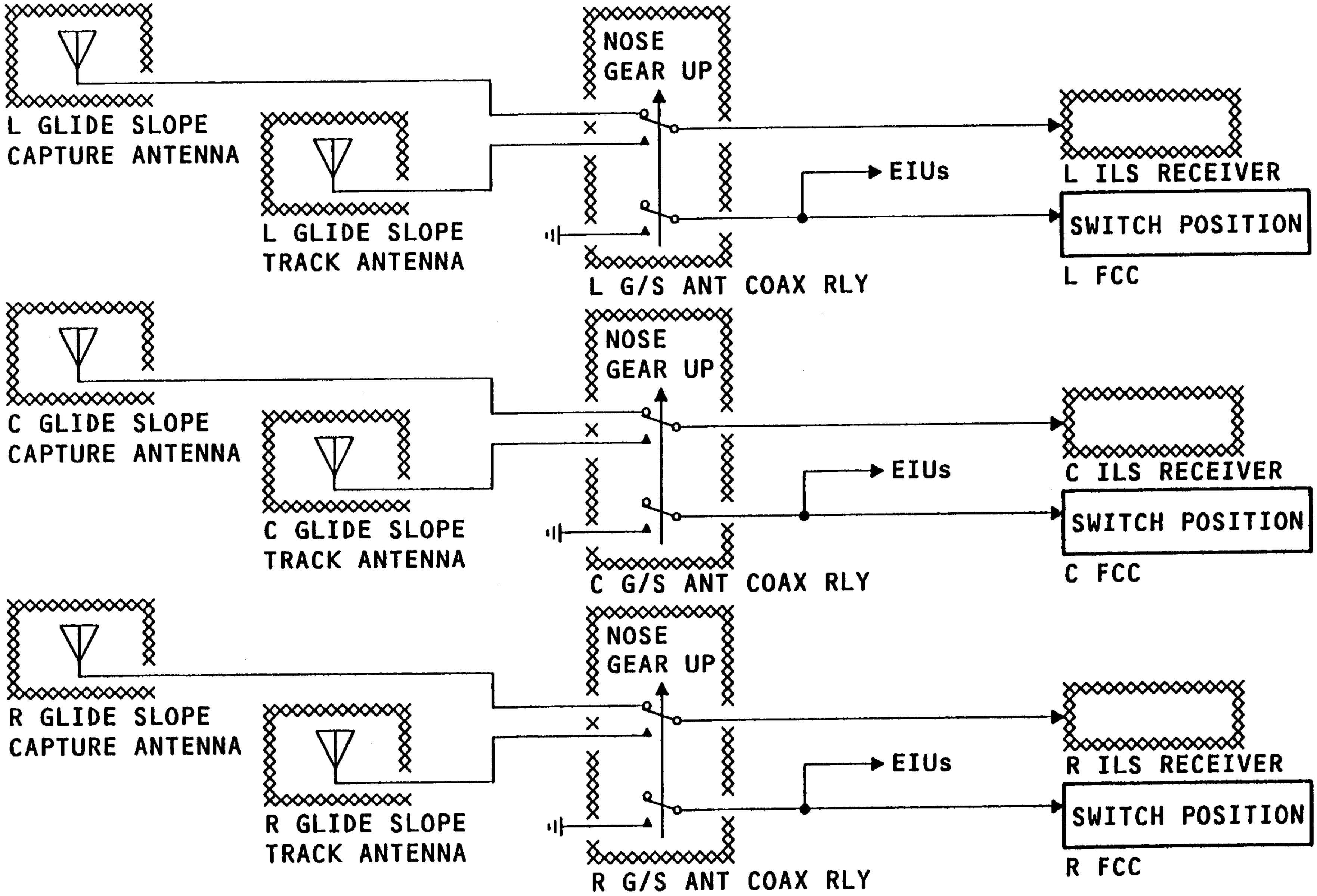


Figure 18 Glideslope Antenna Switch Interface

AIRPLANE CONFIG. SENSOR INTERFACE

General

The airplane configuration sensors provide the flight control computers with analog signals for the flap and stabilizer position and speedbrake handle position. The FCCs receive this data, process it, monitor for validity and transmit the data to the other FCCs on the cross channel data bus. The FCCs also receive discrete signals for hydraulic pressure and air/ground status.

Discrete Signals

The hydraulic interface module (HYDIM) monitors four hydraulic systems for valid pressure. The HYDIM sends a HYDRAULIC PRESSURE VALID discrete to the FCC that uses that hydraulic system for the autopilot servos. The FCC uses hydraulic pressure valid for diagnostic purposes only.

Each FCC determines if the airplane is on the ground or in the air with two ON GROUND discretes. This logic is used for ground test only.

Analog Signals

Three RVDTs sense the speedbrake handle position to provide an output to each FCC.

The inboard and outboard trailing edge flap drive systems have three RVDTs each. The FCCs receive only inboard flap position. One RVDT is at the power drive unit (PDU). The other two show the left and right flap drive linkage position.

The RVDT output is conditioned and monitored by the flap control unit (FCU). A buffered output is provided by the FCUs to the AFDS and other airplane systems.

Three RVDTs provide stabilizer position data to the FCUs. This data is processed by the FCUs similar to the trailing edge flap position.

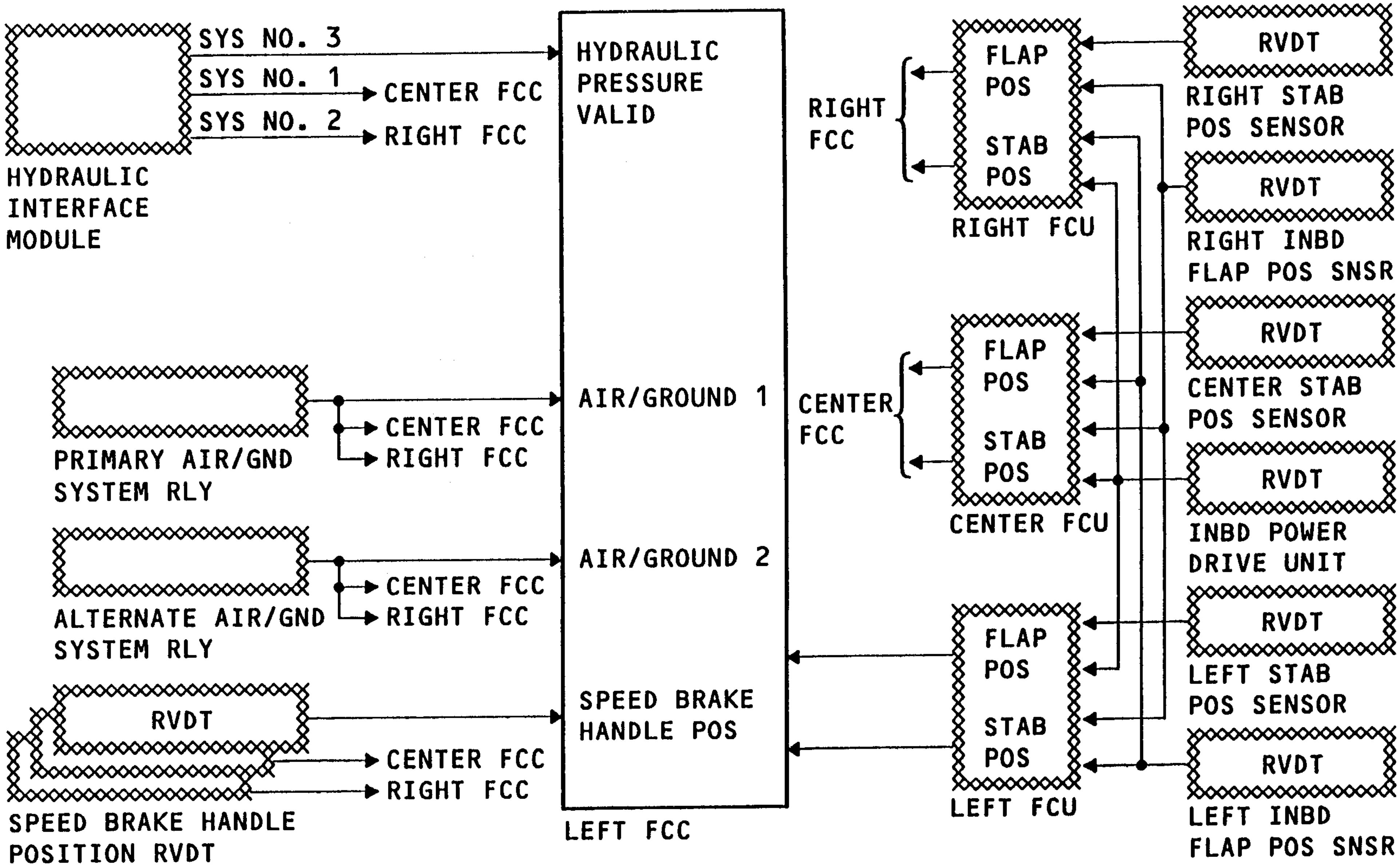


Figure 19 Airplane Configuration Sensor Interface

FCC/MISCELLANEOUS DISCRETE INTERFACE

General

The miscellaneous discrete inputs to the AFDS are:

- Autopilot disengage switches
- Go-around switches
- Heading reference switch
- Flight director source select switches

Interface

Two go-around switches, on thrust levers 2 and 3 produce the go-around discrete input for the FCCs.

The autopilot disengage switches are on the captain’s and first officer’s control wheel.

The captain and first officer select the data source for the cockpit displays with the instrument source select switches (ISSS). The FCC uses the F/D switch selection data only during ground test.

The FCC uses heading data from the IRU referenced to magnetic north or true north depending on the position of the heading reference switch. The heading reference switch is on the EICAS control panel.

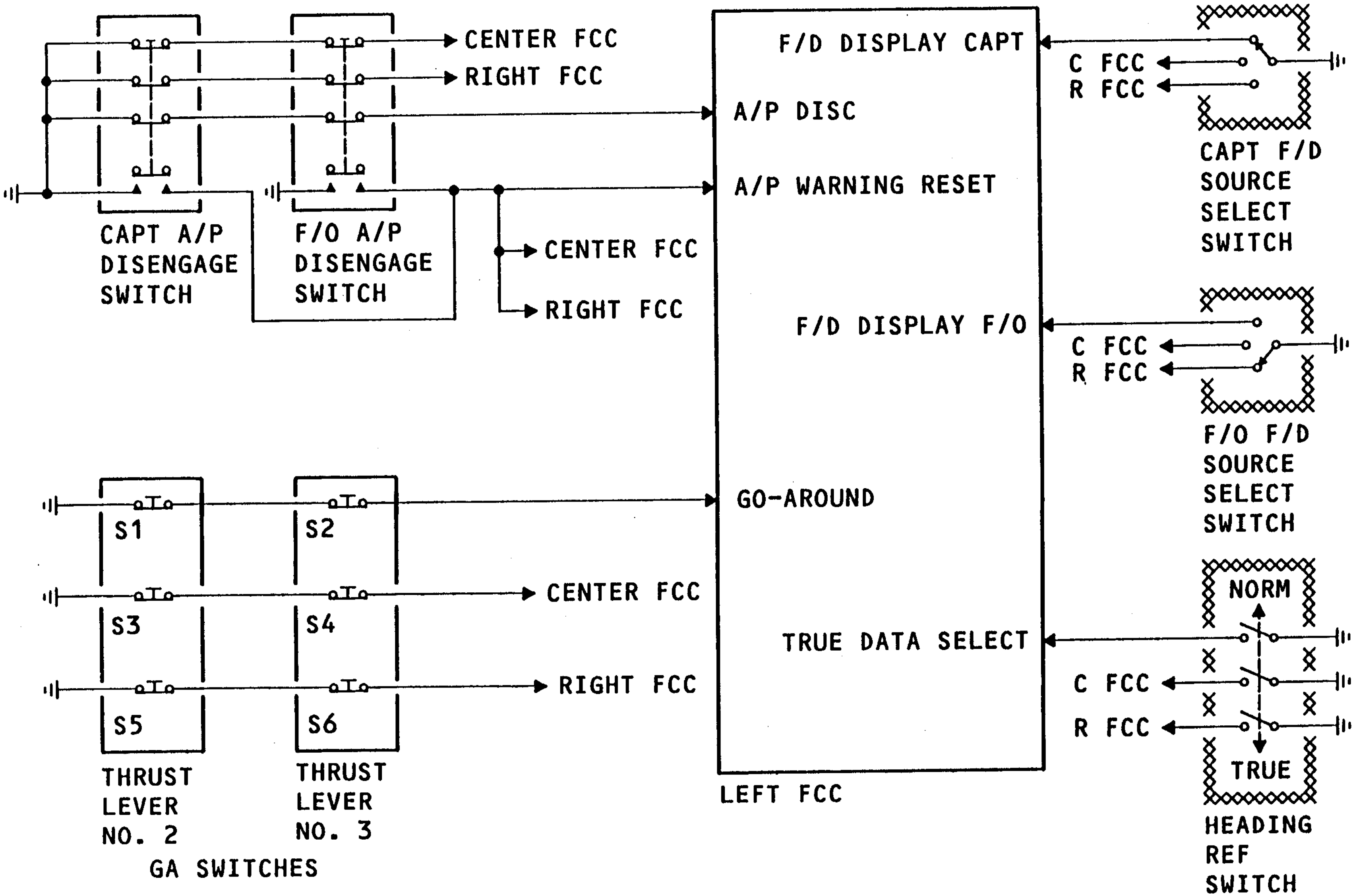


Figure 20 FCC/Miscellaneous Discrete Interface

FCC/AUTOPILOT SERVO INTERFACE

General

The AFDS has an interface with the primary flight control systems through the elevator, lateral and rollout autopilot servos. one elevator and one aileron servo are used for cruise operation with a second and third elevator and aileron servo added for autoland. The rollout power control package is engaged only in the dual (fail passive) or triple (fail operational) configuration. In a multi-channel configuration, the autopilot servos are force-voted to the airplane's flight control system.

Operation

Each FCC servo command output is a dc analog signal to an electro-hydraulic servo valve (EHSV). Two LVDTs in the servo package provide ac analog servo position and surface position feedback to the FCC. These positions are also monitored to make sure the autopilot system works correctly.

The arm and engage 28 volts is used to energize the arm and engage solenoids.

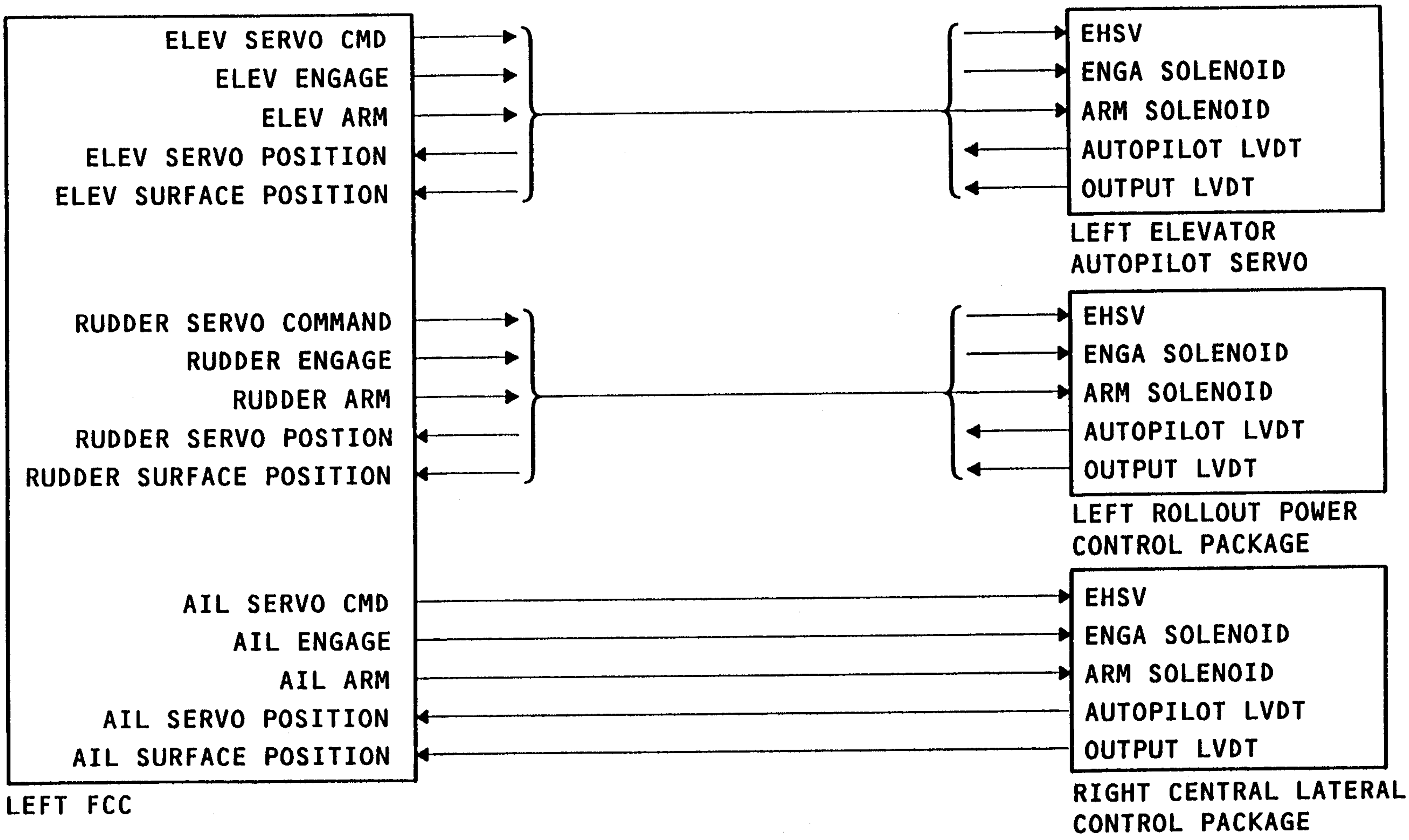


Figure 21 FCC/Autopilot Servo Interface

FCC/AUTO STAB TRIM SYSTEM INTERFACE

General

The AFDS has an interface with the stabilizer trim system. The autopilot commands stabilizer trim through the stabilizer control system when an autopilot channel is engaged. Each of the two systems has a stabilizer trim/rudder ratio module (SRM) and a stabilizer trim control module (STCM).

The left flight control computer (FCC) interfaces with the left SRM. The right FCC interfaces with the right SRM. The center FCC interfaces with the left and right SRMs.

Interface

The SRM requires both autotrim arm and control commands from a FCC to engage autotrim. During single and triple channel (fail-operational) operation, automatic stabilizer trim is controlled by a single trim system. During a portion of a fail-passive autopilot approach (LAND 2), both trim channels are engaged to provide two time the normal trim rate (full rate autotrim).

The autotrim valid discrete from the left SRM is transmitted to the left and center FCC and from the right SRM to the right and center FCC. This discrete is used by the FCC to control autotrim and for engage interlocks.

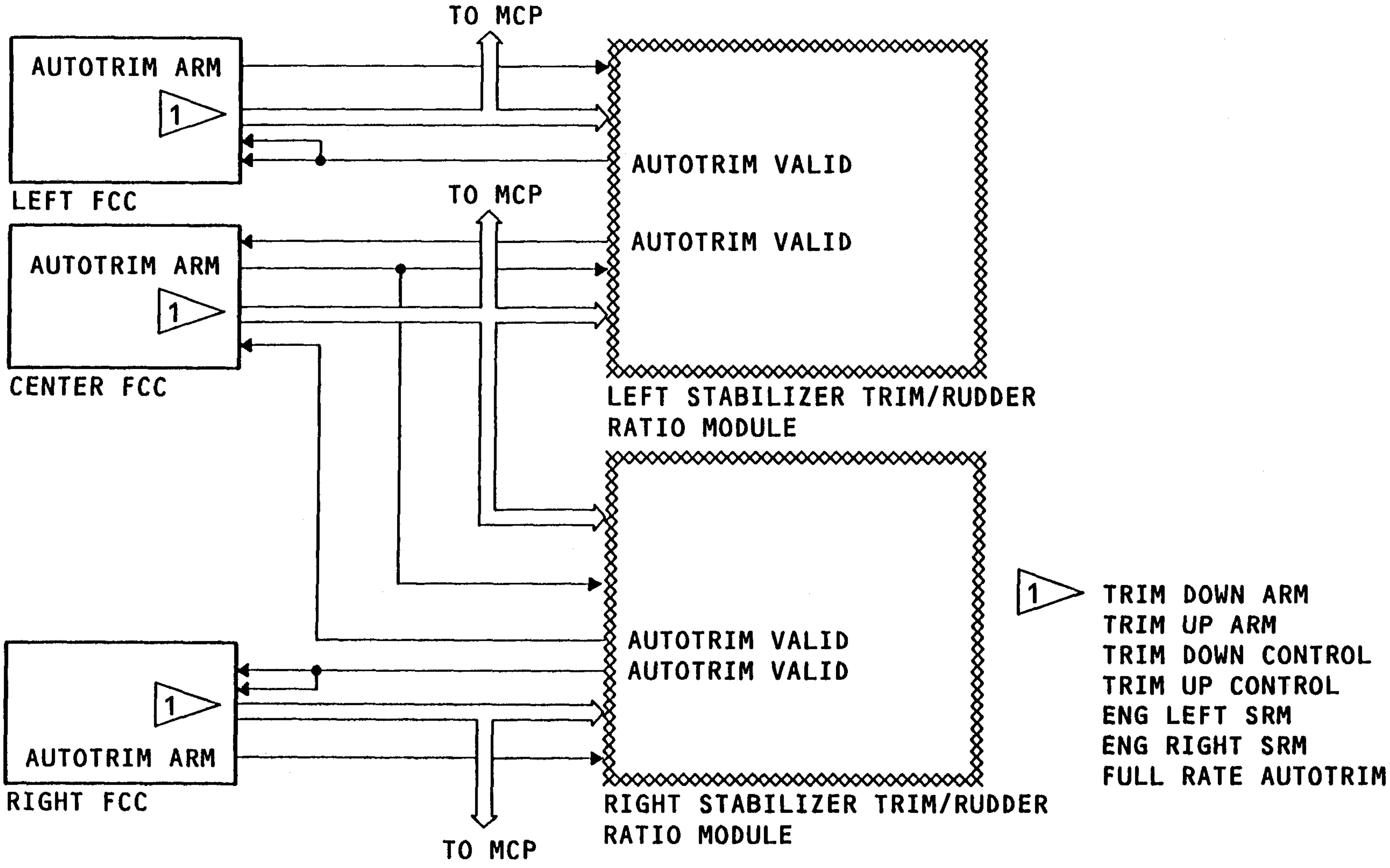


Figure 22 FCC/Automatic Stabilizer Trim System Interface

FCC/IDS AND MAWEA INTERFACE

General

The FCC sends this data to the EIUs for the EICAS, PFD and ND displays:

- Autopilot warning
- Autopilot caution
- EICAS status
- AFDS mode
- Autoland status
- Engage status
- Flight director commands
- Flight crew selected data

The FCC also sends warning discretes to the MAWEA for master warning annunciation.

Caution, Warning, Status and Advisory Interface

The FCC sends caution, warning, status and advisory data to the EIUs on ARINC 429 busses. Also, they send an A/P WARN 1 BATTERY DISCRETE to the left EIU to make sure a warning shows.

The FCC sends discrete data to the MAWEA for master warning annunciation. The MAWEA turns on the master warning

lights and necessary aural tones. The EIU turns on the master caution lights.

EFIS Interface

The FCC sends pitch and roll mode data, autopilot engage/ASA status, flight director commands and flight crew selected data to the EIUs. The flight crew selected data is:

- Altitude
- Airspeed
- Vertical speed
- Heading

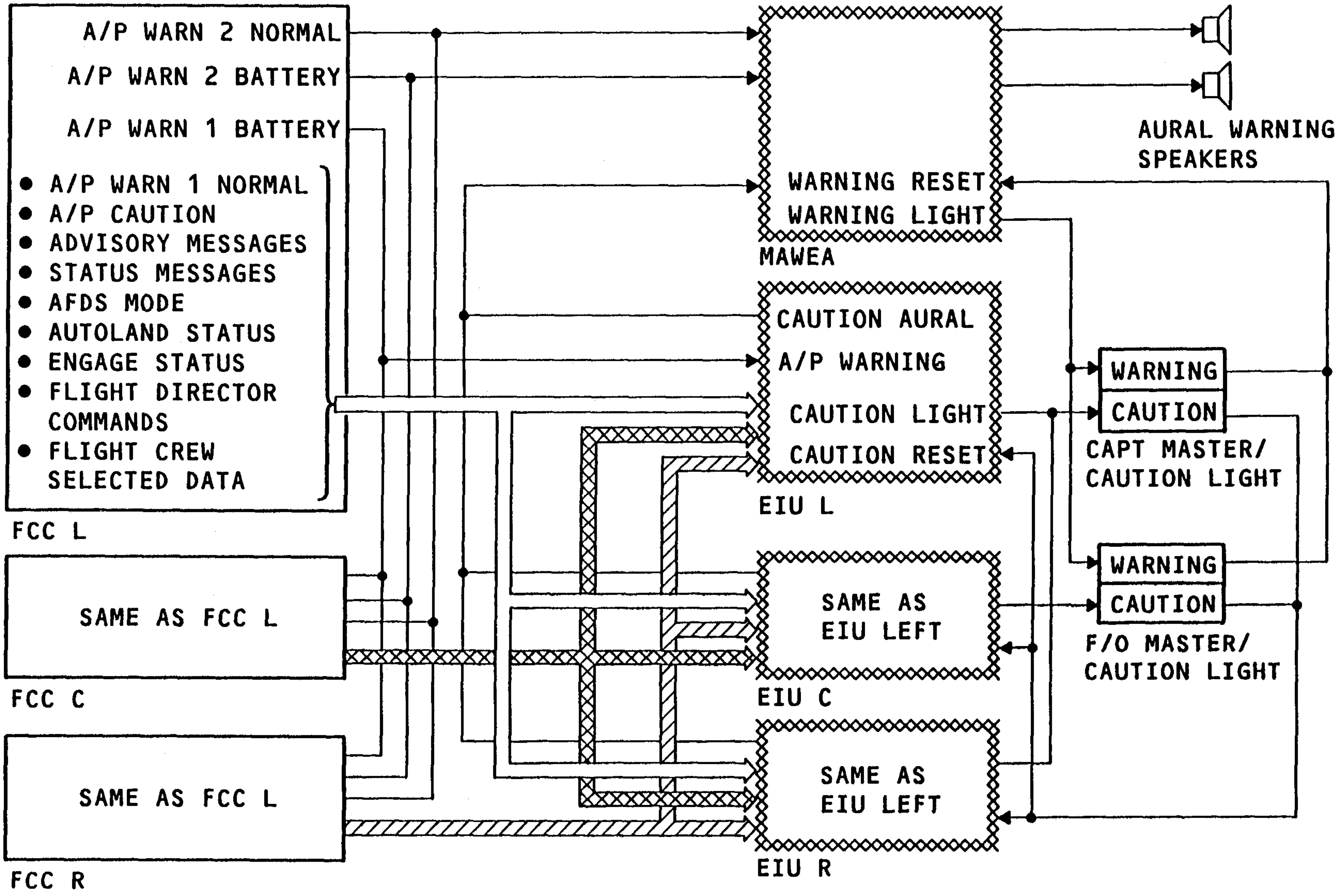


Figure 23 FCC/IDS and MAWEA Interface

FCC/CMC INTERFACE

General

The central maintenance computer (CMC) does continuous, power-up, functional and ground tests. It also stores and reports test-related data.

FCC Interface

The CMCs send a GROUND TEST analog discrete to each FCC. When the discrete is low the CMC signals the FCC to go to a ground test mode. The left CMC also sends test control data to each FCC on an ARINC 429 data bus This test control has discrete words that request a specific ground test.

Each FCC sends data to both CMCs. This data includes fault data, ground test data, interface fault data, test word.

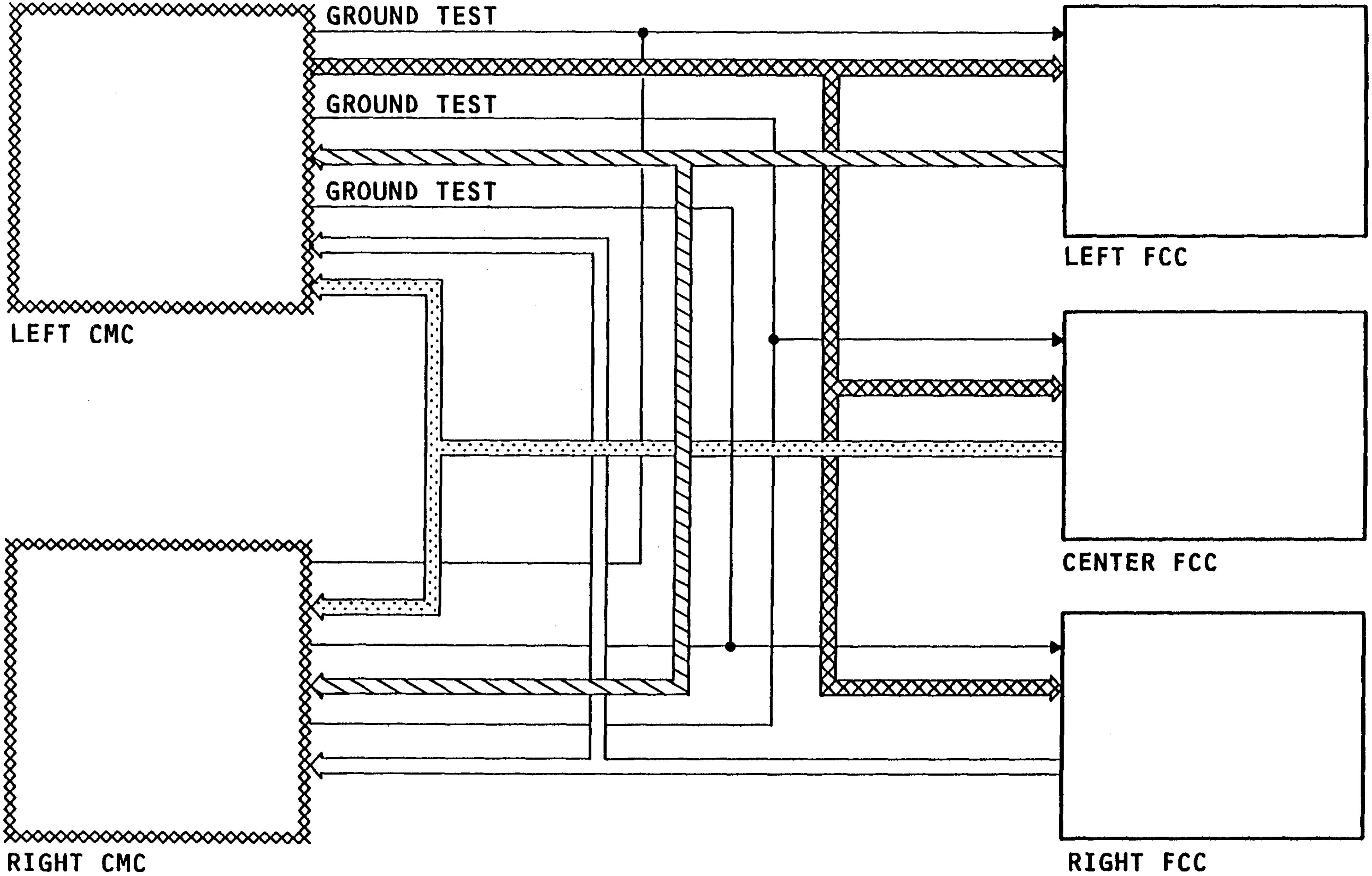


Figure 24 FCC/Central Maintenance Computer Interface

FLIGHT CONTROL COMPUTER

General

The flight control computer (FCC) provides the input, output, monitoring and computing functions for the autopilot flight director system.

Operation

The FCC has modules, sub-assemblies, and a chassis assembly in an ARINC 600 size 8 unit. The FCC is mounted with ’front hold-down hooks to install in a standard ARINC rack.

A handle on the front panel is used to remove and handle the unit.

The case has two removable side covers to provide access to all circuit cards and modules. The top and bottom covers allow cooling air to come in at the bottom and leave at the top.

One three-section connector on the back of the FCC connects with a receptacle on the rack.

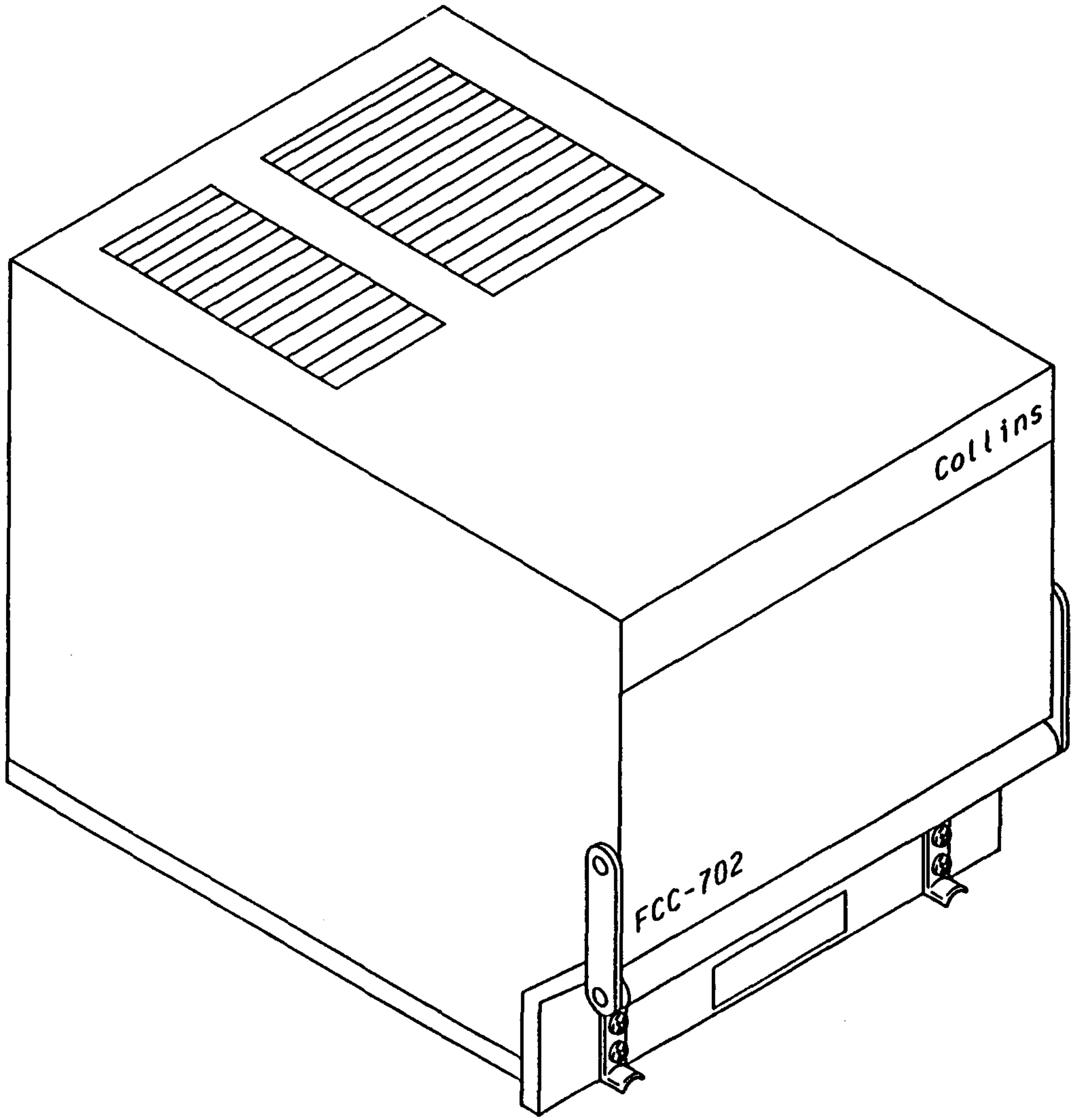


Figure 25 Flight Control Computer (old)

AFDS - FLIGHT CONTROL COMPUTER

General

The flight control computer (FCC) supplies the input, output, monitoring and computing functions for the autopilot flight director system. (AFDS).

Physical Features

The FCC has modules, sub-assemblies, and a chassis assembly in an ARINC 600 size 8 unit. The FCC has front hold-down hooks for installation in a standard ARINC rack. The folding handle, installed on the front of the FCC, helps in the removal and handling of the unit.

The cover assembly has removable sides for access to all circuit cards and modules. The top and bottom makes up the external part of the air plenum. Cooling air goes in at the bottom and out at the top.

One three-part connector, installed on the rear of the FCC, allows connection with the rack-installed connector.

The portable data loader connector lets software load directly into the FCCs.

Software

The FCC has two types of software:

- Operational program software (OPS)
- Operational program configuration files (OPC).

The OPS has core programs and application programs for the FCC. The OPS has a software part number that identifies it.

The OPC has configuration data for the FCC for non-intermix operation. In inter-mix operation, the program pins have the configuration data for the FCC and the OPC is not used. The FCC uses configuration data to make sure of correct operation of the OPS. The OPC has a software part number that identifies it.

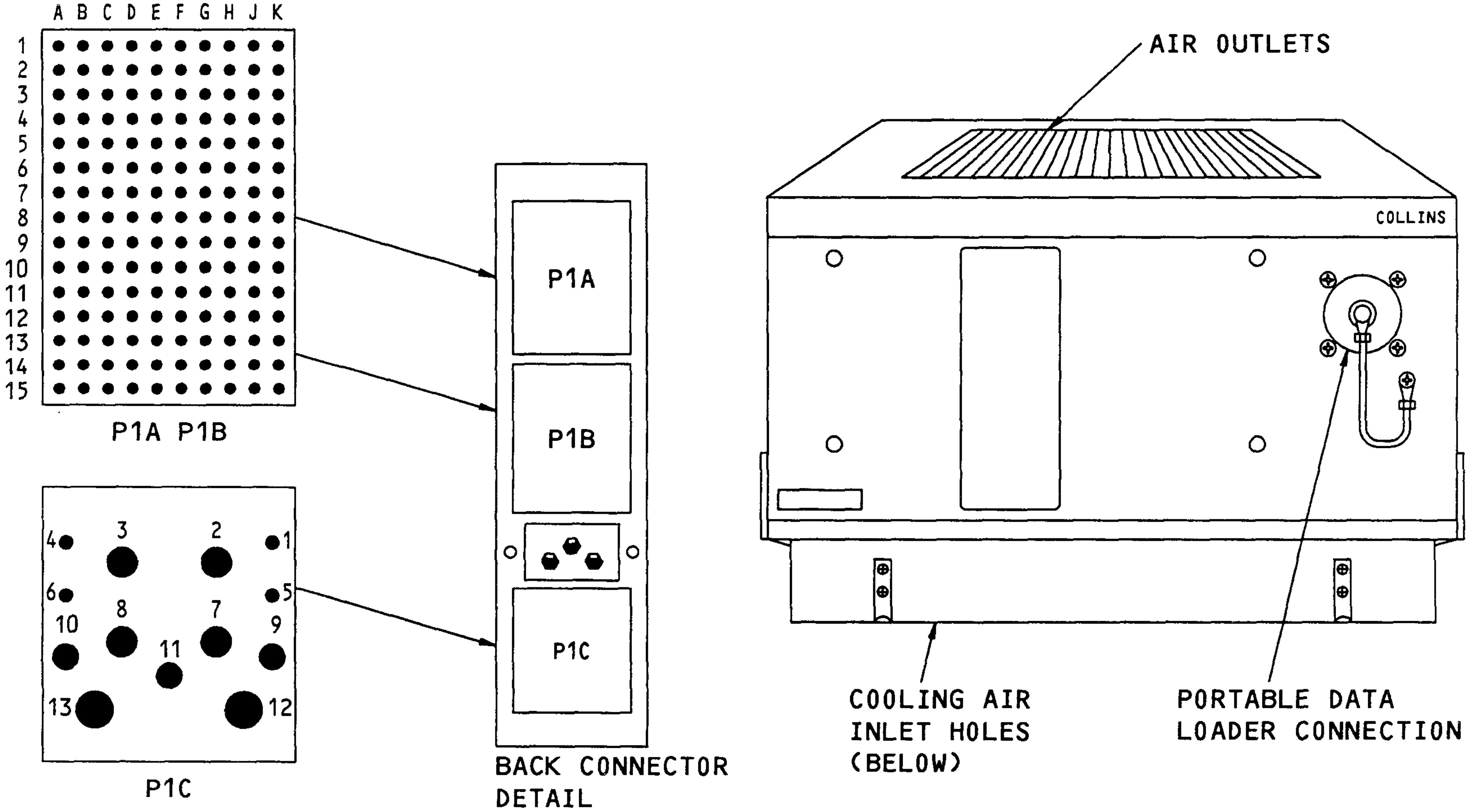


Figure 26 FLIGHT CONTROL COMPUTER (New)

FCC BLOCK DIAGRAM

General

This block diagram shows the major modules in the flight control computer (FCC). A brief explanation of these modules is provided.

Power Supply Module

The power supply module provides +5v dc, +/-l5v dc and 28v dc which are used in the FCC. It also provides 26v ac used for LVDT and RVDT excitation.

CAPS Transfer Bus

The Collins adaptive processing system (CAPS) transfer bus has 16 data lines, 16 address lines and 10 control lines. Data lines give a means for data flow. Address lines give a way to determine which module is to send or receive data. Control lines determine sequence and the control of which module is to transmit or receive. The CAPS transfer bus allows all modules to control and to communicate with other modules.

CAPS Processors

Two 16 bit processors are used. One processor controls pitch and the other controls roll and yaw for all modes of autopilot and flight director operation. The processors have two software functions to perform. Foreground processing which includes the control laws is done every 25 milliseconds. Background processing which includes BITE monitors and memory checks is done every 1.5 seconds.

Memory Module

The memory module has dedicated and shared portions for each processor. The types of memory are:

- Non-volatile memory (NVM) for fault storage
- Random access memory (RAM) for storing changeable data
- Programmable read-only-memory (PROM) for the main operating program.

Input/output Module

The input/output module has ARINC 429 low speed and high speed inputs. Discrete inputs are for program pins, customer options and switches. Discrete outputs are for autopilot disconnect warning and inter-channel discrete data. Analog inputs are for LVDT, RVDT and analog DC inputs.

Cross Channel Receiver

The cross channel receiver receives ARINC 429 high speed inputs from the relative left and relative right FCCs.

Arm Control Module

The arm control module gives a ground to energize the elevator/aileron arm relay and the rudder arm relay. The arm relays send 28v dc to the arm solenoids in the autopilot servos.

Engage control Module

The engage control module has the same function for the engage relays and the engage solenoids. In addition, the engage control module provides a discrete output for autotrim arm to the SRM.

Pitch Servo Driver

The pitch servo driver sends the analog signal to the electrohydraulic servo valve (EHSV) in the elevator autopilot servo. This driver also receives the LVDT signals for servo and surface position which are used for control follow-up and to detect a camout condition.

Roll/Yaw Servo Driver

The roll/yaw driver has the same function for the aileron and rudder servos,

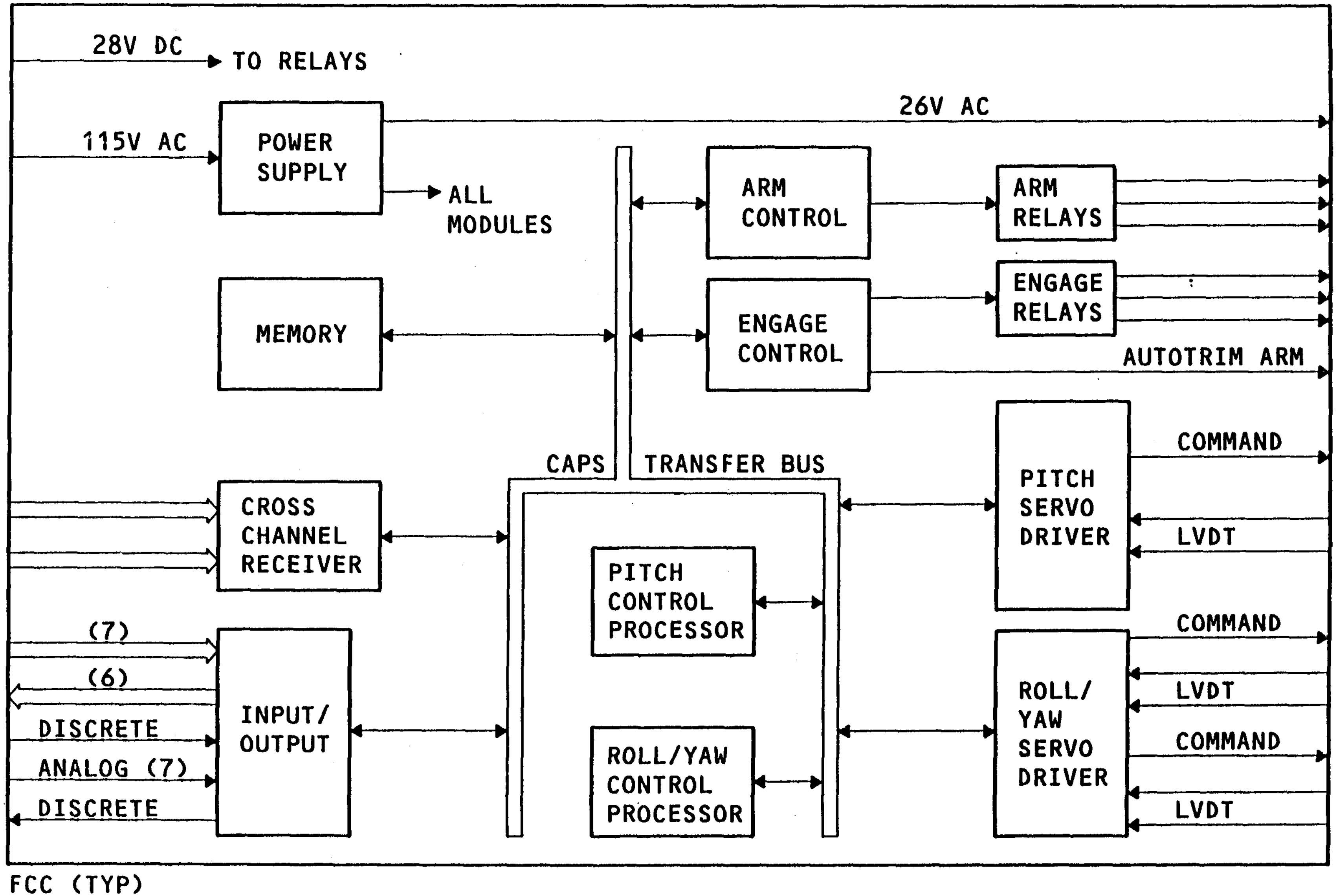


Figure 27 FCC Block Diagram

AFCS MODE CONTROL PANEL

The mode control panel (MCP) is the primary interface between the flight crew and the flight director, the autopilot and the FMC autothrottle systems. Front panel controls and displays allow engage, mode select and control of these systems.

Three quick-disconnect connectors on the rear of the MCP provide 28-volt dc power and 5-volt ac panel lighting. The connectors also provide ARINC data buses, discrete inputs and outputs and 28-volt dc servo power.

Forced airflow from the equipment cooling system enters the rear of the MCP.

The MCP weighs about 16 pounds. Four screws hold the MCP to the mounting rails on the glareshield structure. They connect to floating locknuts in the bottom of the MCP.

Each lighted pushbutton switch contains four bulbs. These bulbs are replaceable from the front without removing the MCP. The top two bulbs use 5v ac power and are controlled by master dim and test circuits. The lower two bulbs show a dot-bar matrix

light to indicate that the mode or status is selected. The lower bulbs use 28v dc and are controlled by both microprocessors.

The displays are magnetic wheel displays controlled by the microprocessors. At MCP power-up, the displays show:

- IAS/MACH = 200
- HDG = 000
- VERT SP = blank
- ALT = 10000

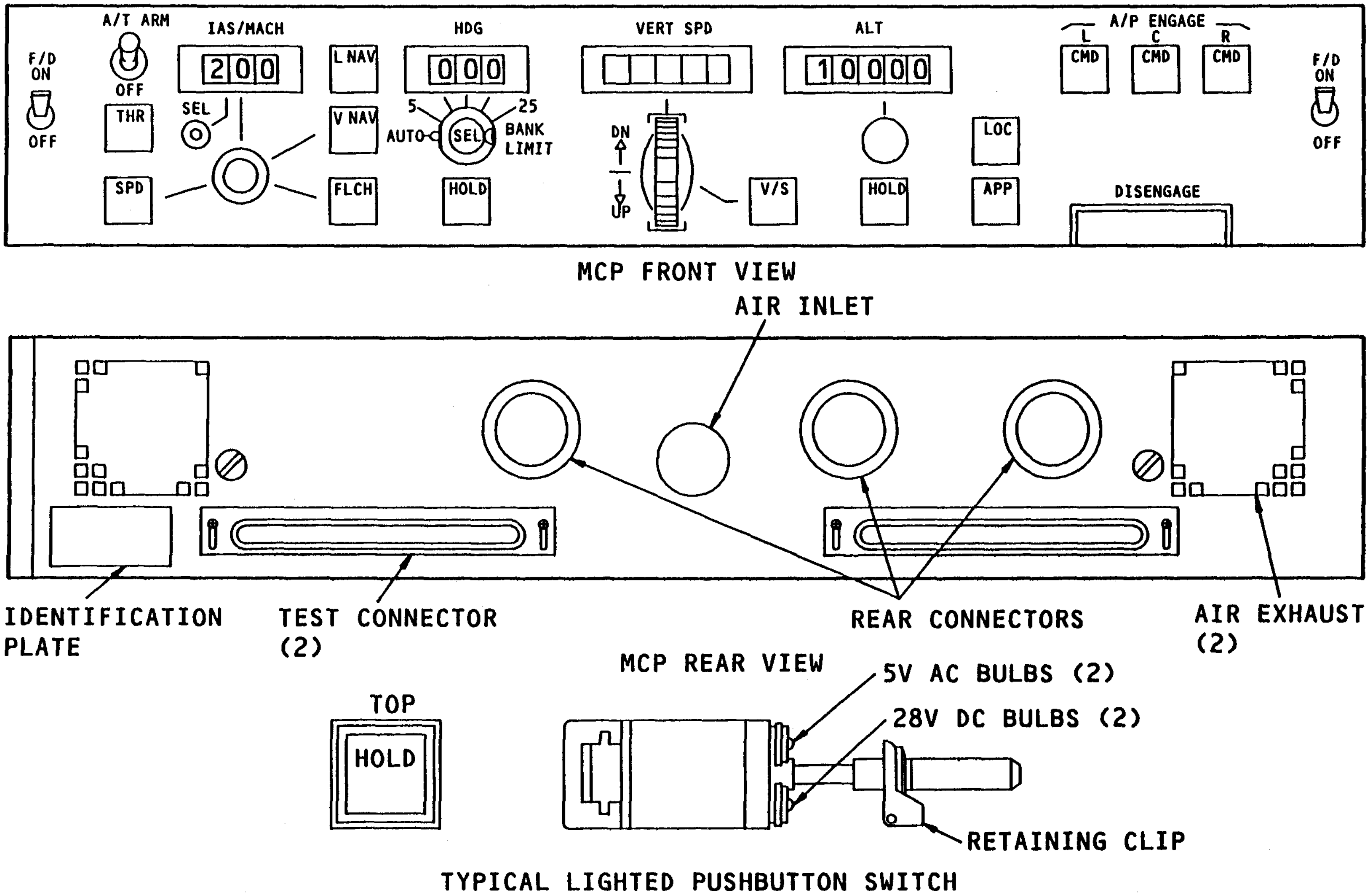


Figure 28 AFCS Mode Control Panel

MCP SIGNAL SOURCE SELECTION

General

The signal source for control of the MCP is either a flight control computer (FCC) or an encoder that is connected to a control knob. The altitude display is used as an example.

Operation

In this example, a signal from the encoder (controlled by the MCP altitude knob) goes through microprocessor A to the left and center FCCs and to the MCP altitude display. The signal also goes to microprocessor B. Microprocessor B then sends this signal to the right FCC.

For most conditions, microprocessor A controls the MCP displays. Microprocessor B controls if microprocessor B is valid and:

- Microprocessor A is not valid, or
- Only the right FCC is valid, or
- Only the right FCC is engaged, or
- Only the first officer's F/D is on.

During a display initialization (power-up or certain AFDS mode changes), the encoder becomes inactive and the FCC is the signal source to control the displays. Normally, the left FCC initializes the MCP displays through microprocessor A. The right FCC is used when microprocessor B is selected (as already discussed).

Microprocessor A uses the center FCC if the center FCC is valid and:

- The left FCC is not valid, or
- The center FCC is engaged and the left FCC is not engaged.

Microprocessor B uses the center FCC if the center FCC is valid and:

- The right FCC is not valid, or
- The center FCC is engaged and the right FCC is not engaged.

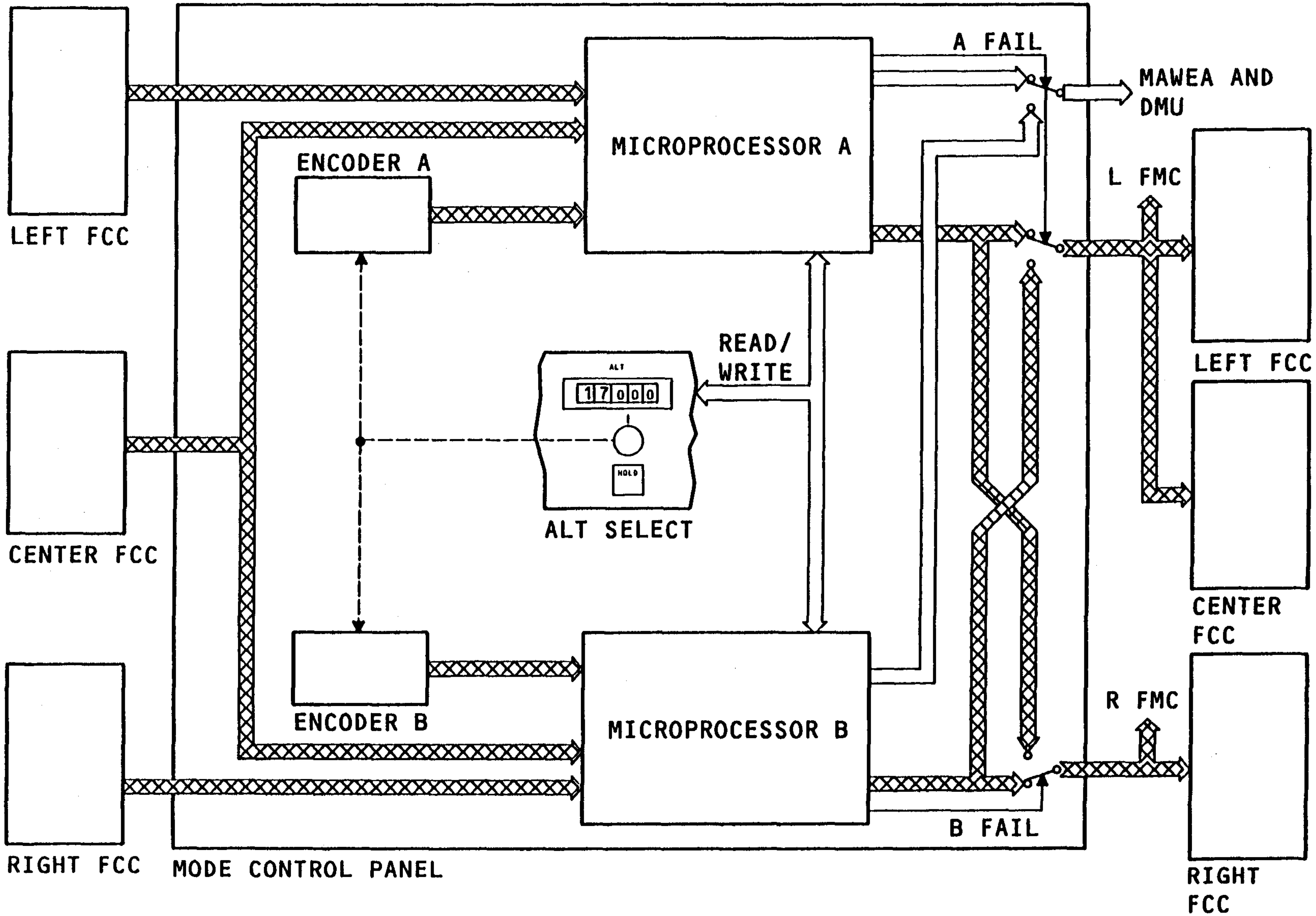


Figure 29 MCP Signal Source Selection

AP DISENGAGE & GO-AROUND SWITCHES

Autopilot Disengage Switches

An autopilot disengage switch is on the outboard side of each pilot's control wheel. Each switch is a single-action, multiple-pole, pushbutton switch.

Go-Around Switches

There is one go-around switch assembly on the number 2 thrust lever and one switch assembly on the number 3 thrust lever. Each assembly contains three switches. They provide the logic discrete to the FCCs used for the takeoff/go-around mode.

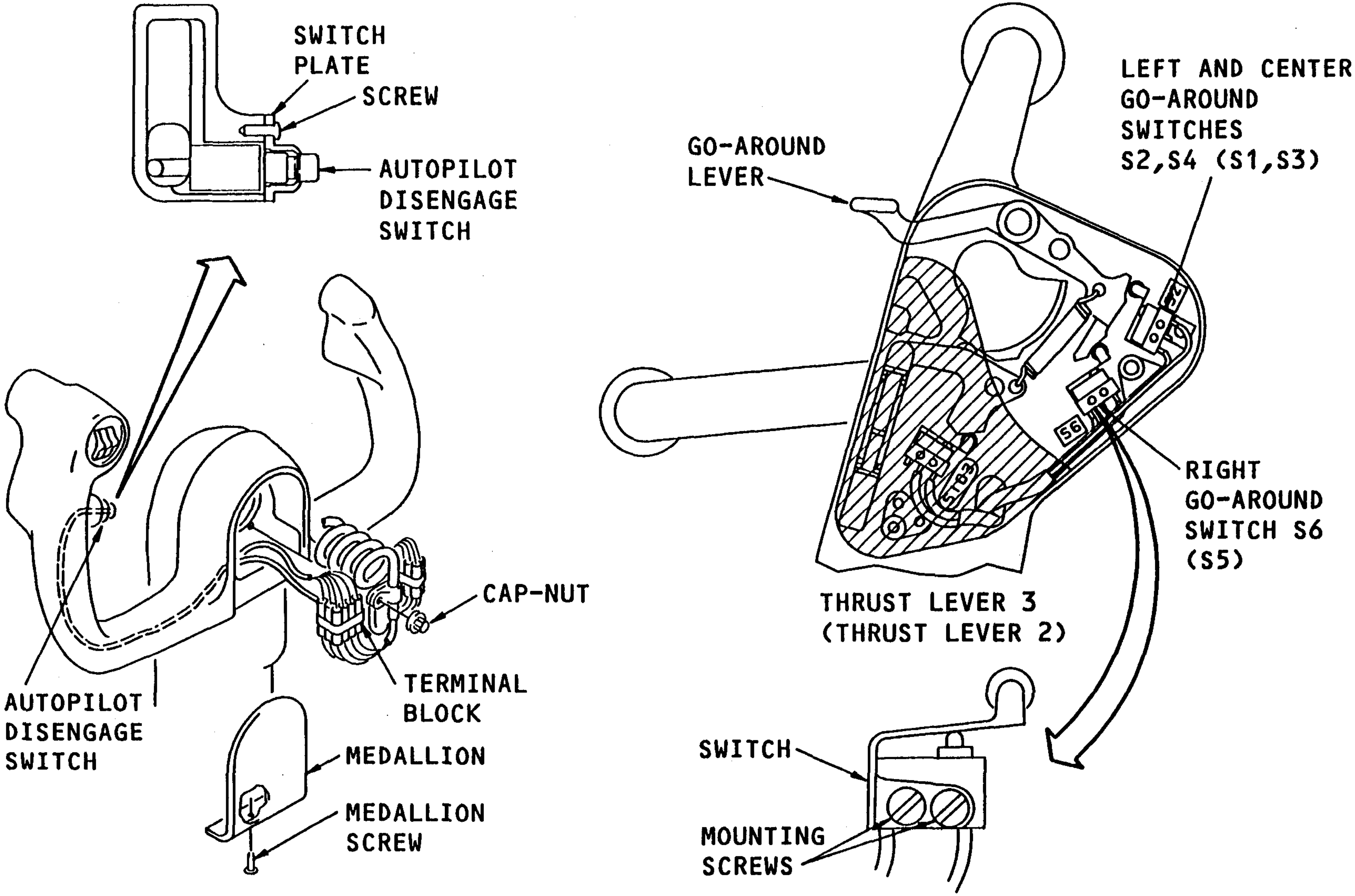


Figure 30 Autopilot Disengage and Go-Around Switches

AUTOPILOT SERVO INTRODUCTION

General

There are two different types of autopilot servos. One type of servo is used in lateral control. The other type of servo is used for elevator and rollout control. However, both types of servos are similar. A drawing of both styles is shown below.

Operation

Flight control computers (FCCs) control the autopilot servos through the electrohydraulic servo valve (EHSV). The EHSV controls hydraulic pressure from one of the hydraulic systems to move the output crank.

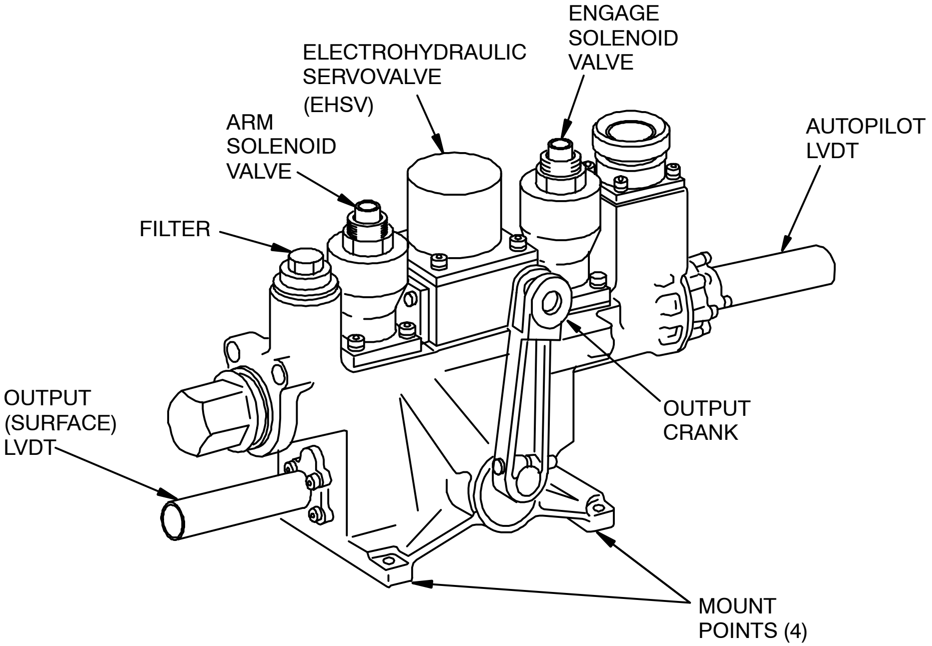
The autopilot servo has three modes.

- Servo disengaged
- Armed
- Servo engaged

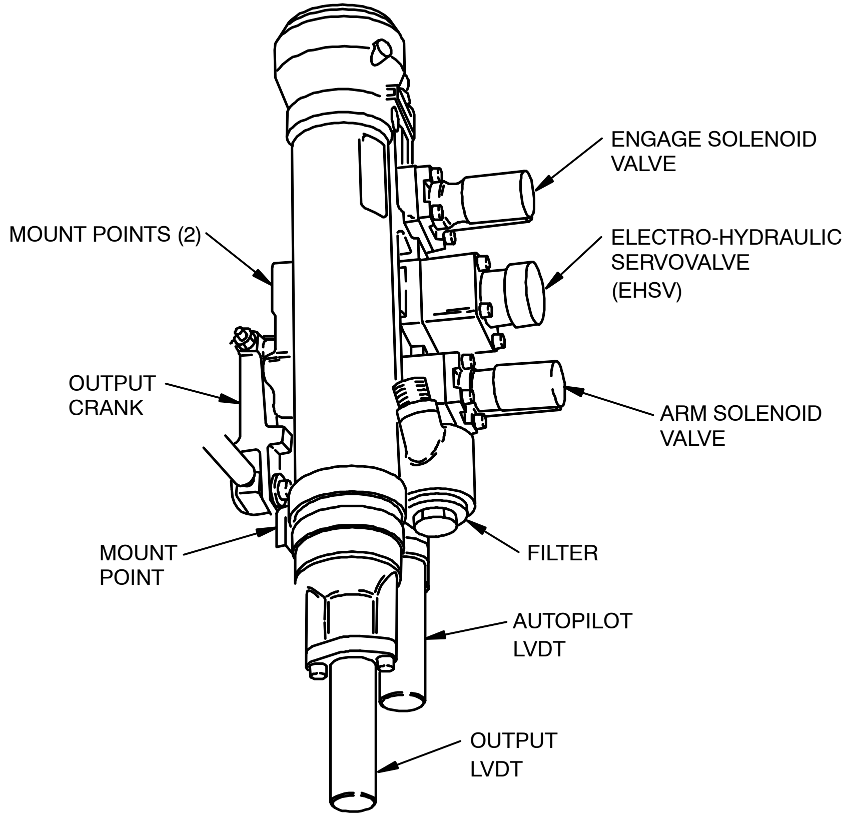
When the servo is disengaged, it is disconnected from linkage to the flight control surface. Any commands from the flight control computer to fly the airplane will not move a control surface.

In the arm mode, the autopilot servo position is synchronized to the flight control surface position.

When the servo is engaged, the servo is connected to the flight control surface. Then the flight control computer flies the airplane with commands to the EHSV.



ELEVATOR AUTOPILOT SERVO AND ROLLOUT POWER CONTROL PACKAGE



LATERAL AUTOPILOT SERVO

Figure 31 Autopilot Servo

AUTOPILOT SERVO - OPERATION

General

The autopilot servos use hydraulic system 1, 2 or 3 and are controlled by a flight control computer (FCC).

Disengaged

When the servo is disengaged, the engage and arm solenoids are de-energized. The engage pistons retract by springs, and the output crank can move freely.

Arm

The FCC energizes the arm solenoid valve to arm the servo. Hydraulic pressure goes to the engage solenoid valve and to the EHSV. The EHSV receives commands from the FCC to move the autopilot actuator piston. During arm, this piston is moved by the FCC to make its position (as sensed by the autopilot LVDT) the same as the position of the output crank (as sensed by the output LVDT). When the hydraulic piston assembly is correctly positioned, the autopilot servo is synchronized to the surface.

Engage

The engage command energizes the engage solenoid valve. Hydraulic pressure then goes to the pressure regulator. From the pressure regulator, reduced hydraulic pressure moves the detent pistons which hold the output crank. FCC inputs to the EHSV will now move the output crank.

If the output crank motion is blocked,. or if the crank moves without FCC input, a condition called camout occurs. In camout, the hydraulic pressure that holds the detent pistons is overpowered by the motion of the output crank. The FCC senses this camout condition because the autopilot LVDT signals and the output LVDT signals do not agree.

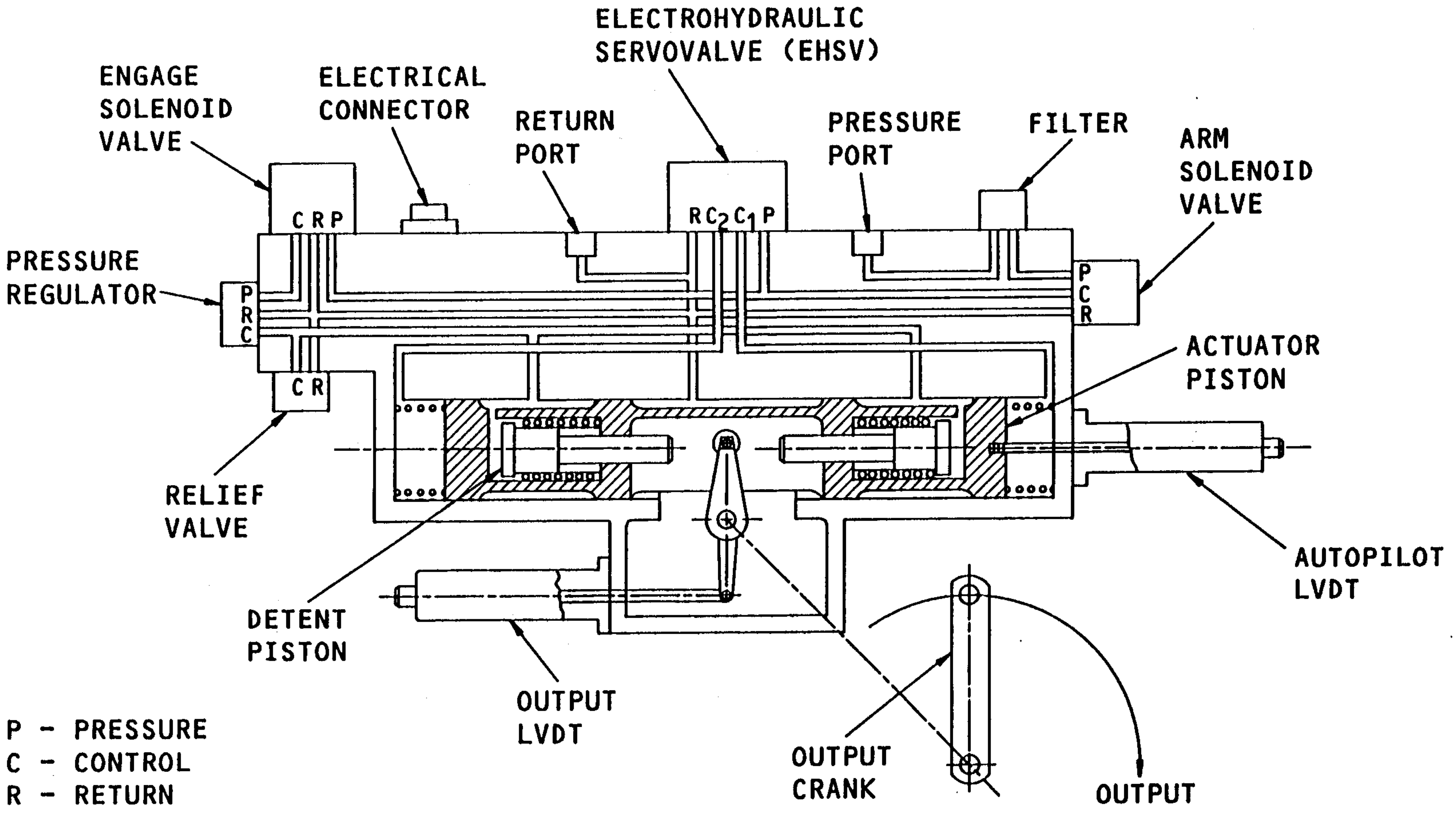


Figure 32 Autopilot Servo - Operation

CENTRAL LATERAL CONTROL PACKAGE

General

The central lateral control package (CLCP) has two sections. They are an autopilot servo and a power boost.

Operation

The operation of the autopilot servo section of the CLCP is the same as for the autopilot servo. The power boost section provides a boost to change pilot control wheel movement to input for the aileron and spoiler systems.

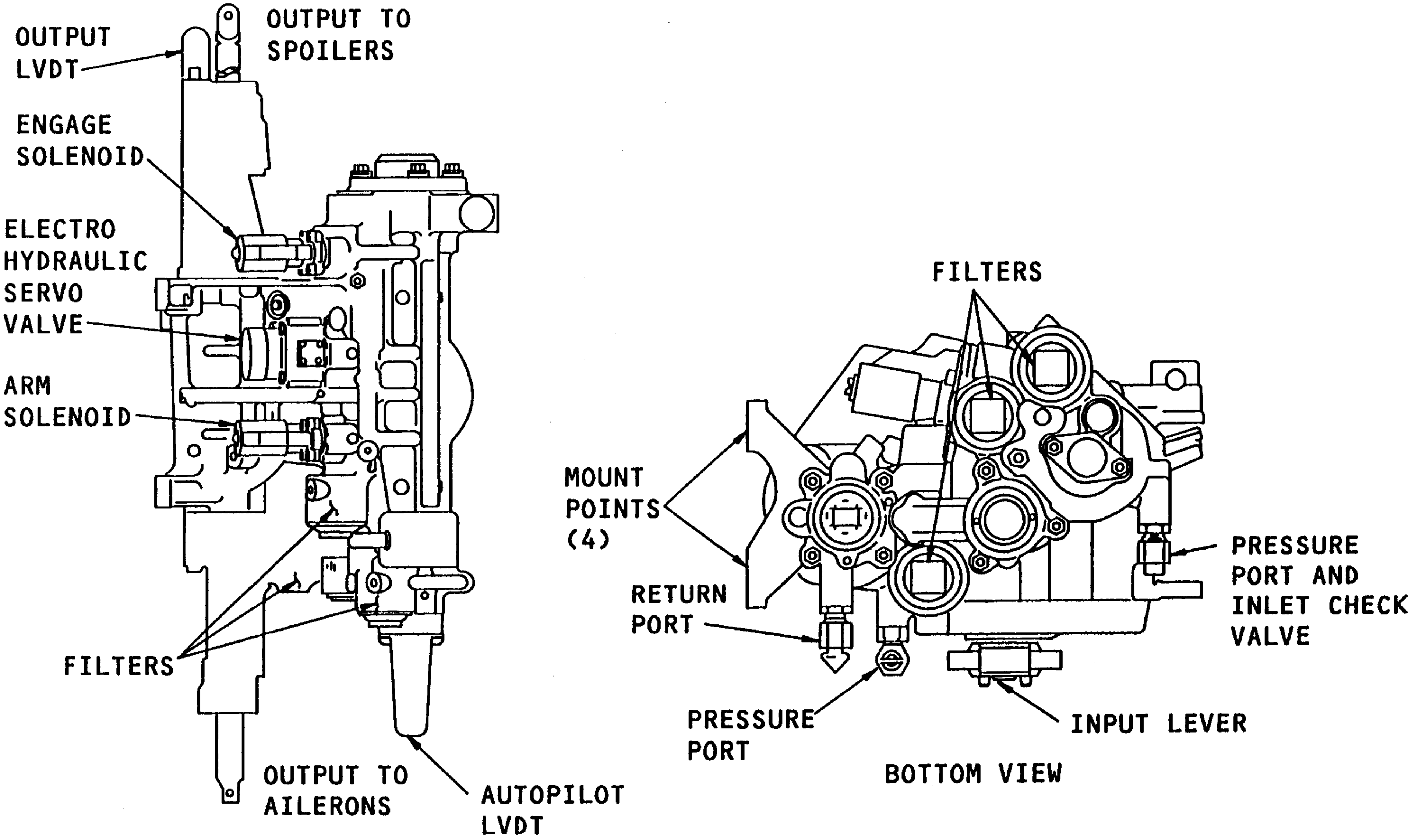


Figure 33 Central Lateral Control Package

CLCP - OPERATION

General

The operation of the upper part of the central lateral control package is similar to the autopilot servo. The CLCP is different than the autopilot servo because it has a power boost section. This section of the CLCP is shown in the lower part of the diagram.

Power Boost Operation

Two hydraulic systems are used for the power boost. Both hydraulic systems go through a filter and then to the main control valve. To describe the operation of the lower boost section, start with the autopilot not engaged. The detent pistons (on the autopilot actuator piston) retract and the upper part of the summing lever is free to move.

A pilot movement of the input lever moves the control valve. Hydraulic pressure from two systems is then sent to the main actuator. The main actuator moves opposite to the direction of the control valve.

The main actuator moves the summing lever which moves the control valve so that hydraulic pressure is removed from the main actuator. The effect is that the main actuator has moved and stopped in a new position with the control valve centered.

Autopilot Operation

When the autopilot is armed, the autopilot actuator piston is synchronized to the flight control surface the same way as in the autopilot servo. When the autopilot engages, the detent pistons move to hold the top of the summing lever. FCC inputs to the electrohydraulic servo valve move the autopilot actuator piston which in turn moves the control valve. From this point, operation of the CLCP power boost section is the same as described for pilot inputs.

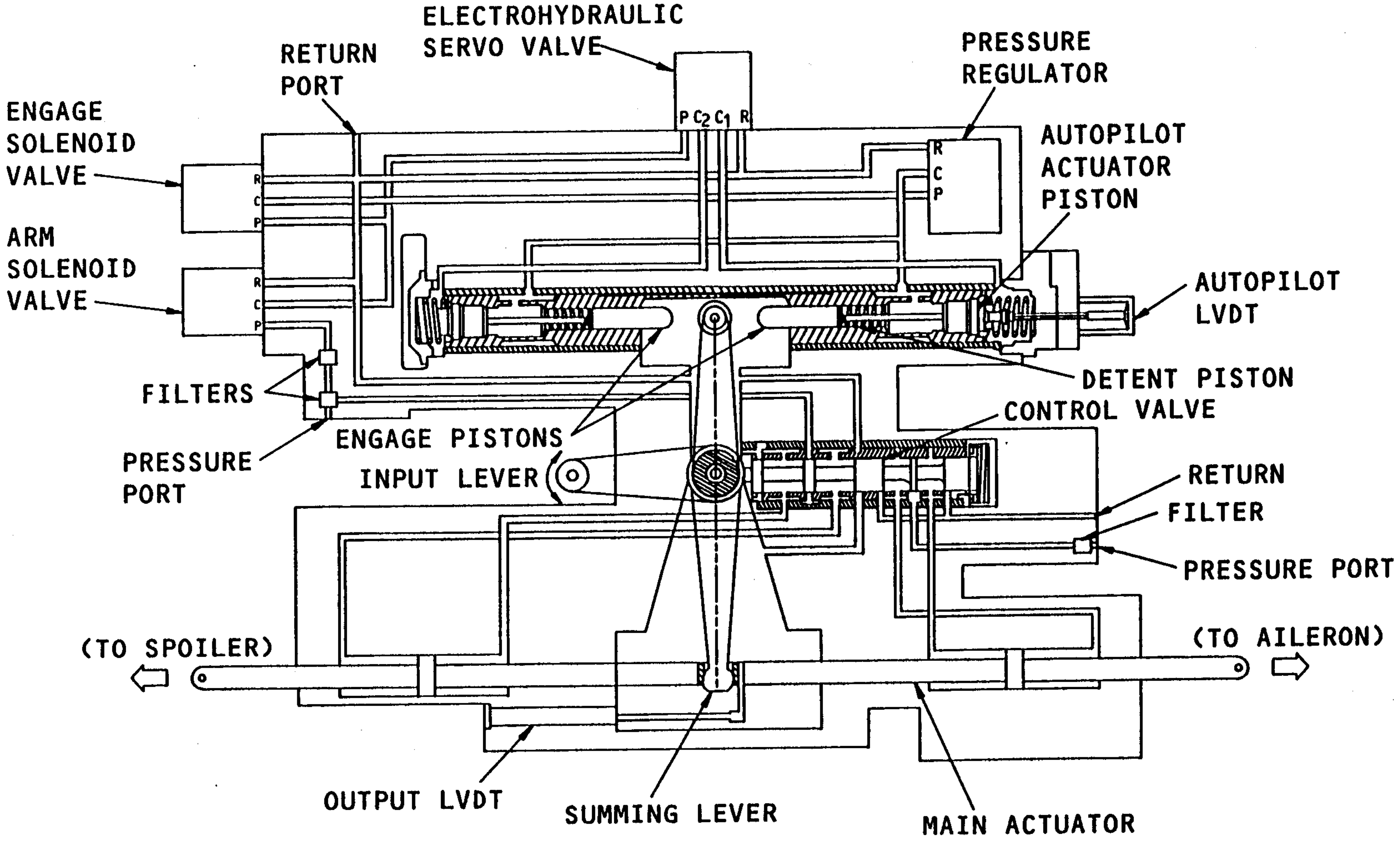


Figure 34 CLCP - Operation

PFD AND ND - NORMAL

General

The AFDS data that shows on the primary flight display (PFD) is:

- Flight director roll and pitch commands
- AFDS roll and pitch modes: shows armed and operate modes for the autopilot and flight director
- AFDS status: shows AFDS engage and autoland status
- Flight crew selected data

The flight crew selected data is:

- Airspeed/mach
- Altitude
- Vertical speed
- Heading

Engage Status

The AFDS engage status annunciations are:

- FD (green): shows that a flight director is on
- CMD (green): shows that an autopilot is engaged to CMD
- TEST (green): shows that an autopilot CMC ground test is in progress

Autoland Status

Below 1500 feet radio altitude, in a multi-channel condition, the autoland status annunciation replaces the AFDS status. The annunciation is one of these:

- LAND 3 (green): This shows the autopilot is in a fail-operational capacity because three autopilots channels are engaged, there are three independent sources of power and all sensors needed for autoland are valid.
- >LAND 2< (green with white triangles): This shows the autopilot is in a fail-passive capacity because at least one of the above categories has degraded such that only two are available.
- NO AUTOLAND (yellow): This shows no automatic landing capability because at least one of the above categories has degraded such that only one is available.

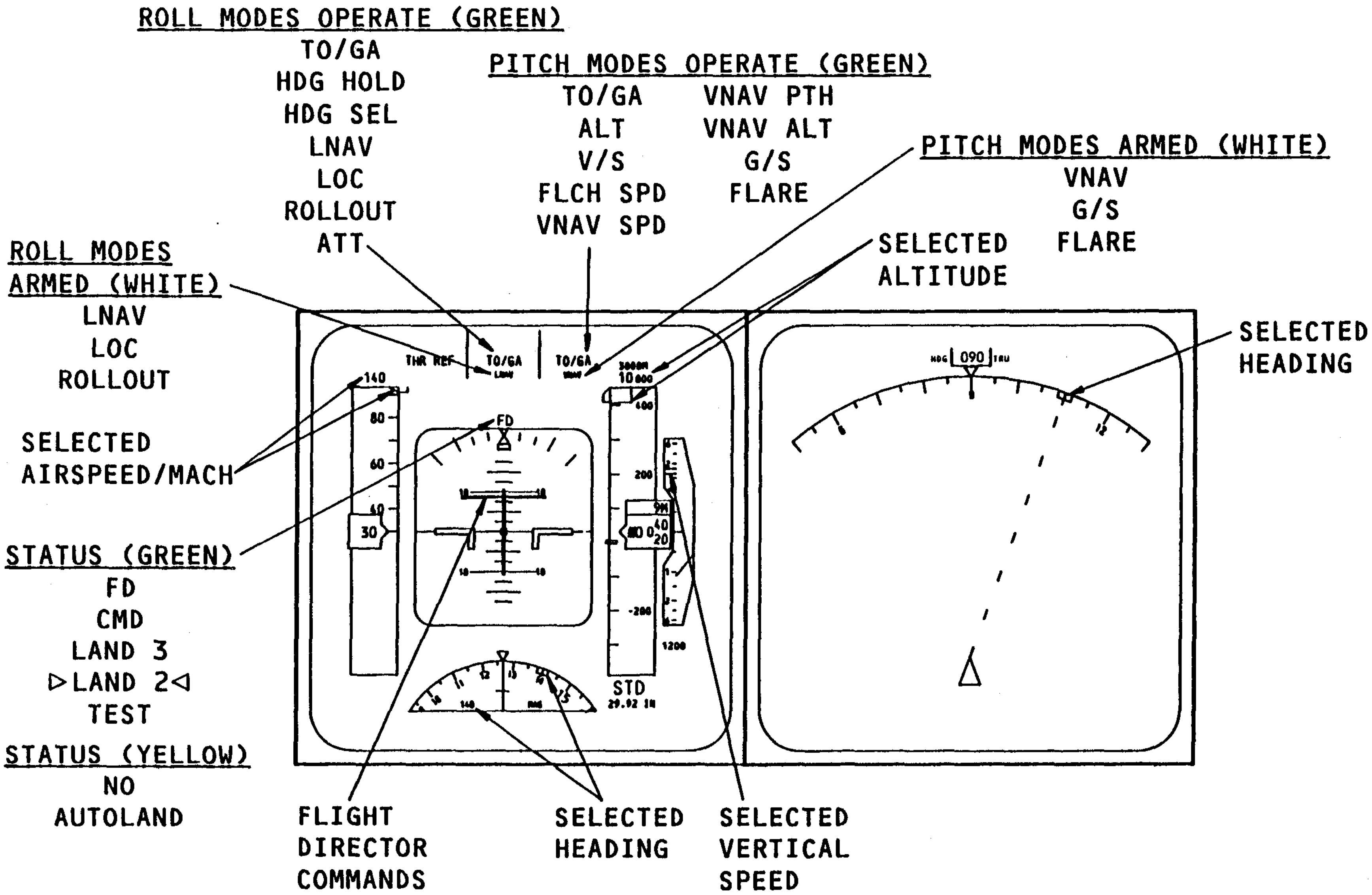


Figure 35 PFD and ND - Normal

PRIMARY FLIGHT DISPLAY - NON NORMAL

General

The purpose of non-normal PFD displays is to show failures of the AFDS.

Mode Display

An autopilot/flight director roll or pitch mode shows a horizontal yellow bar through it when the mode has failed.

Invalid data from the FCC selected for F/D causes the flight director fail flag to show and F/D bar to be biased out of view.

Flight Crew Selected Data

When any flight crew selected data from the FCCs is invalid or no computed data (NCD) the data (pointer and digital) is removed.

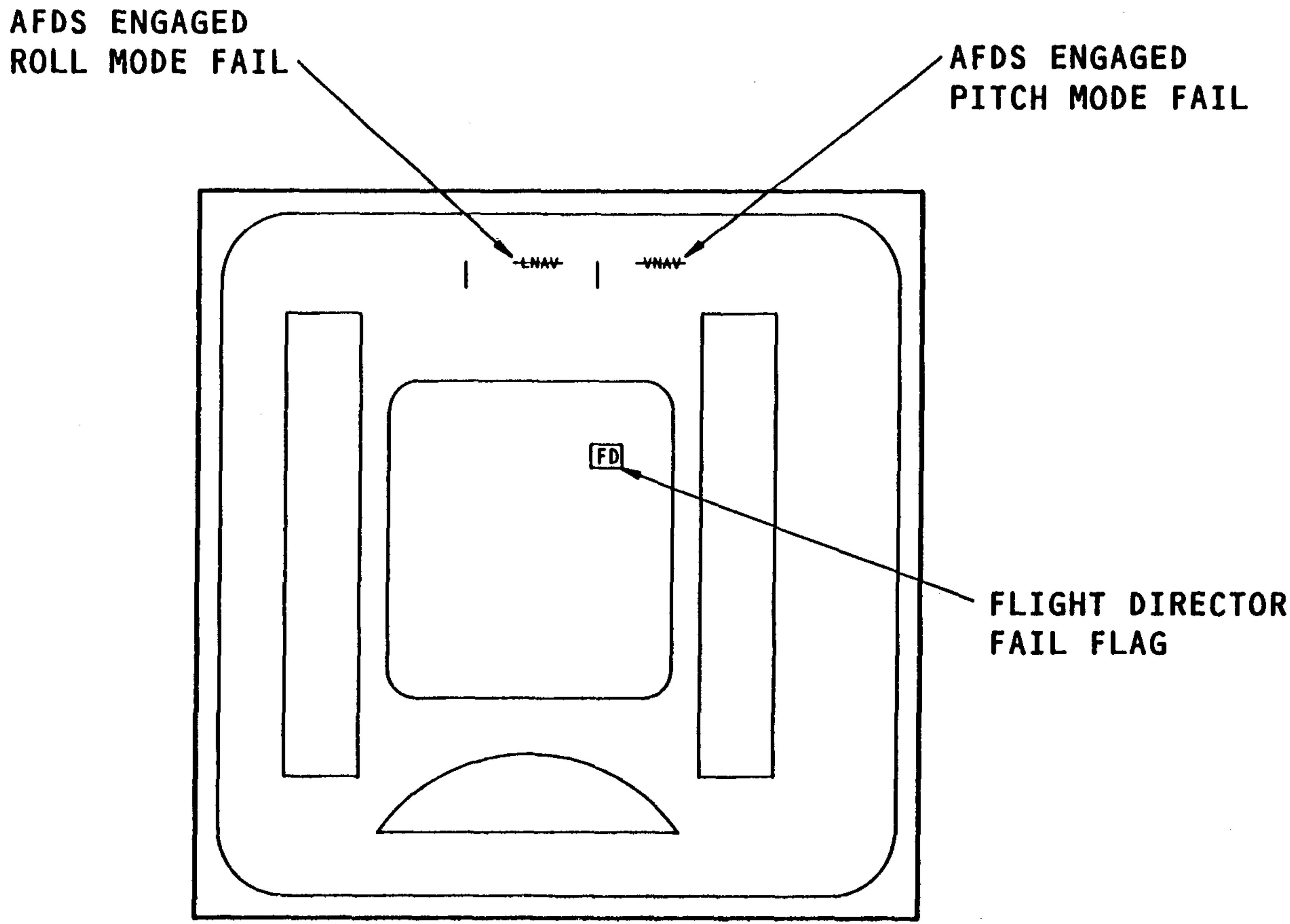


Figure 36 Primary Flight Display - Non Normal

WARNING AND CAUTION ANNUNCIATIONS

Autopilot Warning

The red >AUTOPILOT DISC warning message shows on EICAS when the autopilot disconnects either manually or automatically. An aural warning also occurs. To cancel the warning annunciations, push one of the autopilot disengage switches or re-engage the autopilot.

Autopilot Caution

The amber >AUTOPILOT caution message shows on EICAS when there is a degraded autopilot condition. An aural caution also occurs. To cancel the caution annunciations, disengage the autopilot or select a different mode for which the condition does not apply.

Master Annunciations

The master warning and master caution lights on the glareshield are controlled by the autopilot disconnect and caution logic.

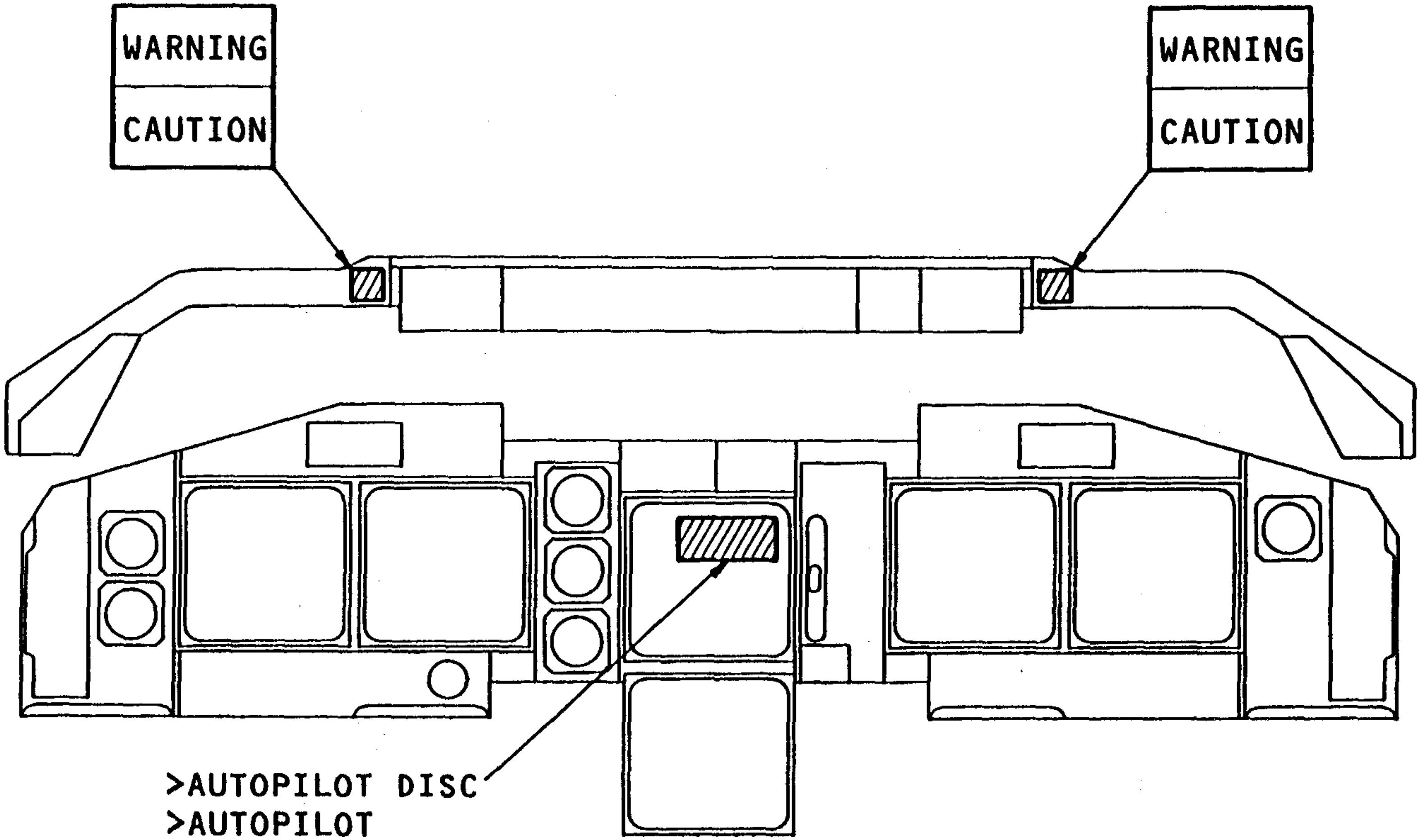


Figure 37 Warning and Caution Annunciations

AUTOLAND DEFINITIONS

General

The definitions on this graphic are general and apply to any autopilot system. The definitions for the annunciations apply to the 747-400 airplane and autopilot.

The certification and determination of landing category minimums are the responsibility of the regulatory agencies. These minimums are defined in terms of runway visibility range (RVR) and decision height (DH). The airplane certification is only one factor in this process. Other factors are:

- Ground facility certification
- Flight crew proficiency
- Airplane maintenance

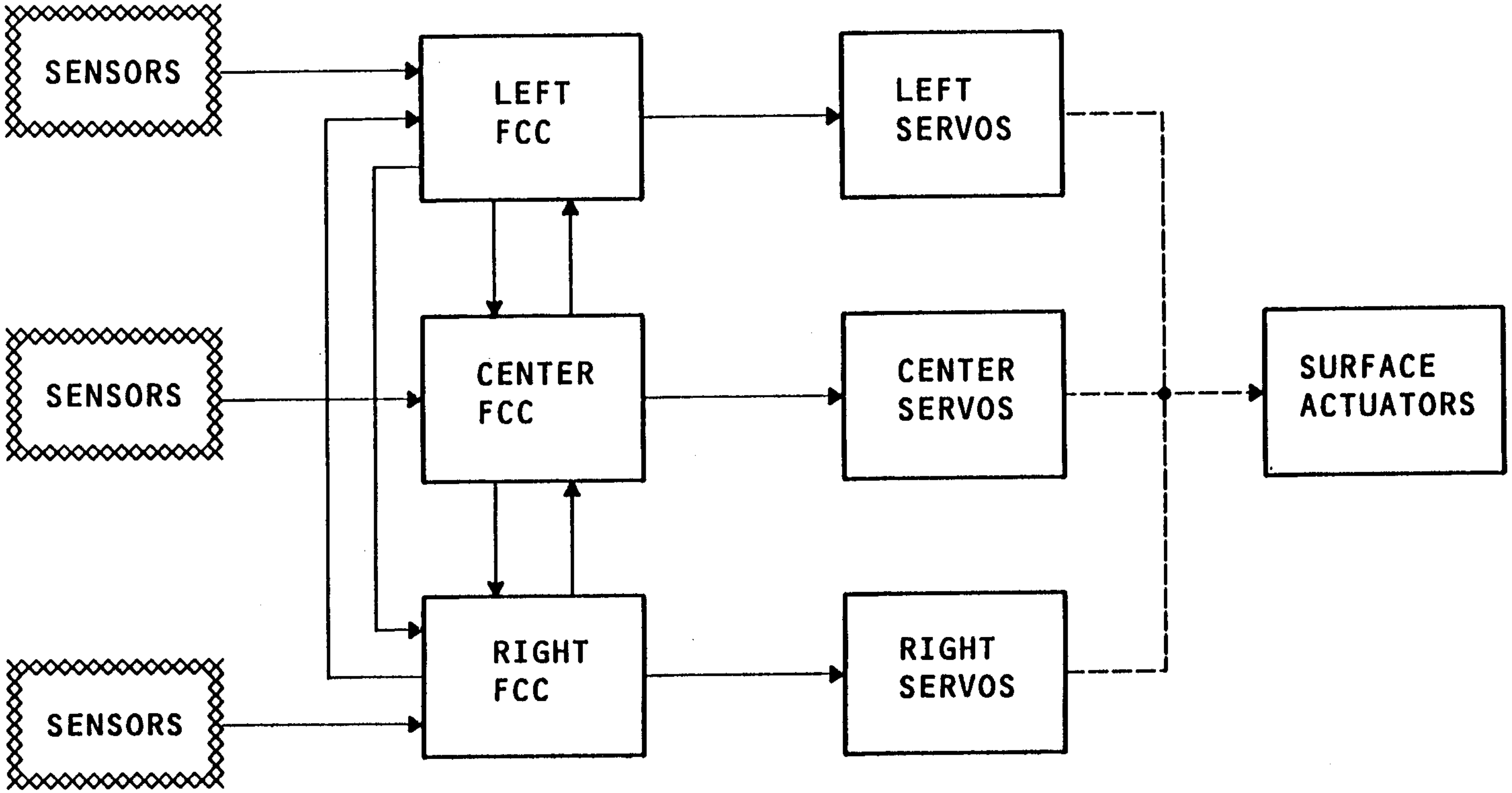
The AFDS design maintenance philosophy is based on these assumptions:

- Average time between autolands is 500 hours
- Each autopilot channel is engaged in cruise or first-in-command in approach at least once every 125 hours.
- Operational and maintenance procedures are established so that the assumptions are realized.

It should be noted that LRU and/or system tests are required only as a result of maintenance action or for troubleshooting a reported problem. There are no periodic tests to be done to validate or certify the airplane for autoland capability.

Autoland Status Annunciation

- LAND 3: There is triple redundancy of power sources, engaged flight control computers and autoland sensors. (Fail-Operational)
- LAND 2: There is a least dual redundancy of engaged flight control computers and autoland sensors. (Fail-Passive)
- NO AUTOLAND: A LAND 3 or LAND 2 capability is not possible due to multiple component or sensor failures.



FAIL OPERATIONAL: THE LEVEL OF REDUNDANCY IS SUCH THAT A SINGLE FAILURE THAT OCCURS BELOW ALERT HEIGHT ALLOWS AUTOLAND TO CONTINUE WITH THE REMAINDER OF THE AUTOMATIC SYSTEM.

FAIL PASSIVE: THE LEVEL OF REDUNDANCY IS SUCH THAT A SINGLE FAILURE DOES NOT CAUSE A SIGNIFICANT CHANGE IN FLIGHT PATH AND LEAVES THE AIRPLANE IN TRIM.

Figure 38 Autoland Definitions

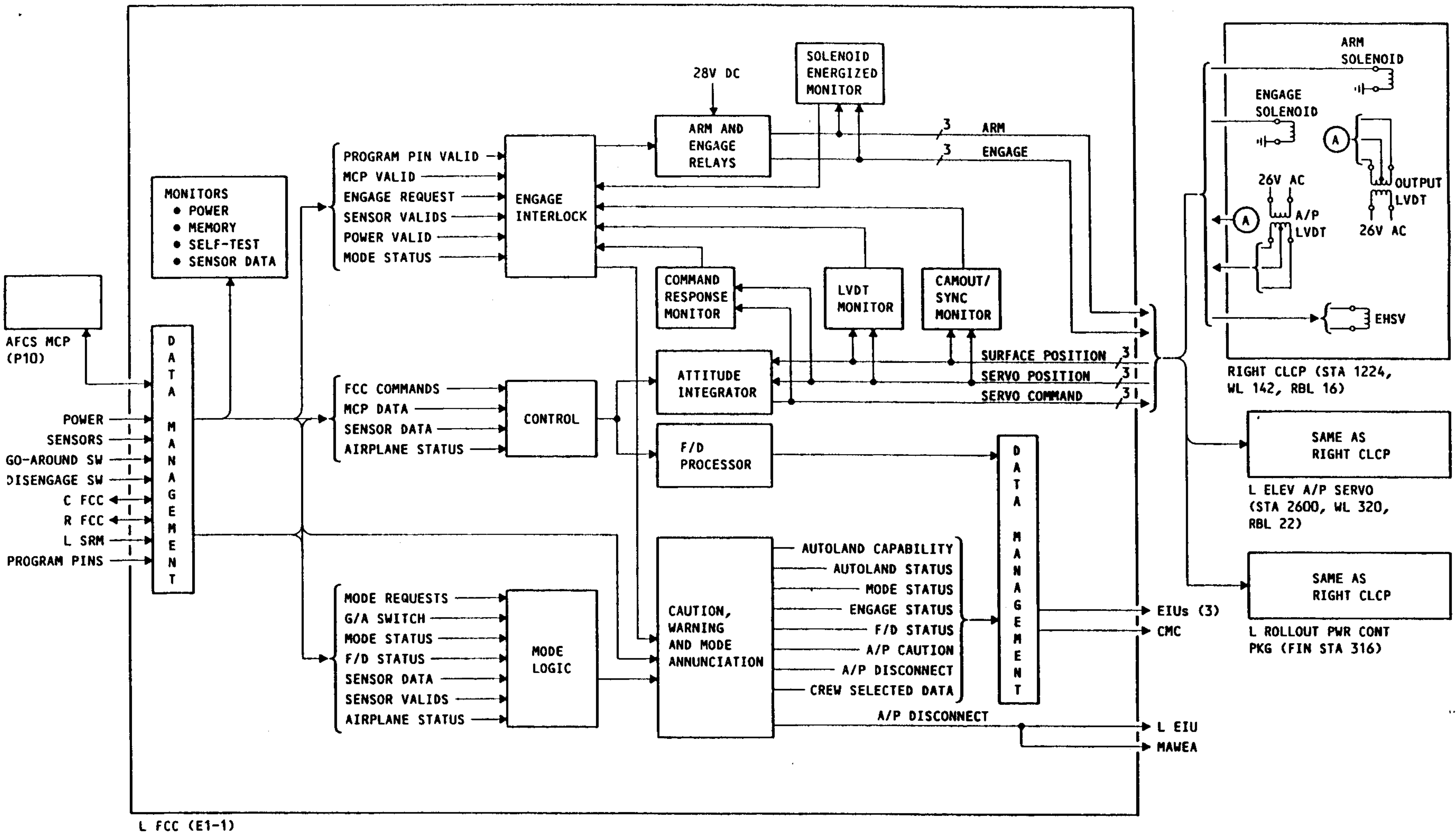


Figure 39 AFDS - Schematic Diagram

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