PMDG MD-11 Simulation

Aircraft Systems

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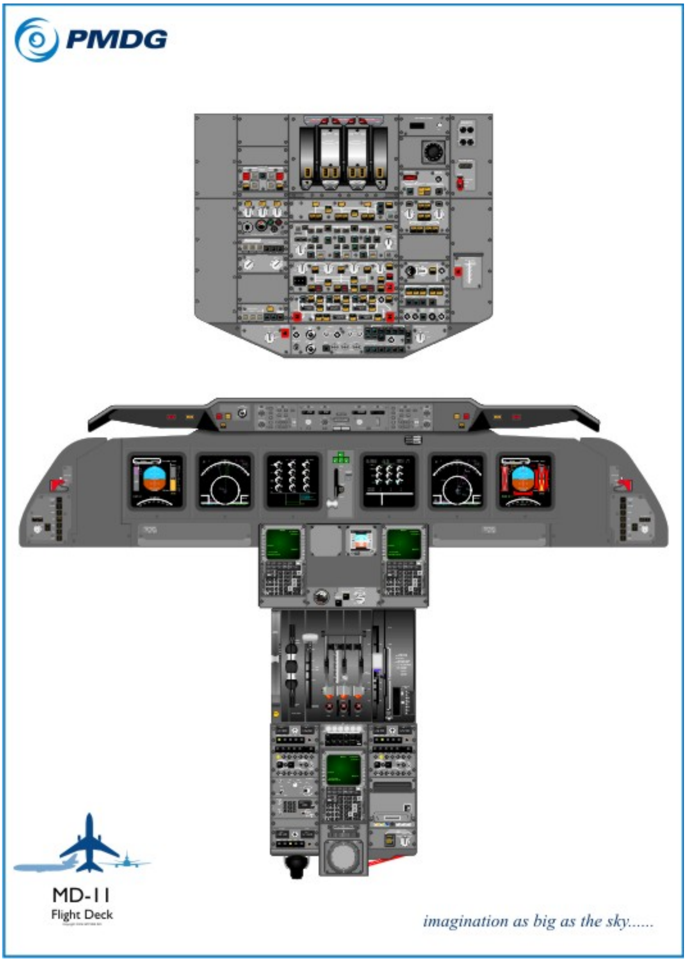

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Introduction

About this Manual

This PMDG MD-11 Systems Guide is designed to help simulator pilots learn the mechanical systems and technical details of the PMDG MD-11. This manual shows how each system is configured, how it is operated and how the crew can interact with the airplane.

How to use this Manual

This manual should be used by simulator pilots who are interested in learning how the PMDG MD-11 operates and how to utilize the various systems on the airplane effectively in all phases of flight.

The MD-11 is a marvelously sophisticated airplane with fully automatic control of nearly all functions from takeoff to landing. In spite of this automation, it is important that pilots have a comprehensive understanding of what each system on the airplane is doing, how it is controlled in automatic mode, and what operations might be impeded in the event of a failure.

This manual is broken into chapters with each chapter providing in detail on one particular subsystem or system type. You can read through an individual chapter to learn how a system on the MD-11 is operated, or you can read through the entire manual section by section to learn how the entire airplane is operated.

Gaining the most from this Manual

The best method to improve your understanding of this airplane is to launch the simulator, then load the PMDG MD-11 and sit in the virtual cockpit while reading through this material. This technique will allow you to touch, feel and explore the systems operation of the PMDG MD-11 and see how the airplane responds to pilot interaction.

Learning more about the PMDG MD-11

Once this manual has been completed, it is recommended that the simulator pilot read the Flight Crew Operating Manual in the same manner. The FCOM builds upon the systems knowledge provided in this manual and applies that knowledge to the normal and abnormal operation of the PMDG MD-11. The FCOM will take you through every possible procedure, from power on, to different approach types, to powering down.

In combination with one another, this Systems Manual and the FCOM provide a complete course of study for pilots who wish to operate the PMDG MD-11 effectively.

The PMDG MD-11 is the most sophisticated systems simulation yet produced for the desktop simulator enthusiast, and this manual will help even the most seasoned fliers to learn and enjoy this great airplane simulation to its fullest.

What should I know before I read this Manual?

The best way to gain benefit from this material is to Use this manual as your constant reference when getting started with the PMDG MD-11. Whether you are a novice simulator pilot or a veteran captain for your virtual airline, this manual will keep you flying safely.

Understanding the following “norms” will help you to understand how this manual is laid out and how each section is useful to you.

Organization

This manual is organized in sections around specific systems aboard the MD-11. Each section covers the specific system by dividing the subject matter up into pieces. This simplifies the process of learning each system by standardizing the manner in which the information is presented.

Sections of this manual include Air Systems, Hydraulic, Engines, Flight Controls and many more.

Chapters

Each section is divided into five possible sub-chapters:

- 10 - Description and Operation: This chapter will describe how the system operates, how the crew interacts with the system, and what logic is in place to manage the system automatically during flight.
- 20 - Components: This chapter will describe some of the major components that require crew knowledge.
- 30 - Controls and Displays: This chapter will describe the various display synoptics and cockpit controls that the crew will use to manage the system during operation.
- 40 - Alerts: This chapter will review any of the various Emergency and Abnormal alerts that may be associated with this system.
- 50 - Functional Schematics: This chapter will provide schematic overviews of systems in cases where such diagrams can enhance pilot knowledge.

NOTE: Not all sections will include all five chapters. If any of the chapters will provide redundant or non-useful information, the sub-chapter is merely skipped.

Warnings/Cautions/Notes

The following definitions and presentations apply to WARNINGS, CAUTIONS, and NOTES.

WARNING: **Operating procedures, techniques, etc., which could result in personal injury or greater consequences if not carefully followed. Warnings are printed in bold face type and the word/WARNING is underlined.**

CAUTION: Operating procedures, techniques, etc., which could result in damage to equipment if not carefully followed. Cautions are printed in boldface type.

NOTE: Operating procedures, techniques, etc., which are considered essential to emphasize. Information contained in notes may also be safety related. The heading and text are italicized.

System Controller Auto and Manual Operation

The aircraft systems are designed to be operated primarily in the automatic mode, each managed by a single-channel or dual-channel automatic system controller. In the case of a single-channel failure in a dual-channel controller, the controller will continue to operate normally. In the event of a total controller failure, each system will revert to a safe programmed configuration and can be manually operated by the flight crew. The associated system display synoptic and the Pilot's overhead panel will always display the actual system configuration.

When the automatic system controllers are operating in the automatic mode and an overhead panel switch is pushed, no switch action will result and the associated system's MANUAL light will flash. If manual operation of the panel switch is required, the system must be transferred to the manual mode by pushing the system switch.

In the automatic system controllers of the HYDRAULIC system, AIR system and FUEL system (which are dual-channel controllers), certain transient failures can be reset by switching to the other channel of the controller. This can be accomplished by selecting the associated system to MANUAL mode, and then back to AUTO. Note any fault in the maintenance log that is cleared by this procedure. Preflight tests that are in progress will be interrupted by this procedure and must be re-accomplished either automatically or manually.

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General

The MD-11 is powered by three high bypass ratio turbofan engines. It has a fully retractable tricycle landing gear with a load bearing center gear.

The cantilevered wing contains integral fuel tanks, main landing gear, engine pylons, full span leading edge slats, spoilers, trailing edge ailerons, and flaps. The winglets are installed at the wingtips to reduce drag and improve fuel efficiency.

The tail consists of an adjustable horizontal stabilizer with integral fuel tank, right and left two-section elevators, tail-engine pylon, fixed vertical stabilizer, and two-section (four-segment) rudder.

Most MD-11 systems are automated with manual backup operation provided.

Avionics and Controllers

Six Display Units (DU) in the instrument panel show the following:

- DUs 1 and 6 are Primary Flight Displays (PFD)
- DUs 2 and 5 are Navigation Displays (ND)
- DU3 is Engine and Alert Display (EAD)
- DU4 is System Display (SD) (secondary engine data and aircraft system data)

Three (1, 2, and aux) Display Electronic Units (DEU) in the avionics compartment drive the DUs. Normally, DEU1 drives the 3 left side DUs, DEU2 drives the 3 right side DUs, and the aux DEU is a spare. The glareshield control panel consists of a Flight Control Panel (FCP) and two EIS Control Panels (ECP) on both ends of the FCP. The ECPs control data display on the PFDs and NDs. SD data is controlled from the Systems Display Control Panel (SDCP) on the aft pedestal.

The Air Data System (ADS) consists of two Central Air Data Computers (CADC) in the avionics compartment. The CADCs send airspeed, pressure altitude, and total air temperature to various aircraft systems.

The Auto Flight System (AFS) consists of two Flight Control Computers (FCC) in the avionics compartment and an FCP on the glareshield. The pilot makes inputs into the AFS with the FCP.

The Flight Management System (FMS) consists of two Flight Management Computers (FMC) in the avionics compartment and two Multifunction Control Display Units (MCDU) on the forward pedestal. The pilot makes inputs into the FMS with the MCDUs.

The Inertial Reference System (IRS) consists of three Inertial Reference Units in the avionics compartment and an IRS control panel on the forward overhead panel. The pilot makes input into the IRS with the IRS control panel.

The Fuel System Controller (FSC) in the avionics compartment and the FUEL control panel on the overhead panel provide automatic and manual control of the fuel system. The Ancillary Fuel System Controller (AFSC) in the avionics compartment provides backup operation.

The Environmental System Controller (ESC) in the avionics compartment and the AIR control panel on the overhead panel provide automatic and manual control of the three engine air bleeds and air conditioning packs.

The Electrical Power Control Unit (EPCU) in the avionics compartment and the ELEC control panel on the overhead panel provide automatic and manual control of electrical power distribution.

The Hydraulic System Controller (HSC) in the avionics compartment and the HYD control panel on the overhead panel provide automatic and manual control of the three separate hydraulic systems.

The Miscellaneous System Controller (MSC) in the avionics compartment automatically controls:

- Auxiliary Power Unit (APU)
- Pitot, AOA, and TAT heat
- Engine ignition and start

- Cargo door test
- Cargo fire system
- Emergency light battery test

The HSC, ESC, and FSC are dual channel controllers in which certain transient faults can be cleared by switching channels. This is accomplished by selecting the associated system to manual mode, and then back to auto. Record any fault that is cleared by this procedure in the maintenance log. Preflight tests that are in progress will be interrupted by this procedure and must be performed again either automatically or manually.

The Centralized Fault Display System (CFDS) consists of a Centralized Fault Display Interface Unit (CFDIU) in the avionics compartment and an MCDU on the aft pedestal. Maintenance personnel can access CFDS data by using the MCDU.

Configuration Designators

The following designators may be used in this manual:

- P - MD-11 passenger airplane
- F - MD-11 freighter airplane
- CF(P) - MD-11 convertible freighter in passenger configuration
- CF(F) - MD-11 convertible freighter in freighter configuration

Cockpit

The cockpit of the MD-11 is arranged in the conventional manner. The Captain's seat is on the left and the First Officer's seat is on the right. There is a right observer's seat behind the First Officer's seat.

When the aircraft is ready for normal flight, most of the switches on the overhead panel will be dark (not illuminated). This informs the crew that the panel is in the correct configuration and no abnormalities are present. Under normal conditions, little used switches will illuminate blue as advisory indicators.

Three columns of alerts may be displayed on the lower third of the EAD. The EAD is normally DU-3. Level 3 alerts (warnings) have the highest priority and will not be overwritten. Level 3 alerts are displayed in red within a red box and have leading triangles. The latest level 3 alert appears at the top of the list starting at the top left of the alert area.

Level 2 alerts are displayed as boxed, amber messages below the red alerts and have priority over level 1 and level 0 alerts. Level 1 alerts are displayed as amber messages below level 2 alerts and have priority over level 0 alerts.

Level 1 and 2 alerts may be reset when the appropriate system cue switch on the SDCP is pushed. When an alert is reset, the alert is removed and replaced by an amber reminder message (boxed for level 2 alerts) placed in a dedicated position in the bottom two rows of the right hand column. This reminder message consists of the associated system name as used on the SDCP (e.g. generator faults would be indicated by an ELEC reminder message).

Some level 1 alerts are maintenance alerts that appear on the SD STATUS page only and will not illuminate an SDCP cue switch or the MASTER CAUTION lights.

Level 0 alerts (advisories) have the lowest priority and are displayed as cyan messages starting above the reminder messages at the bottom right side of the alert area. The latest level 0 advisory is added to the top of the level 0 list.

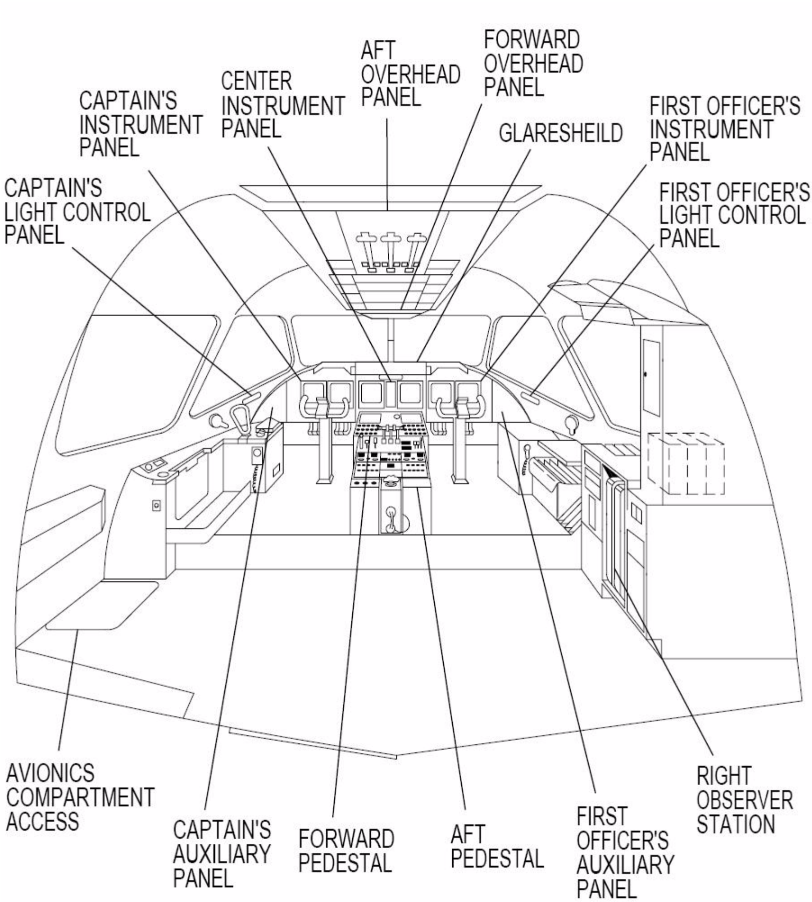
Pushing the corresponding system cue switch will cause a synoptic of the system to appear on the SD. The SD is normally CRT4.

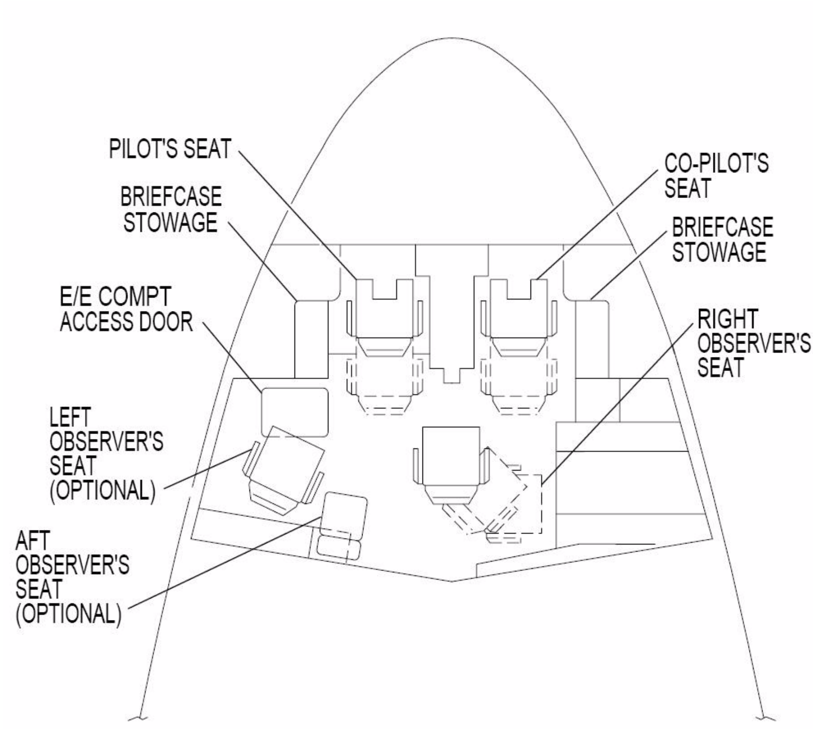
Cockpit Panel Locator

IDENT. NO.	SYSTEMS DESCRIPTION CHAPTER
1	Airplane General
2	Air/Pneumatics
3	Auxiliary Power Unit (APU)
4	Automatic Flight
5	Communications
6	Electrical Systems
7	Emergency Equipment
8	Engines
9	Fire Warning and Protection
10	Flight Controls
11	Flight Management System
12	Fuel
13	Hydraulics
14	Ice and Rain Protection
15	Instrumentation and Navigation
16	landing Gear and Brakes
17	Warning and Alerting

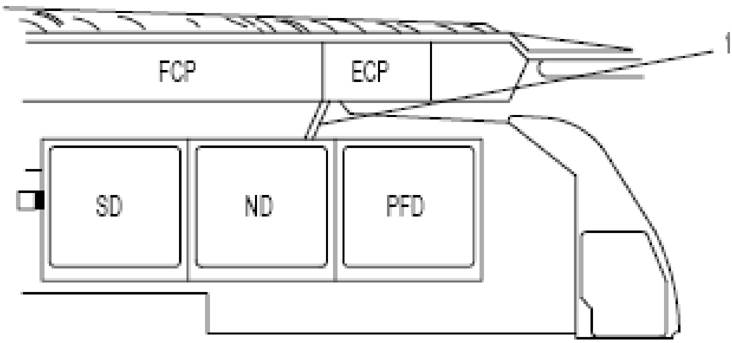
The circled identification numbers on the following pages refer to the chapters where detailed information for each item may be found. The cockpit panel locations are typical and intended for general reference only. Use the corresponding Systems Description chapters noted above for specific arrangements.

Cockpit Arrangement




PILOT'S SEAT
BRIEFCASE STOWAGE
E/E COMPT ACCESS DOOR
LEFT OBSERVER'S SEAT (OPTIONAL)
AFT OBSERVER'S SEAT (OPTIONAL)
CO-PILOT'S SEAT
BRIEFCASE STOWAGE
RIGHT OBSERVER'S SEAT

Seats - Eye Locator



Captain's View looking toward alignment stripes on FO side of cockpit.

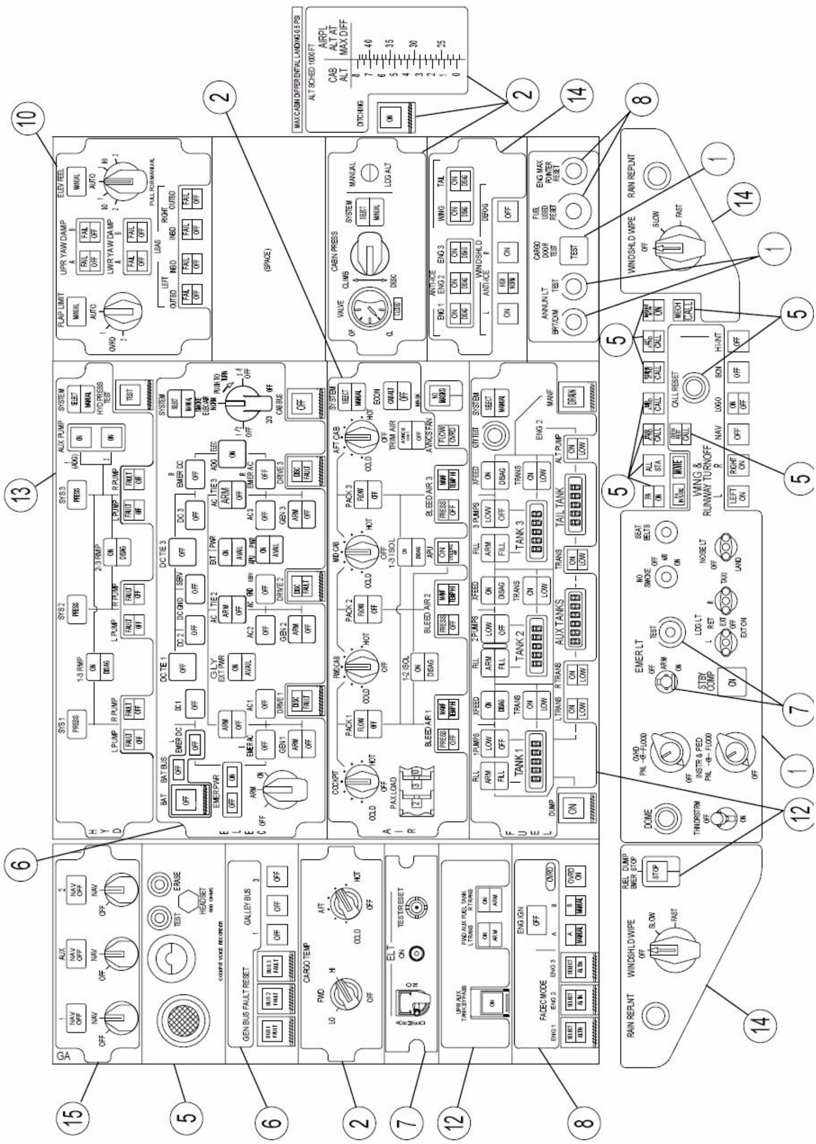
1. Panel Stripes (Works in VC only)

   Adjust respective (Captain or First Officer) seat as follow:

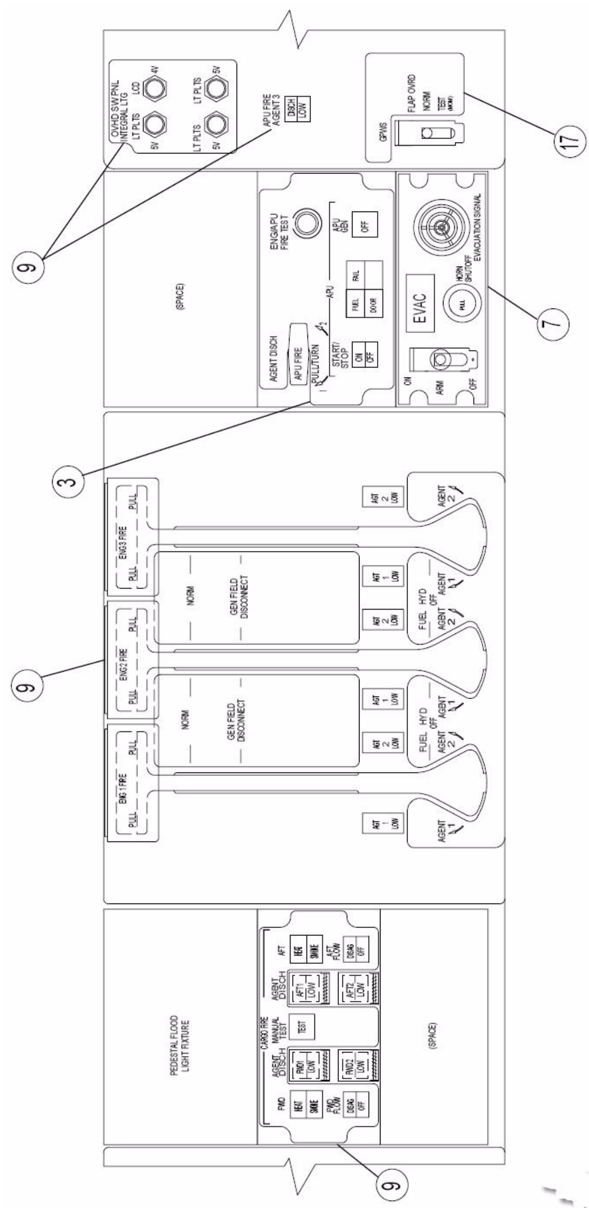
   - Adjust seat back for comfort.
   - Looking at the white lines on the other pilot's instrument panel, move the seat forward until the lower edge of the space between the FCP and the ECP is between the two white lines.
   - Adjust the seat up or down until the line of sight is just over the top of the glareshield.

   NOTE: The Captain and First Officer eye point locations are pre-programmed correctly in the PMDG MD-11 virtual cockpit. We recommend setting your view zoom to 0.60 or 0.70 as this yields the most realistic first person view.

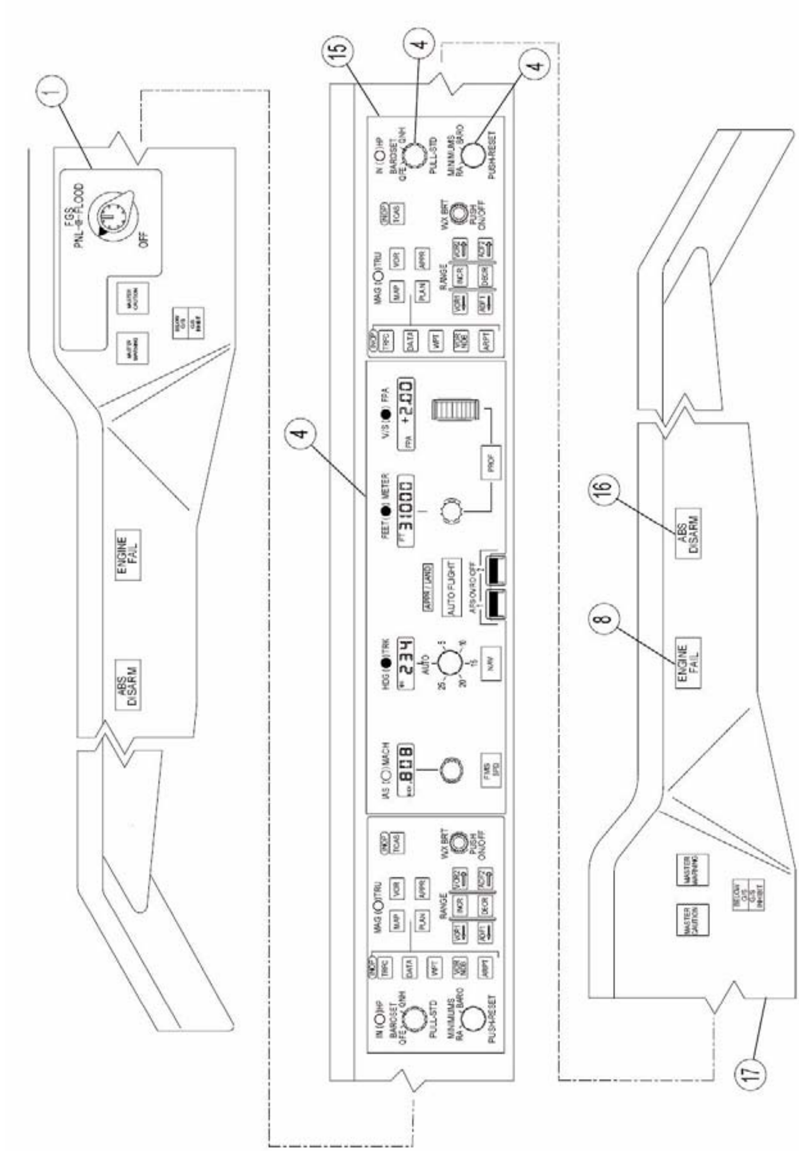
Forward Overhead Panel [Typical]



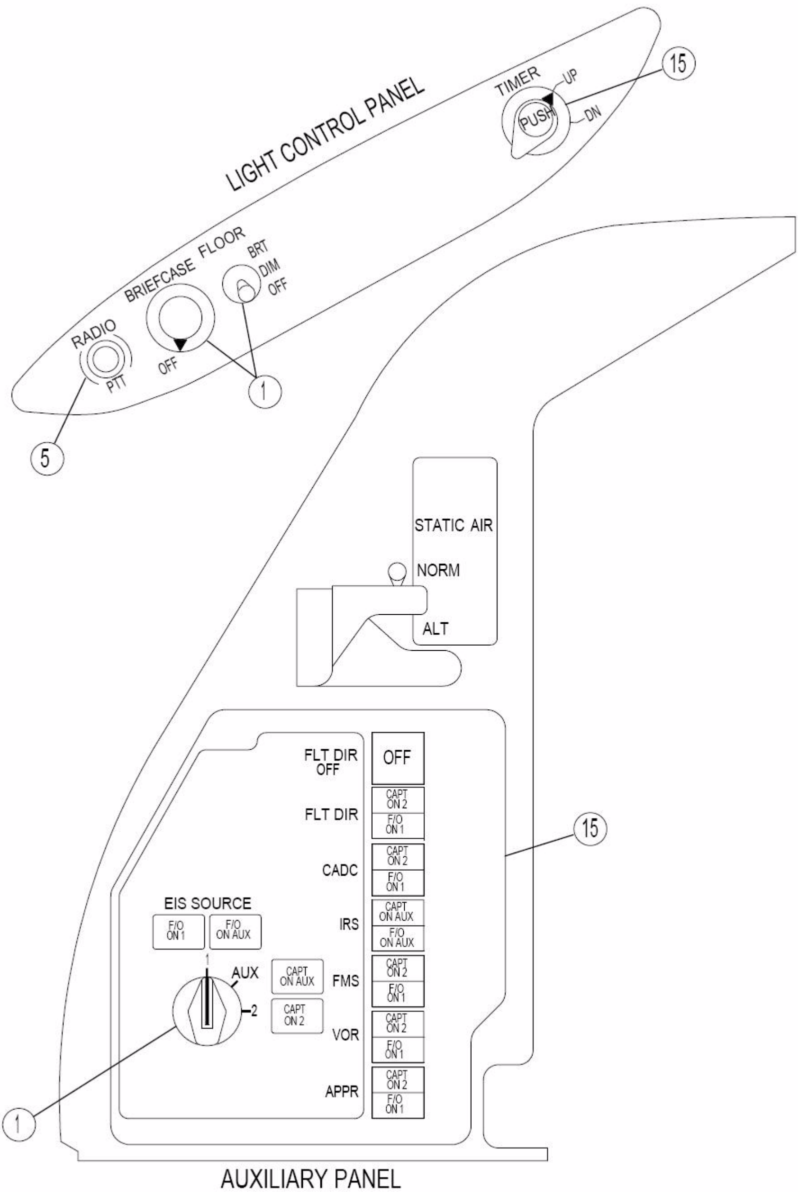
Aft Overhead Panel [Typical]



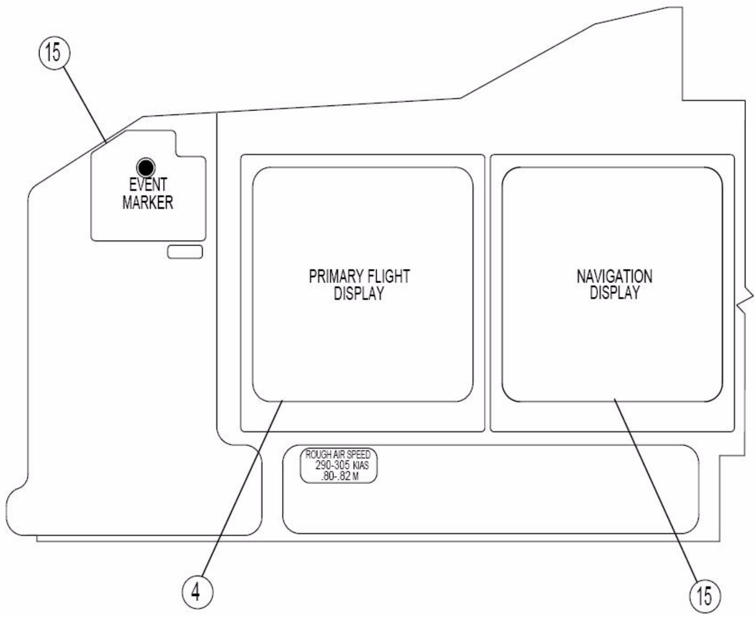
Glareshield [Typical]



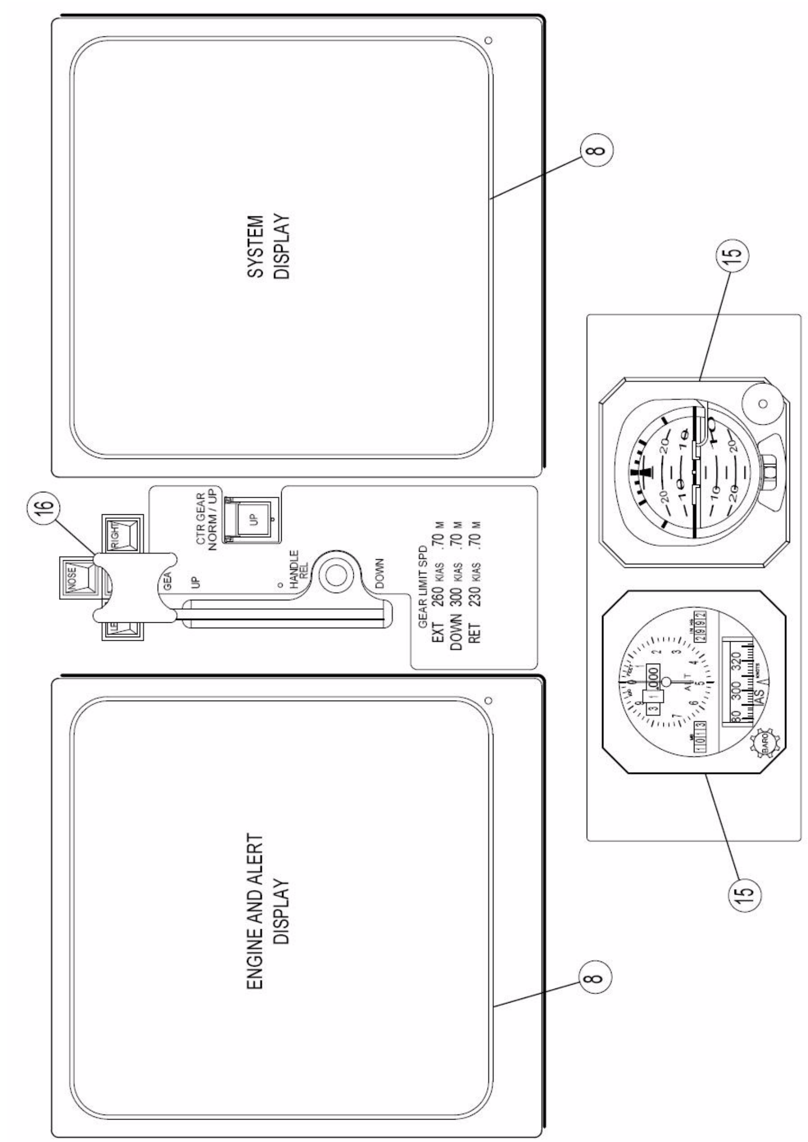
Captains Auxiliary and Light Control Panels



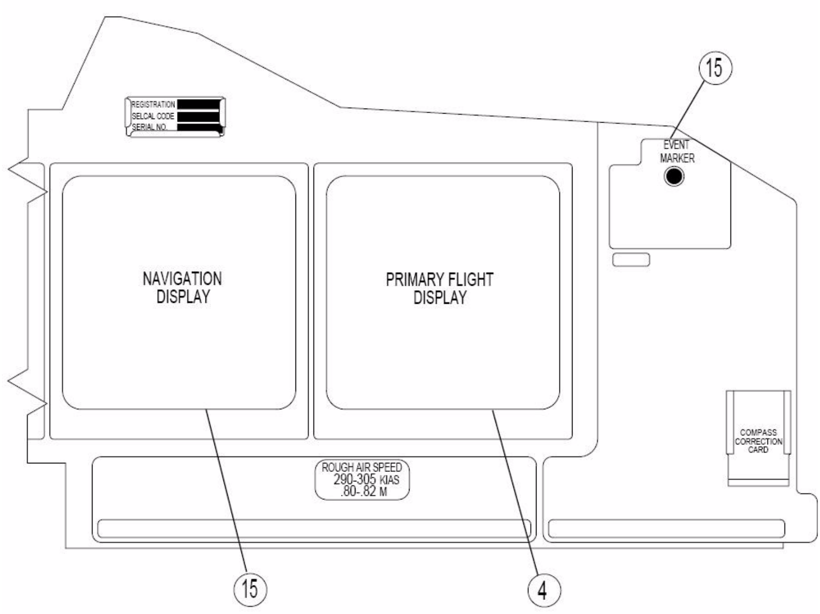
Captains Instrument Panel [Typical]



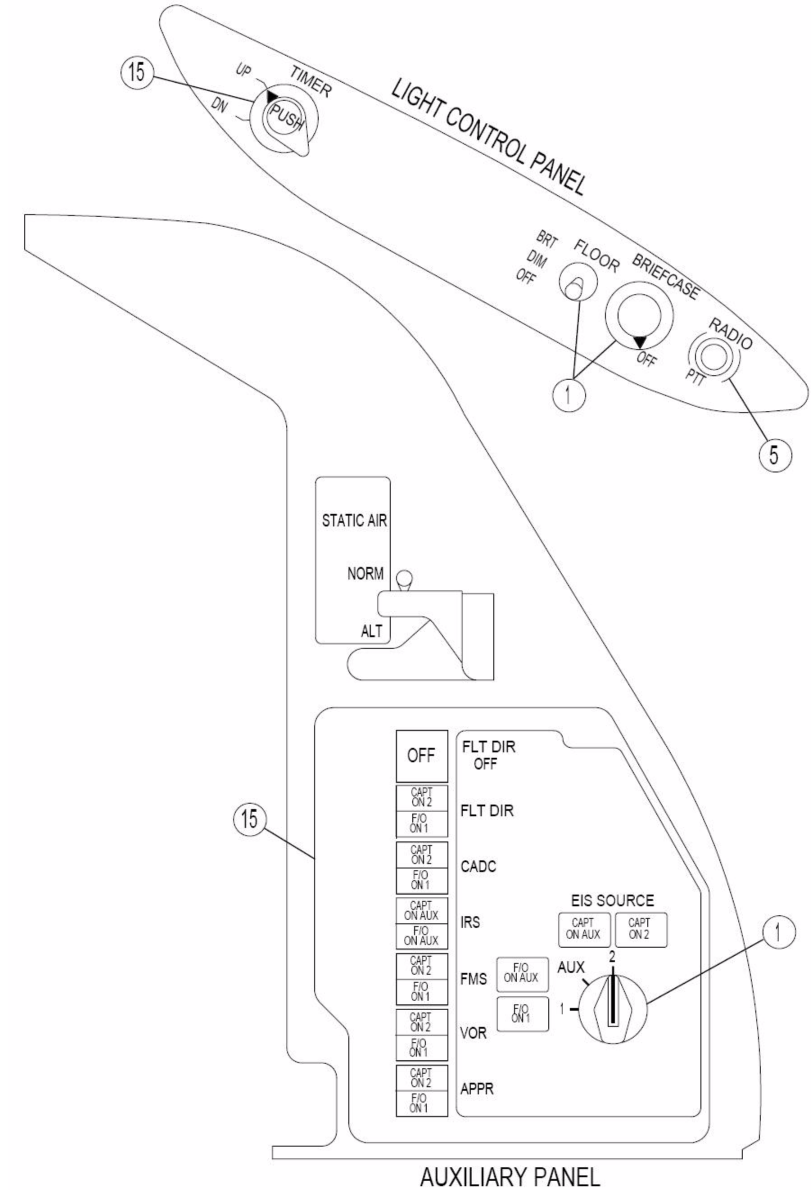
Center Instrument Panel [Typical]



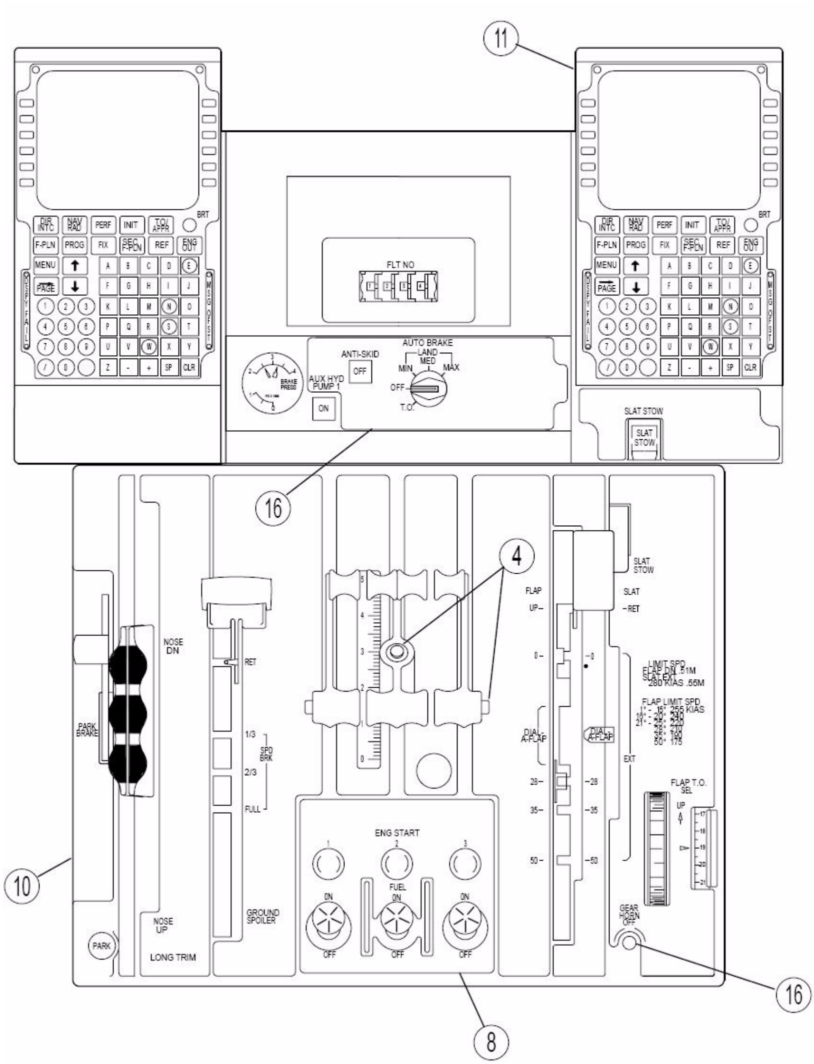
First Officers Instrument Panel [Typical]



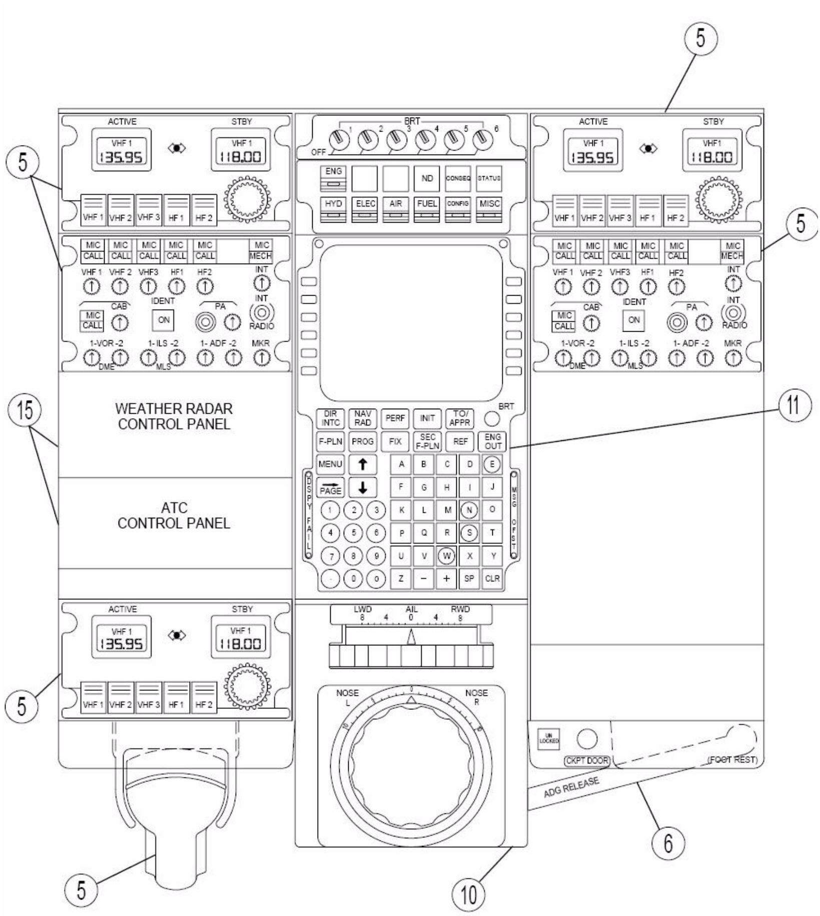
First Officer's Auxiliary and Light Control Panels



Forward Pedestal [Typical]



Aft Pedestal [Typical]



Electronic Instrument System

The Electronic Instrument System (EIS) consists of six DUs installed in the instrument panel, two EIS Control Panels (ECP) on the glareshield, one System Display Control Panel (SDCP) on the aft pedestal.

The EIS displays will appear on the six DUs (numbered 1 through 6 starting on the far left side). The displays are:

- DU1 and DU6 are the Primary Flight Displays (PFD). The PFDs display attitude, airspeed, barometric altitude, radio altitude, vertical speed, heading, vertical and lateral deviation, limits, and flight modes. Controls for the PFDs are on the glareshield. The PFD and associated controls are described in the Automatic Flight chapter.
- DU2 and DU5 are Navigation Displays (ND). The NDs display aircraft position, waypoints, navaids, and airports. Controls for the NDs are on the glareshield. The NDs and associated controls are described in the Instrumentation and Navigation chapter.
- DU3 is the Engine and Alert Display (EAD). The primary engine display appears on the upper 2/3 of the EAD. Alerts appear on the lower 1/3 of the EAD. The primary engine display is described in the Engines chapter. Alert display is described in the Warning and Alerting chapter.
- DU4 is the System Display (SD). The SD displays either secondary engine data, systems synoptic, status pages, miscellaneous pages, or consequences pages. Selection is made by pushing the associated cue switch on the SDCP. The SD synoptic is described in the associated system chapter. SD alerts and related pages are described in the Warning and Alerting chapter.

In case of DU failure, the EIS will reconfigure to display all data required for operation of the remaining DUs.

Six controls are provided for on/off and manual brightness control of each DU. Turning the knobs fully counterclockwise through a detent turns off the associated DU.

Turning off a DU automatically causes the system to reconfigure the other DUs so that the minimum data required for flight remains displayed. The DUs are also reconfigure automatically when the aircraft is in an emergency power condition.

In an emergency power condition only DU1, DU2, and DU3 are powered.

Seven cue switches on the SDCP allow the flight crew to identify the system that is generating alerts and/or warnings. Pushing a cue switch will cause the associated system synoptic to be displayed on the SD.

When pushed, a CONSEQ switch on the SDCP will cause alert related consequences to be displayed on the SD.

When pushed, the STATUS switch on the SDCP will cause all aircraft system faults to be displayed on the SD.

If five or fewer DUs are operating, pushing the ND switch will cause the existing SD to become an ND. If all six DUs are operating, THIRD NAV DISPLAY NOT AVAILABLE will appear on DU4.

Alerts and Advisory Indicators

When the aircraft is ready for normal flight, most of the switches on the overhead panel will be dark (not illuminated). This informs the crew that the panel is in the correct configuration and no abnormalities are present. Under normal conditions, little used switches will illuminate blue as advisory indicators.

Three columns of alerts may be displayed on the lower third of the EAD. The EAD is normally DU-3. Level 3 alerts (warnings) have the highest priority and will not be overwritten.

Level 3 alerts are displayed in red within a red box and have leading triangles. The latest level 3 alert appears at the top of the list starting at the top left of the alert area.

Level 2 alerts are displayed as boxed, amber messages below the red alerts and have priority over level 1 and level 0 alerts. Level 1 alerts are displayed as amber messages below level 2 alerts and have priority over level 0 alerts.

Level 1 and 2 alerts may be reset when the appropriate system cue switch on the SDCP is pushed. When an alert is reset, the alert is removed and replaced by an amber reminder message (boxed for level 2 alerts) placed in a dedicated position in the bottom two rows of the right hand column. This reminder message consists of the associated system name as used on the SDCP (e.g. generator faults would be indicated by an ELEC reminder message).

Level 0 alerts (advisories) have the lowest priority and are displayed as cyan messages starting above the reminder messages at the bottom right side of the alert area. The latest level 0 advisory is added to the top of the level 0 list.

Pushing the corresponding system cue switch will cause a synoptic of the system to appear on the SD. The SD is normally CRT4.

Colors

A consistent set of colors is used for all the displays to allow the flight crew to readily recognize and associate various types of data. All information is conveyed with distinctly shaped symbol as well as changes in color.

White is used for scales and associated figures and also denotes manual entry or action. White symbology includes:

- Scales
- Manually selected values
- Manually initiated autopilot/autothrottle modes
- Weather radar turbulence [not modeled]
- Inactive schematic lines on the SD

Cyan is used for status indication. Cyan symbology includes:

- Status messages in the alert list
- Available, but not used, navigation data base items

Green is used to indicate validity. Green symbology includes:

- Track diamond
- Autopilot/autothrottle land modes
- Landing gear safe
- Trend data
- Weather radar precipitation less than 4 mm/hour [not modeled]
- Active schematic line on the SD (except electrical)

Magenta signifies electronically generated or derived data. Magenta symbology includes:

- Flight management system (FMS) selected values
- Flight Director commands
- Radio navigation data
- Weather radar precipitation more than 50 mm/hour [not modeled]
- Weather radar turbulence [not modeled]
- Localizer and glideslope deviations

Amber identifies conditions that require immediate crew awareness and possible subsequent corrective action. Amber symbology includes:

- Failures
- Cautions
- Abnormal sources
- Weather radar precipitation 4 to 12 mm/hour [not modeled]
- System abnormal conditions

Red identifies conditions that require immediate crew action or impose consistent limitation on the aircraft. Red symbology includes:

- Warnings
- Autopilot/autothrottle disconnect and failures
- VMO/MMO and stickshaker speeds
- High or low airspeed limits
- Pitch and roll limits (when exceeded)
- Engine limits and exceedances
- Landing gear not safe

Failure Annunciations

Invalid data and cross-side miscompared data are the two types of failure annunciations. Invalid data is removed from the screen. Miscompared data is displayed with a flag.

When invalid data is removed from the screen, it may be replaced by a flag (some non-essential data is removed from the screen only). These flags consist of an X covering the area of removed data.

The Xs may be of two colors:

- Red Xs signify a loss of data requiring immediate crew awareness and action to restore the loss of data.
- Amber Xs signify a loss of data requiring immediate crew awareness but action to restore the data may be momentarily deferred.

Cross-side miscomparisons are generated when the EIS detects significant differences between the displayed data of the Captain's and First Officer's instruments. These comparisons are limited to attitude, airspeed, altitude, radar altitude, ILS and heading.

The detected miscomparisons will be displayed in amber in the upper left-hand corner of the PFD, just outside of the attitude sphere. This annunciation will blink for five seconds, then remain as long as the miscompared condition remains.

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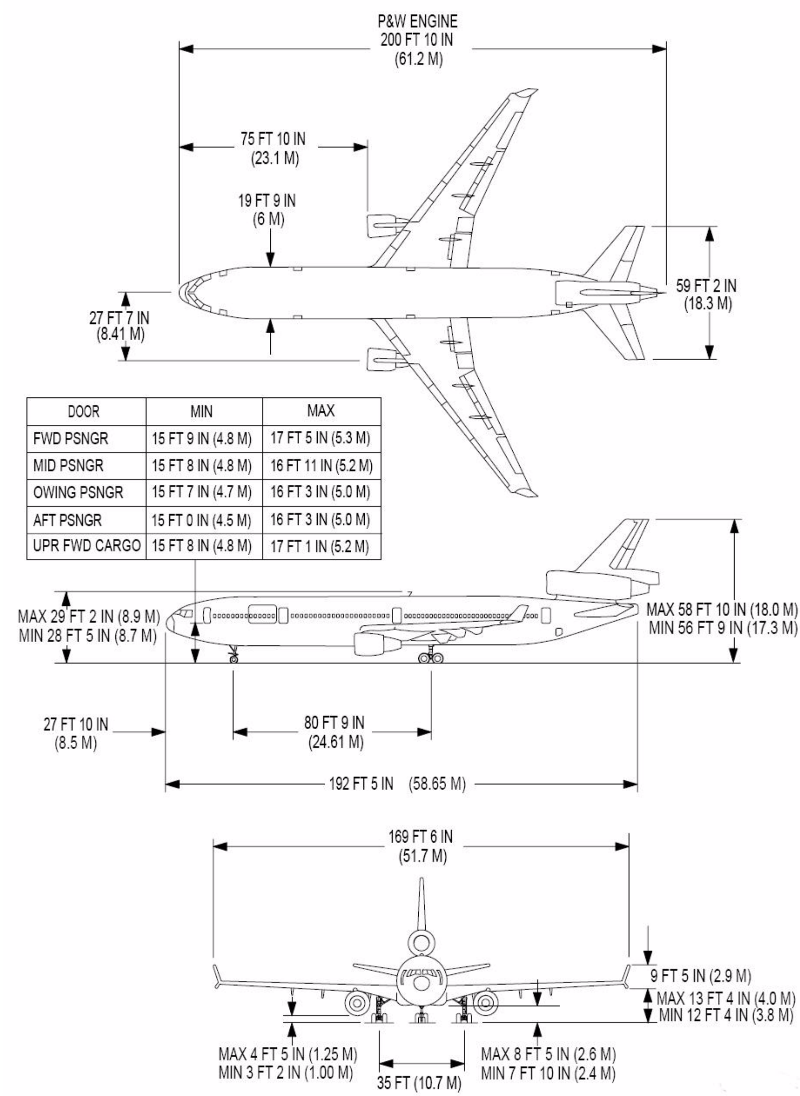
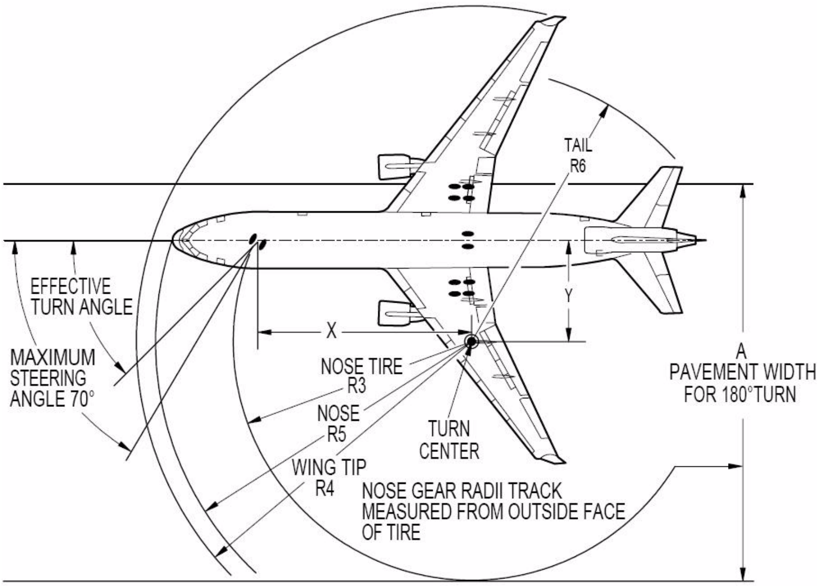
Functional Schematics

Airplane Dimensions



DOOR	MIN	MAX
FWD PSNGR	15 FT 9 IN (4.8 M)	17 FT 5 IN (5.3 M)
MID PSNGR	15 FT 8 IN (4.8 M)	16 FT 11 IN (5.2 M)
OWING PSNGR	15 FT 7 IN (4.7 M)	16 FT 3 IN (5.0 M)
AFT PSNGR	15 FT 0 IN (4.5 M)	16 FT 3 IN (5.0 M)
UPR FWD CARGO	15 FT 8 IN (4.8 M)	17 FT 1 IN (5.2 M)

Turning Radius (Minimum)



1

NORMAL TURNS
- SYMMETRICAL THRUST
- NO DIFFERENTIAL BRAKING
- SLOW CONTINUOUS TURN
- AFT CENTER OF GRAVITY
- MAX GROSS WEIGHT

2

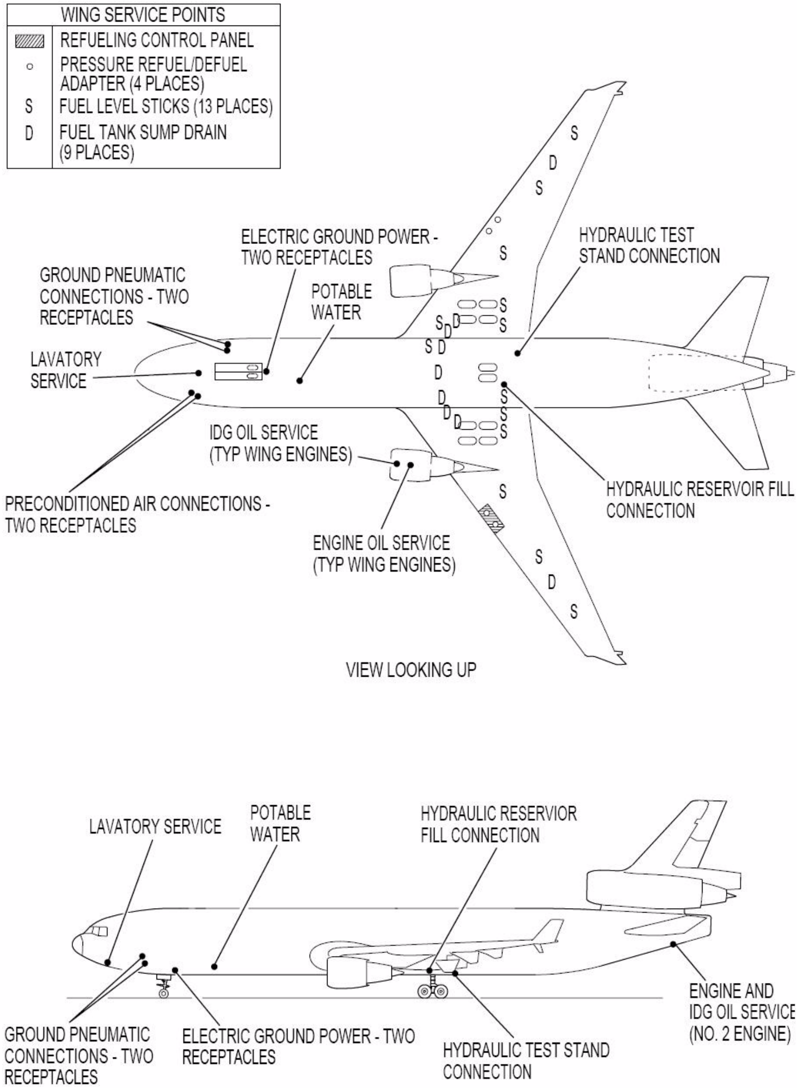
MINIMUM RADIUS TO AVOID EXCESSIVE TIRE WEAR, USE VARIOUS COMBINATIONS OF :
- STEERING
- ASYMMETRIC THRUST
- LIGHT DIFFERENTIAL BRAKING

3

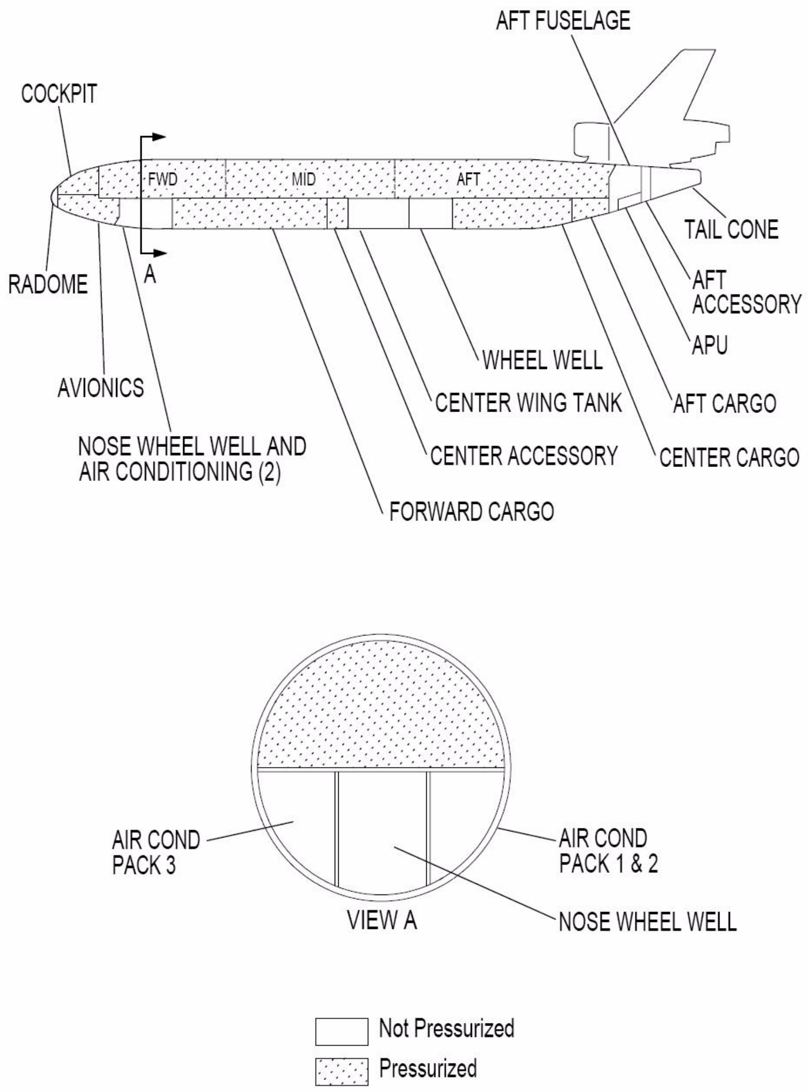
MINIMUM RADIUS
- ASYMMETRIC THRUST
- LIGHT DIFFERENTIAL BRAKING
- SLOW CONTINUOUS TURN
- AFT CENTER OF GRAVITY
- MAX GROSS WEIGHT

TYPE TURN	EFFECTIVE TURN ANGLE	TIRE SLIP ANGLE	X (Ft/M)	Y (Ft/M)	A (Ft/M)	R3 (Ft/M)	R4 (Ft/M)	R5 (Ft/M)	R6 (Ft/M)
1	60.8°	9.2°	81.2 / 24.7	45.3 / 13.8	160.6 / 49.0	94.7 / 28.9	136.4 / 41.6	118.1 / 36.0	111.9 / 34.1
2			81.2 / 24.7	42.1 / 12.8	155.8 / 47.5	93.1 / 28.4	133.4 / 40.6	116.9 / 35.6	109.8 / 33.5
3	72.0°	- 2.0°	81.6 / 24.9	26.5 / 8.1	134.6 / 41.0	87.5 / 26.7	118.5 / 36.1	112.6 / 34.3	100.0 / 30.5

Service Connections



Fuselage Compartments



Description and Operation

General

Three air systems provide the pneumatics required for:

- Engine Start
- Air Conditioning
- Pressurization
- Anti-ice
- Avionics Cooling
- Galley Ventilation
- Cargo Compartment Heating/Ventilation
- Potable Water Pressurization (Refer to Water and Waste Chapter)
- Cargo Loading System

The normal source of pneumatics for each of the three air systems is its associated engine. The three systems normally operate independently, but may be interconnected through two isolation valves, if fewer than three engine bleed air sources are available. The valve(s), ISOL 1-2 and ISOL 1-3, identify the air systems that are interconnected.

When engine air is not available, the following alternate sources may be used:

1. The APU
2. External air (ground)
3. Any other operating engine

Each air system manifold is pressurized by engine compressor air.

For GE engines:

- 8th stage air is low stage heated air and is the main source for normal operation

- 14th stage air is high stage heated air and is used during airfoil anti-ice operation and to compensate for low power settings, such as during idle descent
- 11th stage air is used for engine anti-ice protection and is routed directly to the engine cowl

For P&W engines:

- 8th stage air is low stage heated air and is the main source for normal operation
- 15th stage air is high stage heated air and is used during airfoil anti-ice operation and to compensate for low power settings, such as during idle descent
- 8th or 15th stage air (depending on phase of flight) is used for engine anti-ice protection and is routed directly to the engine cowl

Pneumatics and air conditioning automatically turn off as engine thrust increases for takeoff. Air conditioning remains on, except when airfoil anti-ice is selected prior to takeoff, if the required entry has been made through the Flight Management System (FMS).

Controls for pressurization, air conditioning, and anti-ice are on the overhead panel. Air system flow, temperatures, valve positions, and pressurization status are shown on the Systems Display (SD). Associated alerts are shown on the Engine and Alert Display (EAD).

Air System Automatic Controllers

The air system automatic controllers work in conjunction with one another. One environmental system controller (ESC) functions as the main controller.

The ESC reverts to the manual mode for certain system and internal failures. The air system can be controlled manually from the AIR control panel.

The ESC directs the following:

- Two Pneumatic System Controllers (PSC)
- Three Air Conditioning Controllers (ACC)

- Two Cabin Pressure Controllers (CPC)
- One Manifold Failure Controller (MFC). These eight controllers:
- Manage the pneumatic system
- Manage the air conditioning system
- Manage the trim air system
- Manage the recirculation fan system
- Manage the equipment cooling fan systems
- Control cabin pressurization
- Monitor pneumatic system manifold failures
- Monitor airfoil anti-ice systems
- Shut down associated pneumatic system during APU or engine fire
- Reconfigure air systems for failure of various elements
- Compensate for inoperative components

Manifold Failure Detection System

The Manifold Failure Detection System (MFDS) controller detects pneumatic leaks in the following:

- The three pneumatic systems
- The three air conditioning packs
- The Center Accessory Compartment (CAC)
- The tail pylon area
- The horizontal stabilizer anti-ice system

The MFDS sends failure signals to the ESC, which then isolates the affected duct from its bleed air system.

Manifold failure indications appear on the AIR synoptic.

Air Conditioning System

The air conditioning system uses engine compressor bleed air from the main engines during flight, and the engines, the APU, or preconditioned air from a ground source during ground operation.

The APU provides sufficient airflow to operate all three air conditioning systems during high performance takeoffs and initial climb without engine pneumatic supply.

Hot, pressurized air is supplied to the air conditioning packs, where it is cooled and routed to a common manifold. The cooled air is mixed with hot air prior to distribution.

The air conditioning system accomplishes the following:

- Air conditioning packs provide conditioned air in response to a temperature control system.
- An Air Conditioning Controller (ACC) determines cockpit and cabin temperature requirements and provides the appropriate signals.
- The distribution system controls conditioned air flow to the cockpit and cabin
- The compartment ventilation system provides ventilation for the avionics, center accessory and right hand aft tunnel.
- The lower cargo compartment temperature control and ventilation system allows temperature sensitive shipments.

Three identical Air Conditioning Controllers (ACC):

- Interface with the Environmental Control System (ESC), and the EIS.
- Interface with the AIR control panel, the altitude warning system, the oxygen mask deployment system, the APU controller, and the CPCS.
- Send altitude warning and oxygen mask signals.

With ignition A, B, or OVRD selected and the air system in auto, air conditioning is unavailable prior to engine start. It remains unavailable for two minutes if there has not been an engine start.

Individual zone temperature requirements are adjusted by mixing hot trim air from the pneumatic duct with air from the conditioned air manifold.

Avionics and Instrument Ventilation System

The ESC controls the avionics and instrumentation ventilation system. The ESC performs a power-up test of all fans, flow sensors, and annunciation circuitry prior to flight.

One of three cooling fans supplies cooling air to the avionics racks. Normally, one cooling fan operates as primary and a second fan as an automatic backup if the primary fan fails. The third fan is optional.

Air flow sensors are installed upstream of the main avionics rack, upstream of the two forward Display Electronic Units (DEU), and just upstream of an overboard venturi to detect exhaust flow. These flow sensors detect loss of cooling airflow.

The AVNCS AIR FLO OFF alert is displayed on the EAD when both flow sensors detect a no flow condition. The AVNCS EXH OFF alert is displayed when not enough airflow exists in the avionics compartment.

The cooling fans take exhaust air from the cockpit. The exhaust air then flows in two directions. Some of the cooling air flows to the auxiliary and main avionics racks. The rest of the cooling air flows to the CRTs and MCDUs in the cockpit.

Piccolo ducts collect compartment air and air that has passed through the avionics racks. This warm air is routed into an exhaust manifold and dumped overboard through the venturi using cabin differential pressure across the venturi.

When aircraft differential pressure is less than 1.3 psid (ground operation), the venturi remains open while an exhaust fan draws air through the manifold and discharges some of the hot avionics air overboard. The remaining hot avionics air is exhausted into an area under the cabin floor above the nose wheelwell. During normal flight operation, the exhaust fan is off.

When the cabin air inflow is too low for cabin pressurization, the avionics overboard venturi valve is closed and the exhaust fan is turned on to discharge avionics exhaust air into the left tunnel and reduce the overboard airflow. This avionics override function is done automatically by the ESC, or manually by the flight crew with the AVNCS FAN switch (ESC must be in manual mode) on the AIR control panel.

The AVNCS FAN OVRD alert is displayed when the avionics exhaust fan and venturi valve are commanded to override. The avionics exhaust fan remains in override until the aircraft cabin air inflow and avionics compartment exhaust airflow are sufficient.

Following takeoff, with 1.3 psid differential pressure and adequate cabin inflow, the ESC automatically turns off the exhaust fan and opens the venturi valve for normal inflight avionics exhaust flow.

Center Accessory Compartment Ventilation System

The Center Accessory Compartment (CAC) has up to three cooling fans. Operation of the fans is similar to those in the avionics compartment. If the last available fan does not produce flow within a specified time after being turned on, a CAC AIR FLO OFF alert is displayed.

Forward Cargo Compartment Heating and Ventilation System

The forward cargo compartment is heated, ventilated, and cooled inflight. Pneumatic system 3 bleed air heats the compartment. Temperature sensors maintain the temperature, as selected by the flight crew. Animals may be carried in this compartment.

A flow detector in the ventilation and cooling system signals an insufficient air flow condition to the flight crew. Flow-through ventilation, for animal transport, exits through a sidewall outlet, thus relieving compartment pressure.

The miscellaneous systems controller (MSC) automatically shuts off the ventilation system if a compartment fire is detected. The flight crew manually latches off airflow to the compartment. This prevents dilution of the firex agent, and airflow does not resume when the smoke or fire signal ends. The firex agent remains isolated inside the compartment when check valves close.

Center Cargo Compartment Heating System

The center cargo compartment is heated but not ventilated. Pneumatic system 2 bleed air heats the forward compartment.

A thermostat controls temperature between 55° ±5° F (12.7° ±2.8° C) and 65° ±5° F (18.3° ±2.8° C).

Aft Cargo Compartment Heating and Ventilation System

The aft cargo compartment is heated, ventilated, and cooled in flight. Pneumatic system 2 bleed air heats the compartment. Temperature sensors maintain the temperature, as selected by the flight crew. Animals may be carried in this compartment.

The air vented into the compartment exhausts through two ceiling outlets, where it is dumped near the cabin air outflow valve.

A flow detector in the flow stream of the exhaust ducting signals the flight crew of insufficient exhaust airflow. Excess fan flow, over the exhaust flow, maintains positive pressure in the compartment.

The Miscellaneous Systems Controller (MSC) automatically shuts off the ventilation system if a compartment fire is detected. The flight crew manually latches off airflow to the compartment. This prevents dilution of the firex agent, and airflow does not resume when the smoke or fire signal ends. The firex agent remains isolated inside the compartment when check valves close.

Pressurization System

The pressurization system controls the aircraft pressurization. Pressurized air supplies the flight, cabin, cargo, center accessory and avionics compartments.

Pressurization is controlled by regulating the outflow of conditioned air from the pressurized areas of the fuselage. Pressure relief valves limit the cabin differential pressure to 9.1 psi. The CABIN PRES RELIEF alert is displayed when the relief valves open up at a differential pressure of about 8.9 psi.

The Cabin Pressure Control System (CPCS) provides the following functions:

- Pressurization control during all flight phases
- Fuselage over pressurization protection
- Negative pressure relief provided by the door seals
- Data for monitoring pressure levels and cabin altitude change rate

Pressurization is normally controlled automatically. A manual back-up mode is provided in case of failure of the automatic mode.

The CPCS allows flight up to 43,200 feet while maintaining a cabin pressure equivalent to an altitude of less than 8,000 feet. The maximum cabin climb rate is 750 fpm and maximum cabin descent rate 350 fpm.

Comfortable pressure levels are maintained by controlling discharge of cabin air through the outflow valve. The CPCS consists of two digital Cabin Pressure Controllers (CPC), a CABIN PRESS control panel, an outflow valve, and three relief valves.

The CPCS has three modes of control, linked together at a common outflow valve. The three control modes consist of two identical automatic modes and one electric manual mode. Normal pressurization is automatic and requires no crew inputs. The data that the CPC needs for operation can normally be received from other aircraft systems.

The following are the interfaces that the CPC has with other aircraft systems:

- Pressure altitude, computed airspeed, and barometric correction are received from the Air Data Inertial Reference Unit (ADIRU).
- Flight data to the CPC, such as time at top of descent, estimated time of arrival, and landing field altitude, are received from the flight management system (FMS) function of the Versatile Integrated Avionics (VIA) computer. The CPCS is capable of operation without FMS input. The system will revert to internal climb and descent rates. The flight crew needs only to input the landing field altitude in the control panel when this data is not available from the FMS function.

The CPC outputs cabin altitude, cabin rate of change, cabin differential pressure, outflow valve position, and system status for display on the air synoptic page. Cabin altitude and cabin rate data are also displayed on the secondary engine page. The outflow valve position is displayed on the CABIN PRESS control panel and the air synoptic page.

All three ACCs trigger the voice warning "CABIN ALTITUDE" and an alert when the cabin exceed 9,500 feet. The ACCs signal an additional alert when cabin altitude approaches 15,000 feet. The oxygen masks automatically drop.

In the automatic mode, the cabin altitude schedule is calculated by the CPCs as a function of takeoff elevation, landing field elevation, aircraft altitude, and phase of flight.

Cabin altitude remains at departure field elevation until passing through 5,000 feet above departure field elevation.

With FMS data, the CPC schedule is enhanced when cabin rates are set as a function of planned and predicted flight altitudes.

In automatic control, the CPCs:

- Prepressurize to about 100 feet below takeoff field elevation when slats are extended.

- Climb the cabin during aircraft climbout according to takeoff altitude and aircraft altitude.
- Schedule cabin to be at 8.6 psi, or less, higher pressure than ambient during cruise. This limits cabin altitude to 8,000 feet.
- Descend cabin during aircraft descent according to landing elevation and aircraft altitude or, if FMS data is available, the planned flight altitude Schedule.

The CPC FAULT alert indicates one of the two CPCs has failed and control has been switched to the backup CPC.

If the second CPC fails, the system switches to manual mode. The SEL CAB PRESS MAN alert is displayed and the CABIN PRESS SYSTEM SELECT light illuminates.

In manual mode, the flight crew can adjust the outflow valve position with a CABIN PRESS rate selector on the CABIN PRESS control panel.

Automatic Operation

Normal Configuration

During normal configuration operation, the ESC pressurizes the 3 pneumatic systems, operates the 3 packs, reconfigures the pneumatic system for engine start, and monitors for the following failures:

- Manifold failures
- High manifold temperatures
- Low anti-ice pneumatic supply
- Avionics and CAC fan failures
- Cabin pressure failures
- Trim air failures
- Pack failures
- Anti-ice failures

- Recirculation fan failures

Phase of Flight Configuration

The ESC senses phase of flight and operates the systems as required. The phases of flight and the associated functions are:

- Preflight - During normal preflight control actions and engine start operations proper operation of the eight ESC-controlled pneumatic/air conditioning valves is verified. A preflight ESC test verifies trim air shutoff function, and proper operation of the avionics and CAC fans, and the respective flow sensors.
- APU ground operation - The flight crew opens the APU pneumatic isolation valve and starts the APU from the APU control panel. When in auto mode, the ESC pressurizes all 3 pneumatic systems, thus allowing air conditioning.
- External ground pneumatics operation - The flight crew opens the APU pneumatic isolation valve and starts the APU from the APU control panel. When in auto mode, the ESC pressurizes all 3 pneumatic systems, thus allowing air conditioning. (Identical to APU ground operation.)
- Ground conditioned air operation - Conditioned air flows directly into the distribution ducts downstream of the packs. There are no automatic controller functions.
- Ground engine start with APU pneumatic supply - Selection of engine ignition causes the ESC to:

1. Turn packs off.
2. Verify adequate pneumatic pressure for engine start. Display START AIR PRES LO alert, if pneumatic pressure is not adequate.
3. Close 1-3 ISOL valve and turn on pack 3, after engine 3 start.
4. Close 1-2 ISOL valve and turn on pack 1, after engine 1 start.
5. Turn on pack 2 when flight crew closes APU isolation valve, following engine 2 start.

NOTE: Engine 3 pneumatic supply is inhibited by the PSC when using ground carts until the pressure in all 3 systems has been low for 20 seconds.

- After engine start - Normal air conditioning allowed.
- Takeoff - The three takeoff configurations are:

1. BLEEDS OFF - (Normal) Pneumatics and air conditioning turned off when throttles are advanced for takeoff.
2. BLEEDS ON PACKS OFF - Airfoil anti-ice manually selected on and packs selected off by flight crew after throttles advanced for takeoff.
3. PACKS ON - Packs selected on from FMS TAKEPFF page. Airfoil anti-ice manually selected on or off by flight crew.

NOTE: The avionics exhaust fan turns on and the OVRD light illuminates for a packs off takeoff.

- Climb through landing roll - Climb phase begins when thrust is reduced to climb power, after passing through 1,000 feet above airport elevation. At 4,500 feet above airport elevation, if climb thrust is not set, the ESC automatically configures the aircraft for the climb. Pneumatics and air conditioning are restored. Recirculation fan available with ECON selected.
- Engine shutdown - The flight crew opens the APU pneumatic isolation valve and starts the APU from the APU control panel. When in auto mode, the ESC pressurizes all 3 pneumatic systems, thus allowing air conditioning.

Pneumatic System Management

A Pressure Regulator Valve (PRV) on each engine pneumatic system controls bleed air from that engine. With engines running, only one bleed system may feed a single pneumatic manifold.

The ESC normally keeps all pneumatic systems isolated. However, when one or more systems are tied together, the PSC closes the high stage valve. If the ESC is also in auto, the PRV closes to prevent reverse flow.

- With pneumatic supply from the APU or from a ground external source, the ESC opens the isolation valves to allow pressure into all three manifolds.
- The PSC enters a Reverse Flow Check (RFC) mode when pneumatics are supplied by a ground cart. All high stage valves are commanded closed until the cart is removed.
- The PSC senses cart removal when system pressure in all three manifolds falls below 11 psig for at least 20 seconds. System pressure returns to normal within one minute following cart removal.

Air Conditioning System Management

- Each air conditioning pack may be operated by bleed air from its respective engine, from another engine, from the APU, or from external pneumatics. Normally, each engine supplies its respective pack.
- The packs cannot use air from the APU if exhaust air from engines 1 or 3 is entering the APU air intake.
- When the APU is supplying pneumatics to manifold 2 with engines 1 or 3 running, packs using pneumatics from manifold 2 are commanded off.

Pressurization Control System

The pressurization control system controls cabin altitude throughout the flight, provides gentle pressurization changes enroute, and depressurization during the landing.

Additional ESC Control Functions

The trim air system, the recirculation fan system, and the equipment cooling fans are managed automatically by the ESC.

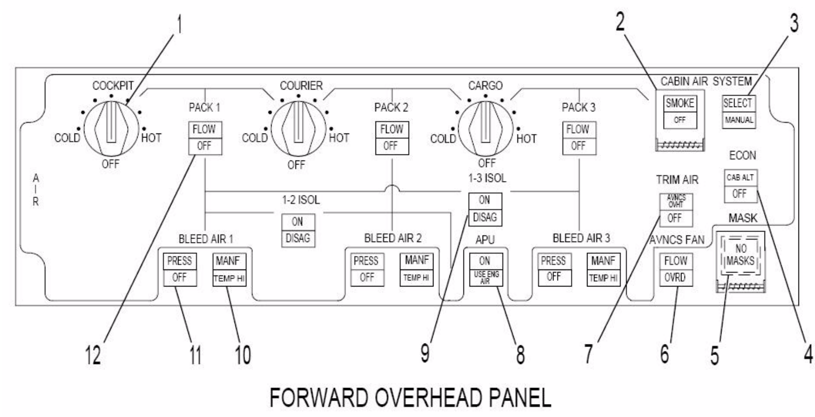
ESC Automatic Operations - Abnormal

The ESC automatic operations include management of the following abnormal situations:

- Monitors MFDS - The ESC reconfigures a failed manifold system to shut off hot air flow. Verifies the failed manifold and restores operative manifolds initially shut down in response to the failure detection. Automatically tests the MFDS before each flight.
- Monitors airfoil anti-ice - The ESC detects failures of the anti-ice manifolds and shuts off air to the associated main manifold. An alert is sent to the flight crew.
- Airfoil anti-ice valves can only be operated by the flight crew. When a triple manifold failure is detected, however, the airfoil anti-ice valves associated with that manifold automatically close. With the valves closed, a valid manifold decay check is enabled.
- Monitors pneumatic systems for engine/APU fire - Shuts down the associated pneumatic system when an ENG or APU FIRE handle is pulled and the ESC is in auto mode.
- When the fire is associated with the APU pneumatic system, the ESC also closes the APU load control valve.
- Monitors environmental system failures and reconfigures - Reconfigures the affected environmental system for a failed component.
- Monitors inoperative components and compensates - Components that may be inoperative by the Minimum Equipment List (MEL) can be entered into the system via the CFDS. The ESC then configures the system to operate with these components inoperative.
- Monitors itself and other components for proper operation - Continually monitors a large number of system components. The ESC uses alternate means to accomplish the task of a failed component, when able.
- Reverts to manual for certain failure modes - Failures within the controller itself, or of a number of essential air system components, results in reversion to manual mode. The SEL AIR SYS MAN alert is displayed.

Controls and Displays

AIR Control Panel (Freighter)



1. COCKPIT/COURIER/CARGO Temperature Selectors

   The zone temperature selectors allow selection of temperature within the range of 65° F (18° C) to 85° F (29° C). Center position is 75° F (24° C).

   - OFF - Respective trim air modulating valve is closed (cold) and the ZONE TEMP SEL OFF alert appears.
   - COLD - All three packs are driven to full cold, causing lower air humidity.
   - HOT - Trim air is added and condensation is reduced in the outlet area.

2. CABIN AIR Switch (Guarded) - amber

   The CABIN AIR switch is a guarded switch that serves as a warning light as well as a control switch.

   - SMOKE - Illuminates when smoke is detected in the upper cargo deck and extinguishes when smoke is no longer detected.

- OFF - Illuminates when the crew pushes the switch closing the conditioned air shutoff valve. Pushing the switch a second time while OFF illuminated will reopen the shutoff valve. The valve should not be reopened.

3. CABIN AIR SYSTEM SELECT Switch - amber

   This alternate action switch allows selection between manual and auto modes.

   There are 2 alternating auto channels. During auto operation, one of the 2 auto channels is not used. Each time auto is selected, the previous unused auto channel is activated.

   - SELECT - Illuminates amber when the air system reverts to manual. The SEL AIR SYS MAN alert is displayed on the EAD, prompting the crew to lock the system in manual by pushing the CABIN AIR SYSTEM SELECT switch.
   - MANUAL - Illuminates amber when the system is in manual. MANUAL flashes when the system is in auto and a switch on the AIR control panel is pushed that has no effect in auto.

4. ECON Switch - red/amber

   This alternate action switch starts/stops the economy operation of the packs. ECON mode may be manually selected on/off when the Environmental Systems Controller (ESC) is operating in auto or in manual.

   In ECON mode, the packs operate on low. When not in ECON mode, the packs operate normally.

   The Air Conditioning Controllers (ACC) and the ESC automatically turn the ECON mode on and off, as required by flight conditions.

   - CAB ALT - Illuminates red when cabin altitude is between 9,500 and 10,000 feet.
   - OFF - Illuminates amber when ECON mode is manually selected off.

5. MASK Switch - red

   The MASK switch is a guarded momentary switch that illuminates if cabin altitude exceeds approximately 14,770 feet and the automatic systems have not deployed the oxygen mask in the lavatory.

   - NO MASKS - Illuminates red when pushed and held for more than 3 seconds. The oxygen mask deploys by using an independent electrical source. The red light in the switch extinguishes

6. AVNCS FAN Switch - amber

   The AVNCS FAN switch is an alternate action switch that starts/ stops override operation of the avionics exhaust fan and the venturi shutoff valve when the system is in manual mode. Normal operation provides automatic cooling airflow through the avionics compartment. Override operation closes the venturi shutoff valve and turns on the avionics exhaust fan. The switch has no effect when the system is in auto mode.

   - FLOW - Illuminates amber when cooling airflow through the avionics is below normal, or cabin inflow is insufficient for pressurization, or cabin altitude is greater than 10,000 feet.
   - OVRD - Illuminates amber when the avionics fan and the venturi valve are commanded to override.

7. TRIM AIR Switch - amber

   The TRIM AIR switch is an alternate action switch that opens/ closes the trim air pressure regulator valves when the system is in manual mode. When on, hot air tempers the air conditioning system cold air output. When off, hot air is prevented from entering the trim air manifold. The switch has no effect in auto mode.

   - AVNCS OVHT - Illuminates amber when an overheat condition is sensed in the avionics compartment. Trim air is latched off.
   - OFF - Illuminates amber when the trim air pressure regulator valves are commanded off.

8. APU Switch - blue/amber

   Refer to the APU chapter for switch description.

9. 1-2 ISOL/1-3 ISOL Switch - blue/amber

   The 1-2 and 1-3 ISOL switches are alternate action switches that open/close the respective pneumatic isolation valves when the system is in manual mode. The switch has no effect in auto mode.

   - ON - Illuminates blue when the ISOL valve is commanded on. If the APU is providing the air conditioning, and the air system is in manual mode, ON illuminates.
   - DISAG - Illuminates amber when the valve position is not in agreement with the commanded position. The light is inhibited for ten seconds when the system is in auto mode. In manual mode, DISAG illuminates when the isolation valves are in transit.

10. BLEED AIR 1/2/3 MANF/TEMP HI Switch (3) - red

    The BLEED AIR MANF/TEMP HI switch is a momentary switch that operates in parallel with and identically to the BLEED AIR PRESS/OFF switch. The switch controls the pneumatic pressure regulator valve and provides the respective engine bleed air disconnect capability when in manual mode. The switch has no effect in auto mode.

    - MANF - Illuminates red when a high temperature is sensed in any compartment through which the respective manifold is routed. A failed or leaking manifold is indicated.
    - TEMP HI - Illuminates red when engine bleed air temperature is excessively high downstream of the precooler.

11. BLEED AIR 1/2/3 PRESS/OFF Switch (3) - amber

    The BLEED AIR PRESS OFF switch is a momentary switch that operates in parallel with and identically to the BLEED AIR MANF/TEMP HI switch. The switch controls the pneumatic pressure regulator valve and provides the respective engine bleed air disconnect capability when in manual mode. The switch has no effect in auto mode.

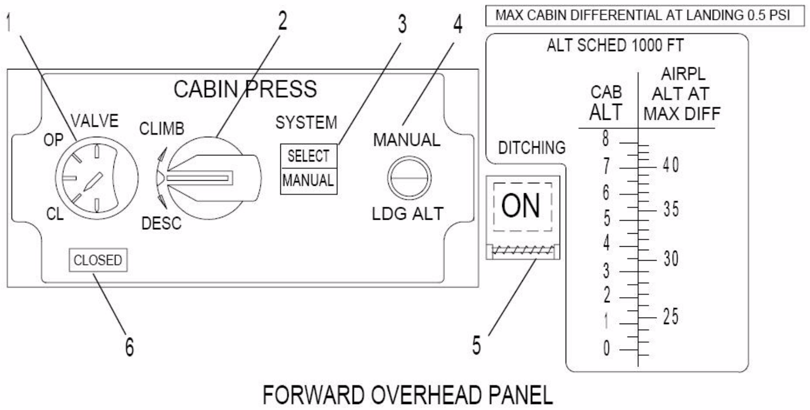
- PRESS - Illuminates amber when the air pressure is less than 11 psi.
- OFF - Illuminates amber when bleed air is selected off.

12. PACK 1/2/3 Switch (3) - amber

The PACK switch is a momentary switch controlling the respective pack flow control valve when the system is in manual mode. When on, air conditioning system control of the respective pack is provided. When off, the associated pack flow control valve and ram air door is commanded closed. The switch has no effect when the system is in auto mode.

- FLOW - Illuminates amber when the respective pack is commanded on, but air flow is insufficient to allow it to operate, or, the pack is commanded off and flow is present.
- OFF - Illuminates amber when the respective pack is commanded off.

CABIN PRESS Control Panel



1. Outflow VALVE Indicator

   Displays position of outflow valve during manual and automatic operation of cabin pressure control system.

2. CABIN PRESS Manual Rate Selector

   This selector is a momentary action, two speed rotary switch that adjusts the position of the outflow valve when the system is in manual. The first detent causes the valve to move slowly. The second detent causes the valve to move faster towards DESC or CLIMB (open or closed). This allows for rapid recovery from failure conditions as well as a fine tuning of cabin altitude rate change.

3. CABIN PRESS SYSTEM SELECT Switch - amber

   This is an alternate action switch that allows selection between manual and auto modes.

   There are 2 alternating auto channels. During auto operation, one of the auto channels is not used. Each time auto is selected, the previous unused auto channel is activated.

   - SELECT - Illuminates amber if the system is in manual with the switch in auto.

- MANUAL - Illuminates amber if the system is in manual. MANUAL flashes if the system is in auto and a switch on the control panel has been pushed that has no effect in auto.

When the SEL CAB PRES MAN alert is displayed on the EAD, the system has reverted to manual. The system may be locked in manual by pushing this switch.

4. CABIN PRESS MANUAL LDG ALT Knob

This knob is used to enter the landing field altitude if the information is not available from the flight management system (FMS). Landing field altitude is shown on the air system synoptic display. The knob has no effect when the system is in manual.

The data is activated when the knob is rotated at least 120 degrees.

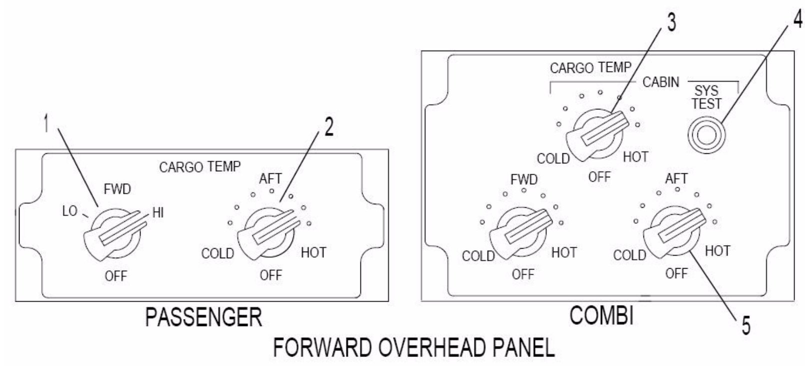
5. DITCHING Switch - amber

- ON - Illuminates amber when pushed, and initiates the following functions:
  - Inhibits GPWS
  - Maintains existing cabin altitude
  - Shuts off packs at 2,500 feet radio altitude or when cabin differential pressure is less than 0.5 psi
  - Closes avionics shutoff valve
  - Closes ram air door (if open)
  - Closes outflow valve

6. CLOSED Light - amber

Illuminates amber when the outflow valve is fully closed.

CARGO TEMP Control Panel



1. FWD CARGO TEMP Selector

   Regulates the temperature in the forward cargo compartment.

   - LO - 40° F (4.4° C)
   - HI - 70° F (21.1° C)
   - OFF - Heating system is off.

2. AFT CARGO TEMP Selector

   Regulates the temperature in the aft cargo compartment.

   - COLD - 39.5° F (4.0° C)
   - HOT - 95.5° F (35° C)
   - OFF - Heating system and aft galley exhaust are off.

3. CABIN CARGO TEMP Selector

   Regulates the temperature in the cabin compartment.

   - COLD - 40° F (4.4° C)
   - HOT - 85° F (29.4° C)
   - OFF - Heating system is off.

4. SYS TEST Button

- Push - (Ground only) Starts a test of the combi exhaust system (CES).

This test also starts automatically when all cargo and partition doors are closed.

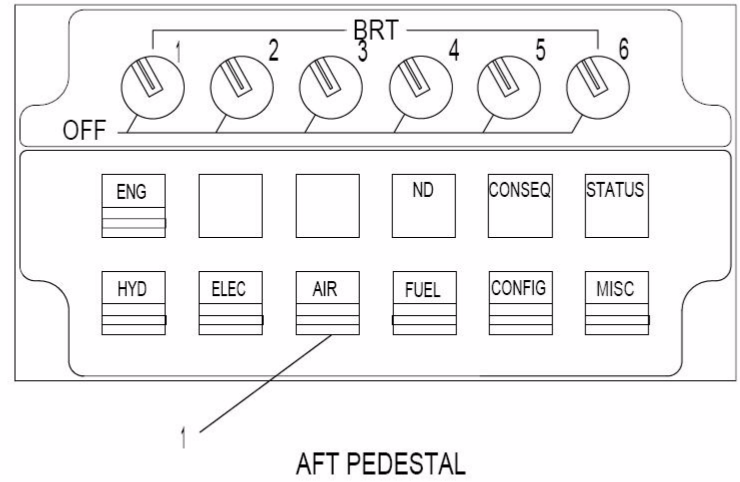
CES FAIL alert is displayed if there is excessive air leakage across the main deck cabin/cargo partition, or there is a failed LRU.

5. FWD/AFT CARGO TEMP Selector

Regulates the temperature in the respective cargo compartment.

- COLD - 38° F (3.3° C)
- HOT - 87° F (30.5° C)
- OFF - Heating system is off.

AIR Cue Switch



1. AIR Cue Switch - white

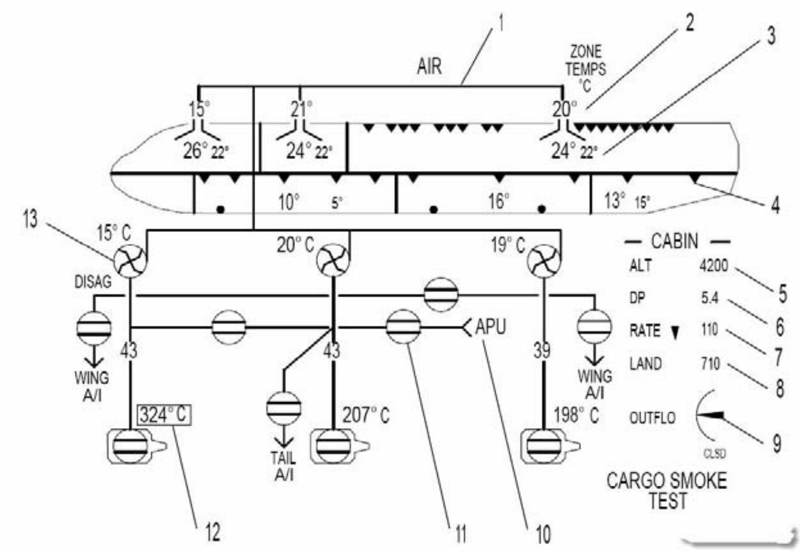
   Illuminates white when AIR alert is displayed on the EAD.

   When pushed:

   - MASTER CAUTION or MASTER WARNING lights extinguish.
   - A reminder message replaces the EAD alert.
   - The synoptic and the corresponding consequences appear on SD.

   Some Level 1 alerts are for maintenance only, and appear on the SD STATUS page only. These alerts do not illuminate the cue switch or the MASTER CAUTION lights.

SD Synoptic - Air (Freighter Configuration)



1. Ducts and Flow Lines - white/green/red/amber

   Ducts and flow lines are represented as a solid line. Ducts with no flow or unpressurized flow lines are shown as white lines. Ducts and flow lines are green when pressurized, red when there is a manifold failure, and amber if turned off following a manifold failure.

2. Duct Temperatures - white/amber

   Duct temperatures are in degrees C (metric) or degrees F (English). Digits are normally white, and boxed amber when there is a duct overheat. Unavailable data is replaced with an amber X.

3. Zone Temperatures - white/cyan/amber

   Zone temperatures are in degrees C (metric) or degrees F (English). Actual temperatures are shown in large white digits. Set temperature is shown in smaller cyan digits. If temperature selector is off, OFF replaces small digits. Any unavailable temperature is replaced with an amber X. All cargo zones are off with the CARGO TEMP switch in OFF.

4. Smoke and Heat Detectors - amber/white

   Detected smoke is shown by a small amber triangle in the appropriate compartment. Detected heat is shown by a small amber circle. During a smoke detector test, CARGO SMOKE TEST is shown in white below the outflow valve. Failed smoke and heat detectors are shown as amber rectangles with an F inside.

5. ALT Readout - white/red/amber

   Cabin altitude (feet) is shown in the right center of the screen. Digits are normally white, but turn red and are boxed when cabin altitude exceeds 10,000 feet. If no valid cabin altitude is available, the digital readout is replaced by an amber X.

6. DP Readout - white/red/amber

   Cabin differential pressure (psi) is shown below ALT readout. Digits are normally white, but turn red and are boxed in red when differential pressure exceeds 9.1 psi. If no valid differential pressure data is available, the digital readout is replaced by an amber X.

7. RATE Readout - white/amber

   Cabin altitude rate (feet per minute) is shown below DP readout. Downward rates are indicated by a downward pointing arrowhead. Upward rates have an upward pointing arrowhead. Digits are normally white, but turn amber and are boxed in amber when the rate exceeds plus 1500 feet per minute or minus 750 feet per minute for 15 seconds, or plus 3000 feet per minute or minus 1500 feet per minute for 5 seconds.

8. LAND Readout - magenta/white/amber

   Landing altitude is shown below RATE readout. Landing altitude is supplied by the FMS and is shown in magenta, or is shown in white and boxed if set manually through the cabin pressure controller. If no valid landing altitude is available through the FMS, the readout is replaced with amber dashes.

9. OUTFLO Readout - white/amber

   Outflow valve position is shown below the LAND readout. This display is normally white, but the letters CLSD turn amber when the valve is fully closed.

10. APU Air Readout - white/green

    Readout appears only when APU air is available. Readout is white when APU bleed air load valve is closed and green when APU bleed air load valve is open.

11. Valve Symbol - white/green/amber

    Valves always reflect the state commanded by the ESC. They are white when closed, green when open, and amber with DISAG displayed above the valve when not in the commanded position.

12. Engine Bleed Readout - white/amber/red/green

    Engine bleed pressure (psi) is shown above the outline of the engine. Digits are normally white but turn amber and are boxed if limits are exceeded. Engine bleed temperature (degrees C) is shown adjacent to the associated engine. Digits are normally white, but turn red and are boxed if high temperature limits are exceeded, or turn amber and are boxed when low temperature limit (ice protection) is exceeded. The pressure regulator valves are shown in the engine outline. The valve is green if the engine is running, the manifold is pressurized, and the valve is commanded open; otherwise, it is white. If no valid engine bleed pressure or temperature data is available, digits are replaced with an amber X.

13. Air Conditioning Pack Readout - green/white/amber/red

    The packs always reflect the commanded state. Operating packs are green circles with green vanes. Non-operating packs (no faults) are white circles. If a pack overheats or is turned off due to a pack manifold failure, it is amber. When a manifold fail occurs, it is red. Pack outlet temperatures are programmed either in degrees F (English) or degrees C (metric). Digits are normally white but turn amber and are boxed in amber when the pack overheats. If no valid pack temperature is available, the digits are removed and replaced with a red X.

EIS Test Display

All AIR synoptic data digits are crossed with amber X's when all of the following conditions are met:

- The aircraft is on the ground and operational.
- The ANNUN LT TEST button on the overhead panel is pushed.
- The AIR synoptic is selected on the SD.

Alerts

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

Red Boxed Alerts (Level 3)

- AIR MANF 1/2/3 FAIL (AIR) - Leak has occurred in respective air system manifold or left wing anti-ice ducting (1)/tail anti-ice ducting (2)/right wing anti-ice ducting (3).
- BLD AIR1/2/3 TEMP HI (AIR) - Respective bleed air system exceeds
- Temperature limit.
- CABIN ALTITUDE (AIR) - Cabin altitude exceeds 10,000 feet.
- CAC MANF FAIL (AIR) - Leak has occurred in pneumatic system ducts in the center accessory compartment.

Amber Boxed Alerts (Level 2)

- AIR SYS 1/2/3 PRES LO (AIR) - Respective air system pressure is low.
- AIR SYS 1-2 OFF (AIR) - A manifold failure has caused air systems 1 and 2 to shut down and air system is in manual mode.
- BLEED AIR 1/2/3 FAULT (AIR) - Respective system bleed air temperature or pressure is low.
- TRIM AIR OFF (AIR) - The air conditioning TRIM AIR has been
- Automatically turned off (a fault exists) or the TRIM AIR switch has been manually selected off.

Amber Alerts (Level 1)

- AIR SYS 1/2/3 OFF (AIR) - Respective air system bleed is off. Associated isolation valves are off. (System 1 isolation valves are 1-3 and 1-2, system 2 valves are APU load control and 1-2 isolation, system 3 valve is 1-3).

- AIR SYS MANUAL (AIR) - Air system is in manual mode.
- AIR 1-2/1-3 ISOL DISAG (AIR) - The respective pneumatic isolation valve is not in the commanded position.
- AVNCS FAN OVRD (AIR) - The avionics exhaust fan, normally off in flight, is operating. The fan turns on automatically when cooling flow goes below normal, or may be manually selected on.
- BLEED AIR 1/2/3 OFF (AIR) - Associated engine bleed valve is closed with associated air system pressurized from another source.
- BLEEDS NOT OFF (AIR) - Packs off for takeoff is selected (anti-ice off) and the bleeds are not selected off prior to advancing the throttles for takeoff.
- CABIN PRES RELIEF (AIR) - Cabin differential pressure has exceeded 8.76 psi and pressure relief valve(s) is open.
- CAB PRES SYS MAN (AIR) - Cabin pressurization system is in manual.
- CABIN AIR OFF (AIR) - The cabin air to the cargo compartment is selected off.
- CABIN INFLO LO (AIR) - Cabin altitude is climbing, outflow valve is closed and one or more packs are commanded ON. If
- AIR SYSTEM SELECT switch is in AUTO, the AVNCS FAN switch will revert to OVRD and remain in override until aircraft is on the ground.
- CABIN RATE (AIR) - Cabin rate of climb/descent exceeds limits.
- CAC AIR FLO OFF (AIR) - All CAC fans are inoperative. There is no CAC cooling.
- CAC MANF DECAY CK (AIR) - CAC air manifold air pressure decay check in progress.
- CPC FAULT (MAINT) - One of the 2 cabin pressure controllers is inoperative and requires ground maintenance.
- CRG FLO AFT/FWD DISAG (AIR) - Associated cargo compartment ventilation does not agree with switch position.

- CRG TEMP CTL OFF (AIR) - FWD and/or AFT TEMP selector in OFF.
- ECON OFF (AIR) - The ECON switch has been selected off. The packs command maximum available flow and the cabin recirculation fans will not operate. LDG ALTITUDE MAN (AIR) - The landing field elevation is set by turning the MANUAL LDG ALT knob on the CABIN PRESS control panel. Selecting the cabin pressure controller to manual and back to auto restores automatic operation.
- LWR CARGO TEMP LO (AIR) - Temperature in one or both lower cargo compartments is below limit.
- OPEN OUTFLOW VALVE (AIR) - Cabin pressure exceeds allowable limits to open doors while aircraft is on the ground.
- PACK 1/2/3 FLO DISAG (AIR) - Associated air conditioning pack flow is in disagreement with the commanded position.
- PACK 1/2/3 OFF (AIR) - Associated air conditioning pack is off, either selected manually by the crew, or automatically by the ESC due to a fault or configuration requirement.
- PACKS NOT OFF (AIR) - During packs off (bleeds on) takeoff, one or more packs are not off.
- SEL AIR SYS MAN (AIR) - The air system has reverted to manual mode but the AIR SYSTEM SELECT switch is in the auto position.
- SEL (FWD or AFT) TEMP OFF - temperature in the respective lower cargo compartment exceeds limits. When the associated cargo temperature returns to normal one attempt may be made to restore the system.
- SEL CAB PRES MAN (AIR) - The automatic cabin pressurization system is inoperative.
- SET LDG ALTITUDE (AIR) - The cabin pressure controller is not receiving landing field elevation data from the FMS and should be set manually. Automatic operation may be restored by selecting the cabin pressure controller to manual and back to auto.

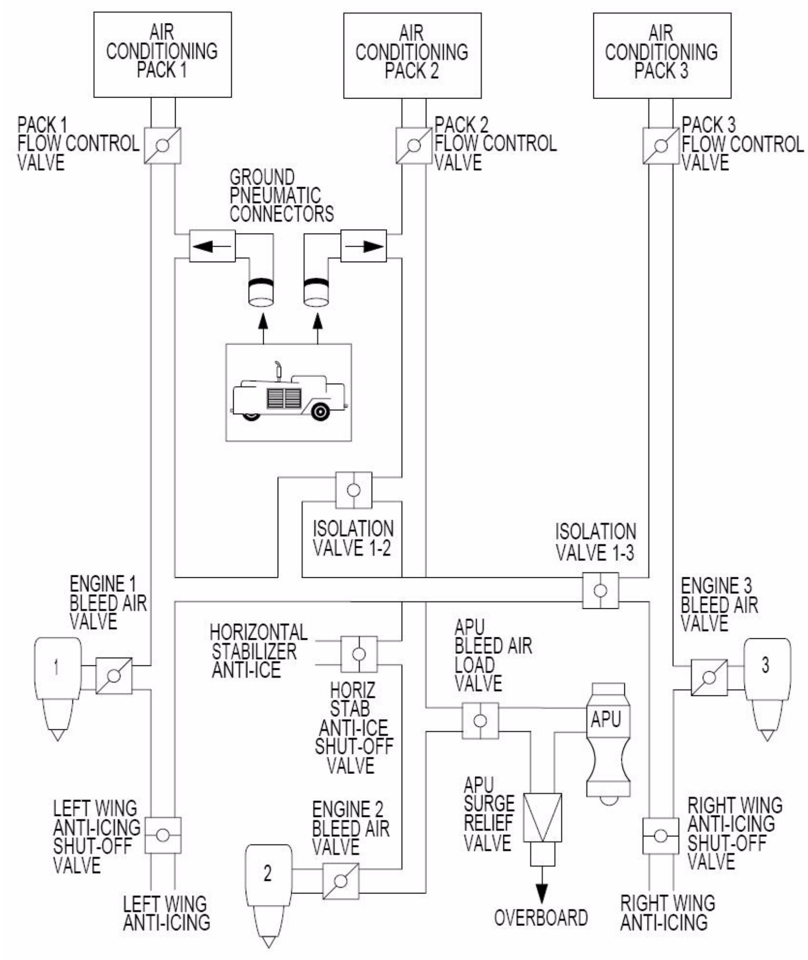
- SEL PACK 1/2/3 OFF (AIR) - Respective pack discharge temperature exceeds limits.
- ZONE TEMP SEL OFF (AIR) - One or more of the cabin zone temperature selectors is selected off.

Cyan Alerts (Level 0)

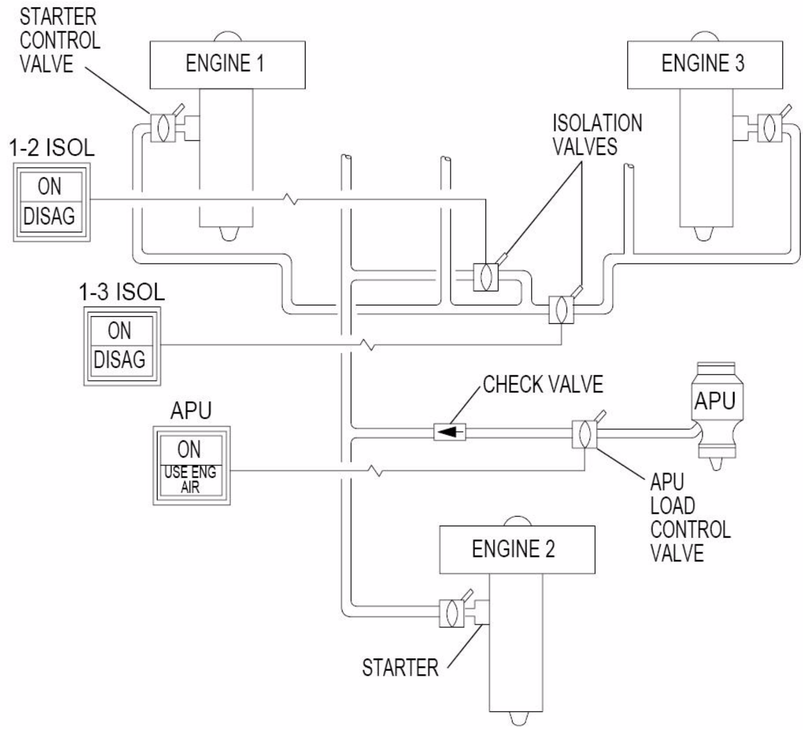
- AIR 1-2/1-3 ISOL ON - Associated pneumatic isolation valve has been commanded on (open).
- AIR SYS TEST - Automatic air system preflight test is in progress.
- BLEEDS ALL OFF - All three bleeds air supplies are turned off for a bleeds off takeoff.
- PACKS ALL OFF - All three air conditioning packs are off for a packs off takeoff.

Functional Schematics

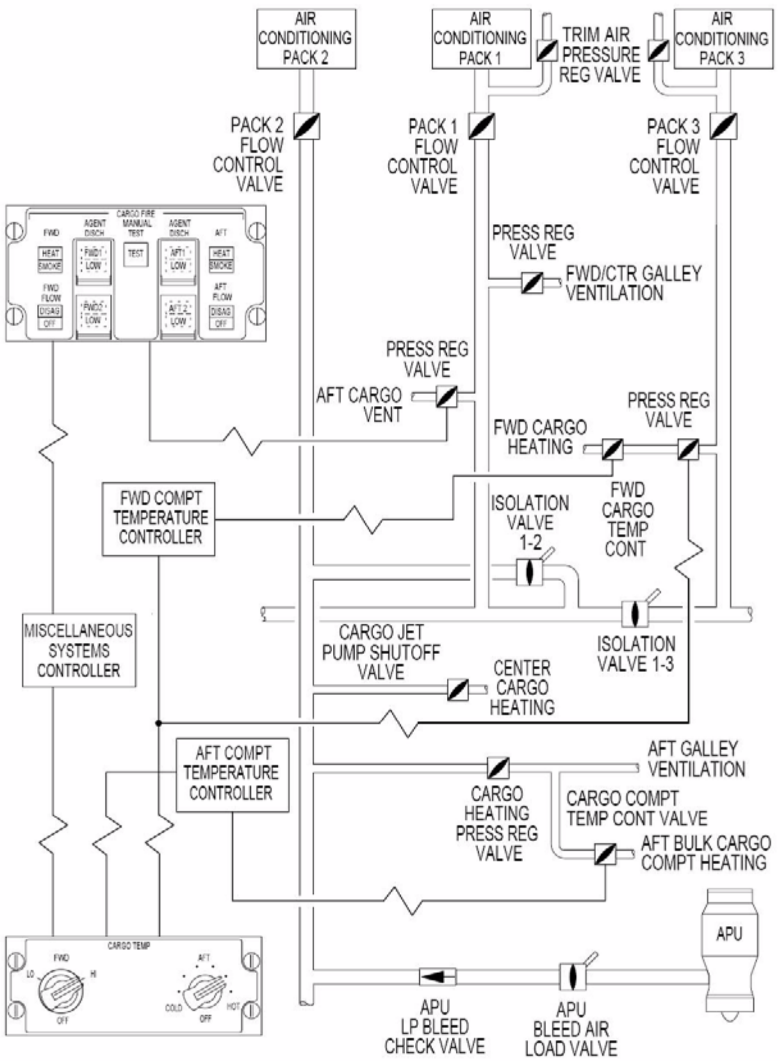
Air System Block Diagram



Pneumatic Manifold Isolation Control



Cargo and Galley Ventilation and Heat



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Description and Operation

General

The Auxiliary Power Unit (APU) provides electrical and pneumatic power for engine start and air conditioning, and supplies ground and in-flight electrical power. Pneumatic and electrical power may be used independently or simultaneously.

The APU is installed in an unpressurized area of the rear pressure bulkhead, beneath engine 2 and the horizontal stabilizer.

APU RPM, EGT, air output and electrical output are controlled by an Electronic Control Unit (ECU).

APU controls are on the overhead panel. The external APU control panel is in the fairing immediately behind the left main gear well. APU parameters are displayed on the Systems Display (SD).

APU Control System

The APU requires battery bus power for start and uses fuel from tank 2. The ECU receives primary power from the battery bus.

The APU supplies air to operate the three air conditioning packs, before or after engine start, as required.

APU Door System

The APU installation has an inward-opening door for the intake duct and an outward-opening half door for the exhaust duct. An electric actuator operates the doors.

The inlet and exhaust door actuation system receives electrical power from the battery bus on command from the Miscellaneous Systems Controller (MS C).

If a door starts to close while the APU is operating, the APU shuts down.

APU Start and Shutdown

The APU START/STOP alternate action (push button) switch on the aft overhead panel commands APU start through the MSC, after determining APU running status.

A DC electric starter motor, mounted on the APU gearbox, uses aircraft battery power for APU start. A battery-powered DC pump provides starting fuel flow to the APU from main fuel tank 2. This pump is used for APU start when AC power is not available. When AC power is available, the AC pump in main fuel tank 2 supplies fuel to the APU.

Following APU start, the ECU controls the APU through the EFCU, maintaining a constant APU N2 rpm speed with all varying loads. The ECU also regulates the surge control valve and the bleed air load valve to meet demand for pneumatic power.

Following APU lightoff, EGT is monitored continuously until the APU is shut down. The EGT value is displayed on the APU data window of the SD. Should EGT limits set by the ECU be exceeded, N1 speed is slowed to N1/EGT cutback. Shut down is automatic if there is still no control.

The following automatic shutdowns, processed through the ECU, protect the APU against hazardous conditions and potential damage:

- N1 or N2 overspeed
- Low oil pressure
- High oil temperature
- Reverse flow
- Loss of EGT signal
- Fire warning
- Loss of N1 or N2 speed signal
- High EGT
- Loss of DC power
- Slow start

- No flame during start
- Inlet door not open
- Starter motor energized over 1 minute
- Overcurrent

APU Pneumatic System

The APU pneumatic system supplies bleed air to the Environmental Control System (ECS) and to the main engine start system.

The APU pneumatic system shares the ducting and valving associated with the engine 2 bleed air system.

When the APU bleed air load valve is opened, low-pressure compressor discharge air flows into the engine 2 bleed line through the air load valve and the low-pressure check valve. This air is directed either to the packs or to the main engine air starters by one or both of the isolation valves.

APU Controls and Displays

APU indications are displayed on the SD. Alerts appear on the EAD and SD. The APU control panel is on the aft overhead panel.

The APU START/STOP switch permits single switch control for manual start/stop and operation under normal ground and flight conditions.

The APU PWR switch on the ELEC control panel also starts the APU, and stops the APU if started with this switch and not supplying bleed air. APU power is automatically supplied to the unpowered generator buses.

With engine integrated Drive Generator (IDG) power from the respective bus, the APU continues to run and to power each main bus during engine shut down.

If the APU is started with the APU START/STOP switch, shut down is not automatic after the load is removed. Manual shutdown with the APU START/STOP switch is required.

The APU cannot be started without battery power. During a battery start, DOOR, FUEL, and FAIL lights, if illuminated indicate malfunctions. During the start sequence, both the AVAIL light on the APU PWR switch and the ON light on the APU START/STOP switch flash.

An APU oil quantity drop is normal during the start sequence.

After APU start, with AC power available, the APU ON alert is displayed on the EAD and N1, EGT, N2, and OIL parameters are displayed on the SD.

The APU door closes when the APU master switch is actuated to STOP. At this time, the APU indication is removed from the SD, and the APU ON alert disappears.

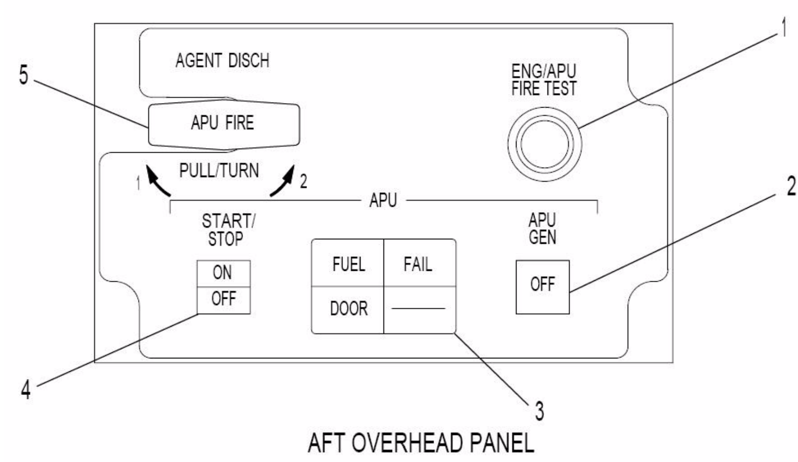
A 90-second time delay provides a cushion against thermal shock to the turbine section. The APU continues to run after it has been commanded OFF if air has been used.

APU shutdown with the START/STOP switch automatically closes the APU bleed air load valve.

The APU symbol is removed from the AIR synoptic when the load valve is commanded closed.

Controls and Displays

APU Control Panel



1. ENG/APU FIRE TEST Button

   For description, refer to Fire Protection chapter.

2. APU GEN Switch - amber

   When pushed, resets APU generator control unit if electrical system is in manual mode.

   - OFF - Illuminates amber when generator is on speed and there is a malfunction.

3. APU FUEL/FAIL/DOOR Status Display - amber

   - FUEL - Illuminates amber when APU fuel pressure is too low. FAIL - Illuminates amber if the APU fails to start.
   - DOOR - Illuminates amber if the APU door does not open. DOOR also illuminates during a normal shutdown if the door does not close.
   - Blank - Illuminates during test only (spare display).

4. APU START/STOP Switch - blue

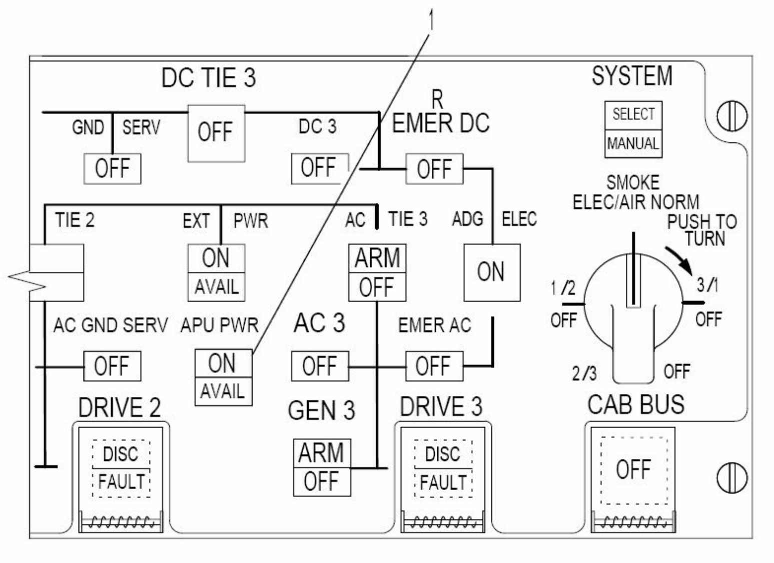
This switch is an alternate action push button switch that starts and stops the APU manually. With OFF selected, the APU shuts down 90 seconds after the APU bleed air stops. The APU bleed air load valve automatically closes.

- ON - Flashes blue when the APU is selected to START, and illuminates steady blue when the APU is running on speed. If the APU shuts down automatically due to a fire signal, ON flashes until the APU START/STOP switch is selected to STOP (OFF).
- OFF - Illuminates steady when the APU is selected to STOP. The APU bleed air load valve closes automatically, and shutdown occurs 90 seconds after the APU is no longer supplying bleed air. OFF remains illuminated until the shutdown cycle is complete.

If the APU is started with this switch, the APU can only be stopped manually with this same switch.

5. AGENT DISCH APU FIRE Handle For description refer to the Fire Protection chapter.

APU PWR Switch



FORWARD OVERHEAD PANEL

1. APU PWR Switch - green/blue

   Push to start the APU.

   - AVAIL - Flashes green during start until N2 reaches 95 percent, then becomes steady green as the APU generator provides power of correct phase rotation, voltage, and frequency.

   If the APU was started from the APU control panel, pushing this switch supplies APU power to the unpowered generator buses if the green AVAIL light is illuminated.

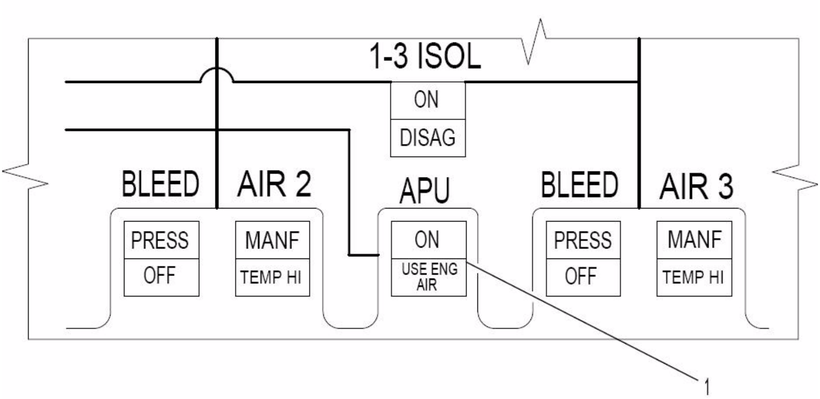
   After start, APU power is automatically supplied to unpowered generator buses. When the IDGs are supplying the generator buses, the APU shuts down 90 seconds after APU air is no longer being used.

   - ON - Illuminates blue when the APU generator is supplying power to any generator bus.

If the APU is on and supplying electrical power, pushing this switch disconnects electrical loads.

If the APU was started from the APU control panel, pushing this switch does not stop the APU.

APU Air Switch



1. APU Air Switch - blue/amber

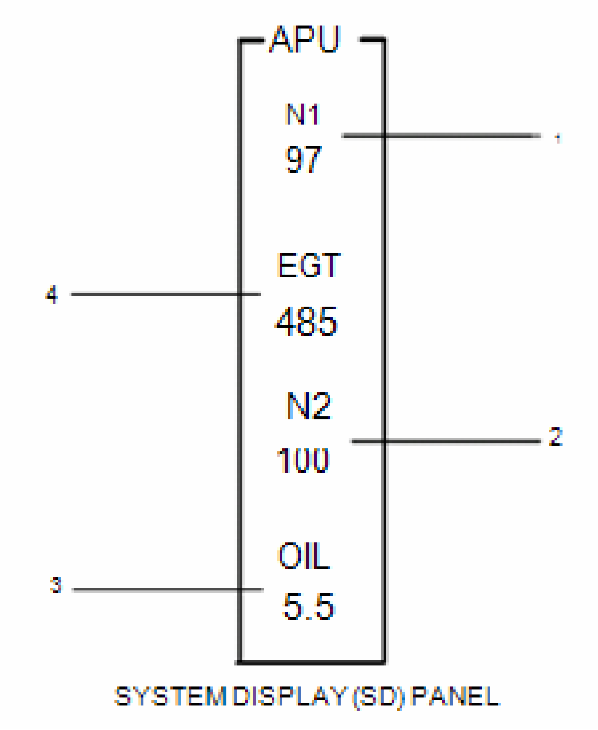
   This switch is an alternate action switch that opens and closes the APU bleed air load valve.

   - ON - Illuminates blue when the valve is selected open.
   - USE ENG AIR - Illuminates amber when the APU air switch is on and cabin differential pressure is more than 1.5 psi.

   If APU air is desired for engine start, this switch must be pushed prior to pulling the ENG START switch.

   NOTE: When the air system is in auto mode, the 1-2 and 1-3 isolation valves are automatically controlled

APU Data Window



1. APU N1 Readout - white/red
   - N1 - White digits turn red and are boxed in red if limits are exceeded (displayed in percent).
2. APU N2 Readout - white/red
   - N2 - White digits turn red and are boxed in red if limits are exceeded (displayed in percent).
3. APU OIL Readout - white/amber
   - OIL - White digits turn amber and are boxed in amber if oil quantity (quarts) is low.
4. APU EGT Readout - white/red

- EGT - White digits turn red and are boxed in red if limits are exceeded (displayed in degrees centigrade).

NOTE: APU data appears on the SD only when the secondary engine display is selected and APU power is on.

Alerts

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

Red Boxed Alerts (Level 3)

- APU FIRE (ENG) - APU fire or air manifold fail conditions in APU compartment.

Amber Boxed Alerts (Level 2)

- GEN APU OFF (ELEC) - APU generator is off (manual mode).

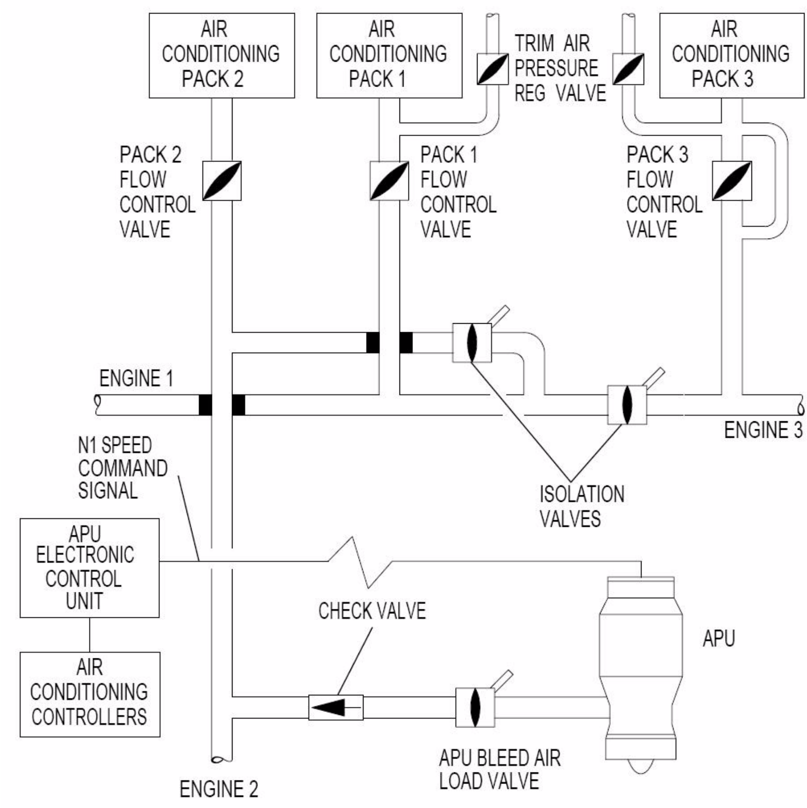
Amber Alerts (Level 1)

- APU AUTO SHUTDOWN (ENG) - The APU has automatically shut down.
- APU DOOR DISAG (ENG) - The APU inlet/exhaust door position is not in the commanded position.
- APU FAIL (ENG) - The APU has automatically shut down due to a failure. A restart should not be attempted.
- APU FUEL PRES LO (ENG) - APU fuel pressure is low.
- APU MAINT DOOR (ENG) - The APU DOOR switch on the upper maintenance panel is in the OPEN position and the APU inlet door is open.
- APU STARTER FAULT (MAINT) - An APU starting system fault exists and the APU should not be started. If APU is already running, may continue to operate.
- APU AIR ON - APU bleed air load valve is commanded open and the APU is providing air.
- APU AIR/ELEC ON - APU is providing air and electrical power.
- APU ON - The APU is running, but not providing air or electrical power.

- APU POWER AVAIL - APU electrical power is available, but not powering any buses.
- APU POWER ON - APU electrical power is connected to at least one of the three buses.

Functional Schematic

Pneumatic Supply



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Description and Operation

Introduction

The purpose of this chapter is to provide an automatic flight system (AFS) general description and operation. It is recommended that the user become familiar with the FMS chapter in this manual since the AFS system closely interfaces with the FMS.

General

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

The AFS Provides the following functions:

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

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

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

The AFS consists of the following:

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

AFS controls and indicators include the following:

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

Flight Control Panel (FCP)

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

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

- Turn to preselect a value.

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

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

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

Primary Flight Display (PFD)

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

Flight Mode Annunciator (FMA)

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

AP Disconnect Switches

The AP disconnect switches are installed on the outboard horn of the Captain's and First Officer's control wheels. These commands can also be mapped to a key command or button from the PMDG Menu.

AP Disengage Warning System

The AP disengage warning system consists of a flashing red AP OFF on the FMA and a cyclic aural warning (tone and voice).

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

ATS Disconnect Switches

The ATS disconnect switches are on throttle levers 1 and 3. Operation of either switch disconnects the ATS. These functions can also be mapped to a key command or button in the PMDG Menu.

ATS Disengage Warning System

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

Go-Around (GA) Switch

The GA switch is on the center throttle. Pushing the switch in flight below 2,500 feet AGL with flaps down or slats extended engages the FD go-around mode. If the AP is on, it will follow the FD commands. There is a also a clickspot on the Upper Left MCP screw for use in the 2D cockpit. Key commands for this item can be mapped from the PMDG Menu.

FLT DIR and FLT DIR OFF Switches

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

Automatic Flight System (AFS) Panel

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

EIS Control Panels (ECP)

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

Roll Control Wheel Steering (CWS)

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

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

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

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

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

Autopilot/Flight Director

Flight Director Engage/Disengage

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

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

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

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

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

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

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

Autopilot Engagement

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

1. If neither AP channel (1 or 2) is engaged, the armed channel will engage.

2. After first AP engagement, each push transfers the AP channel between AP1 and AP2. The channel that is not engaged will be armed (unless inop).
3. If one of the AP channels is engaged and the other channel is inoperative, no transfer will occur.
4. The engaged AP channel will appear on the PFD below the FMA(AP1or AP2).

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

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

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

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

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

- Engage in the existing FD mode and maneuver the aircraft within the attitude limit to acquire and track the FD mode if the engaged FD mode is heading/track select, level change speed select, pitch TO/GA, FMS NAV, or FMS PROF.

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

Autopilot Disconnects

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

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

AP disconnects will also occur as follows:

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

Autopilot/Flight Director Operations

General

AP/FD pitch modes are:

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

FMS vertical flight profile control. AP/FD roll modes are:

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

AP/FD combined pitch and roll modes are:

- FMS non-precision approach
- FD and AP ILS approach

- AP automatic landing
- Stickshaker guidance

AP/FD FCP Vertical Speed/Flight Path Angle

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

- AP engaged and the existing vertical speed is greater than 300 fpm. In this case the V/S-FPA display window on the FCP displays the existing vertical speed and the AP controls to that vertical speed.
- One or both FDs are re-engaged with the AP off and the existing vertical speed is more than 300 fpm.
- The pitch thumbwheel on the FCP is rotated to select the desired vertical speed in the V/S-FPA display window except when the AP is engaged in land mode, dual FD approach mode below 1500 feet, or takeoff/GA mode below 400 feet.
- The V/S-FPA changeover button on the FCP is pushed to V/S from FPA while operating in the flight path angle mode. The vertical speed reference will be the vertical equivalent to the displayed flight path angle at the time of FPA to V/S changeover selection.

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

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

AP/FD Altitude Control

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

AP/FD Heading/Track Select/Hold

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

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

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

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

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

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

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

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

AP/FD Approach

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

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

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

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

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

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

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

FD Only ILS Operation

The approach is restricted to ILS category II minimums.

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

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

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

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

Autoland

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

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

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

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

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

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

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

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

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

When a land mode is engaged, all other modes except go-around are inhibited. Prior to land engagement the aircraft is controlled by a single channel of the engaged AP. The second channel of the engaged AP and both channels of the second AP are on stand-by.

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

Reversion to SINGLE LAND may occur if:

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

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

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

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

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

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

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

At initiation of reverse thrust, the ATS disengages.

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

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

AP/FD Go-Around

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

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

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

FD Takeoff

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

- On-ground conditions exist for more than 20 seconds and,
- The FMS V2 speed has been manually confirmed, and
- Either or both FDs are on and working.

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

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

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

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

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

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

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

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

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

FMS Coupled Operations

General

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

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

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

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

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

AUTO FLIGHT switch to select the other FMC. The pilot must then reengage the desired FMS mode on the FCP.

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

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

FMS Speed Control

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

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

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

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

FMS Vertical Profile Control

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

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

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

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

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

As a customer option, PROF may be armed on the ground. PROF mode disengages if any of the following are true:

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

FMS Lateral Navigation

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

NAV ARMED is reset by:

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

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

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

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

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

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

FMS VOR Approach Mode

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

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

VOR ARMED is reset by:

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

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

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

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

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

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

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

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

Automatic Pitch Trim

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

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

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

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

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

Autothrottle System (ATS) and Engine Trim

General

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

Each FCC contains one ATS control channel that drives a separate section of a 1qdual actuator. This provides two channels of control with fail passive monitoring.

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

The ATS operates in the following modes:

- IAS Hold - Provides control of throttles to maintain the current airspeed.
- IAS Select - Provides control of throttles to acquire and maintain a selected reference speed.
- Mach Hold - Provides control of throttles to maintain the current MACH number.
- Mach Select - Provides control of throttles to acquire and maintain thrust at the thrust limit/target.
- Thrust Limit/Target - Provides control of throttles to acquire and maintain thrust at the thrust limit/target.
- Retard - Provides control of throttles to reduce thrust at the appropriate radio altitude for landing.
- Clamp - Inhibits ATS control during takeoff at approximately 80 knots without causing disengagement of the ATS. Full manual throttle is available during this mode.

ATS Engage

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

The ATS engages automatically to provide high speed or low speed protection if the aircraft speed exceeds the Vmax/Vmin limits.

ATS Disengage

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

- Pushing either throttle 1 or 3 ATS disconnect switches.
- Placing any throttle in reverse thrust.
- System failure (may result in single or dual channel disengagement depending on the fault).
- Pushing down the AFS OVRD OFF switches on the FCP.
- Any one FADEC reverting to the alternate mode of engine control (P&W only).

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

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

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

ATS Clamp Mode

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

- Takeoff mode on the ground and two or more engine thrust commands are less than 70 percent of the maximum takeoff setting.

- Takeoff mode is engaged and IAS exceeds 80 knots.
- In flight when command input places the throttles in flight idle and further thrust reduction is required.

CLAMP mode is annunciated on the FMA.

ATS Unclamp

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

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

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

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

ATS Thrust Control

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

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

The ATS thrust limit control modes are:

- Takeoff
- Go-around
- Climb

- Cruise (alternate climb)
- Idle

The RETARD mode is a form of thrust control. The throttles are driven to the idle stop when the AP goes into FLARE mode or when RA is less than 50 feet, flaps are greater than 31.5 degrees and ATS is engaged. Exit from retard mode is by setting throttles to reverse thrust or initiation of go-around mode.

ATS Speed Control

The ATS speed control is automatically limited by the following speeds:

- Vmin +5 knots as determined by the FMS and normal flap/slat configurations.
- Vmin +5 knots as determined by the FMS and abnormal flap/slat configuration.
- Vmo/Mmo - 5 knots.
- Flap placard speed - 5 knots.
- Slat placard speed - 5 knots.
- Landing gear placard speed - 5 knots.
- FMS 1.2g buffet speed - 5 knots (standard) or FMS 1.3g buffet speed -5 knots (optional).

Pilot selection of the reference speeds is accomplished via the FCP. The FCP provides for preselect of IAS and MACH.

A speed hold function allows the existing speed to be the target speed during steady state flight. It will also allow a smooth capture target speed during aircraft acceleration. Speed control targets are also provided by the FMS profile modes.

The ATS controls to speed targets during approach, altitude hold, vertical speed, flight path angle, and profile modes of the AFS/FMS system.

Flight level change operation transfers the ATS to thrust control. Speed will then be controlled by the pitch attitude. The speed and thrust control are annunciated on the FMA.

The ATS provides for automatic speed reference transitions (IAS/Mach) during climbs and descents as follows:

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

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

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

Speed Envelope Limiting

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

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

Automatic Engagement and Speed Control

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

LSAS Speed Limiting and Stall Protection

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

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

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

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

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

AP/FD Speed Mode Reversions

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

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

At 5 knots over or underspeed:

- The AP/FD pitch control mode reverts to V/S FPA at the existing vertical speed/flight path angle.
- ATS engages in speed-on-thrust speed protection with a Vmin or Vmax speed target.

- The FMA flashes THRUST and V/S or FPA five times before becoming steady.
- The FMA flashes HI SPEED PROTECTION or LO SPEED PROTECTION

At 10 knots over or underspeed:

The AP/FD pitch mode reverts to pitch speed protection with a Vmin or Vmax speed target.

- The throttles are clamped at their existing positions.
- The FMA flashes PITCH five times before becoming steady.
- The FMA flashes HI SPEED PROTECTION or LO SPEED PROTECTION.

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

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

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

At 5 knots over or underspeed:

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

At 10 knots over or underspeed:

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

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

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

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

Altitude Alert System

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

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

The altitude alert activates as follows:

- 1,000 feet from the FCP window altitude - PFD altitude box turns steady amber (and optional tone).
- If more than 0.12g required to capture FCP window altitude - Steady amber PFD altitude box and tone. Active only on first approach to the FCP window altitude and is inhibited when aircraft is within 150 feet. If more than 0.12g is required to capture the FCP window altitude and that altitude is more than 1000 feet from the current baro-altitude, the PFD altitude box will be flashing amber. This condition requires an initial vertical speed of more than 5200 fpm and is rare.
- Deviation of 150 feet or more from FCP window altitude - Flashing amber PFD altitude box and tone. The flashing amber altitude box will reset when the aircraft returns to the set altitude or a new altitude is selected.

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

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

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

FMA Fault Annunciations

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

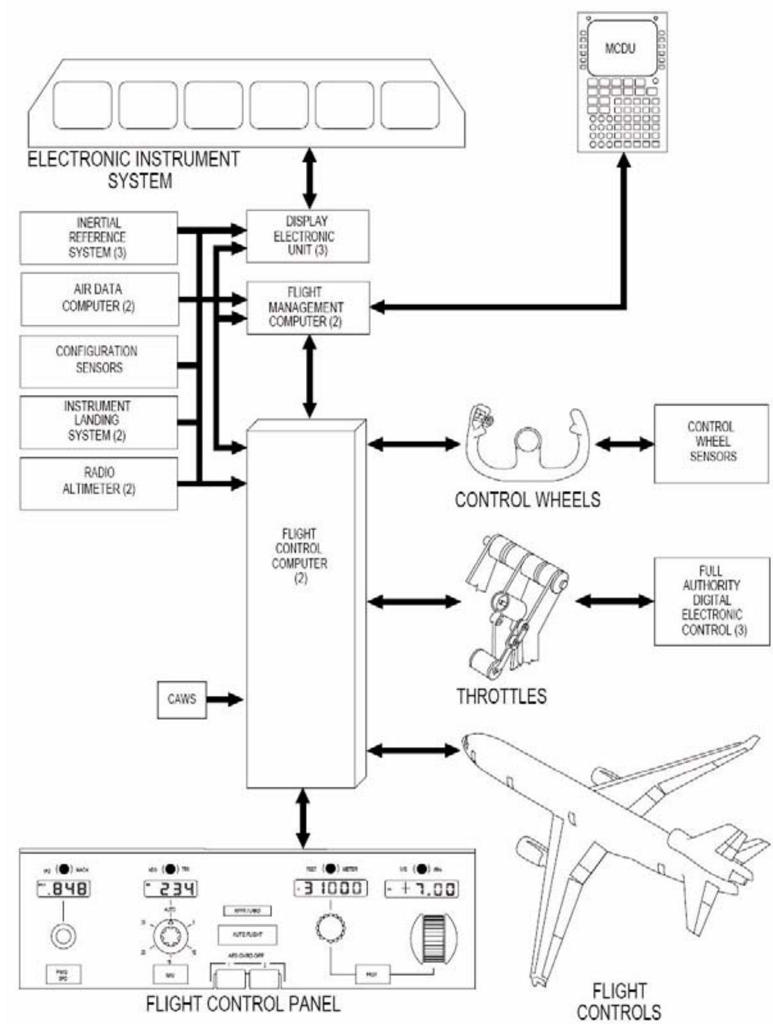
When the autopilot or autothrottle is not engaged, the box and label are white if they are available and amber if not available. For normal autopilot operation, AP1 is shown when FCC1 autopilot is in control, AP2 when FCC2 autopilot is in control, or AP when both autopilots are engaged for DUAL LAND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

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

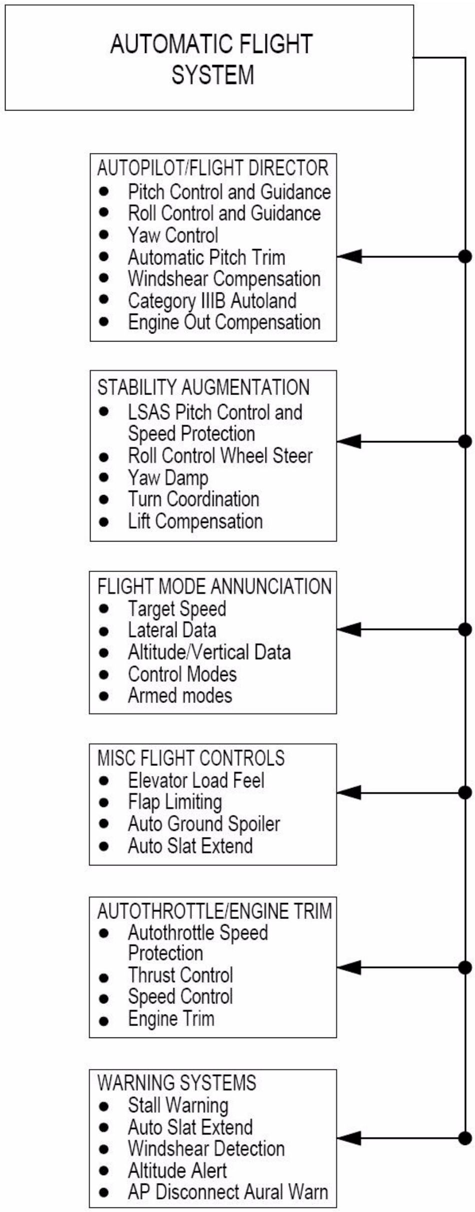
- Selecting a FCP speed within ATS control envelope.
- Disconnecting and/or re-engaging autothrottle within the normal speed envelope.
- Selecting level change, V/S, FMS SPD or FMS PROF within the normal speed envelope.

Components

Major Components

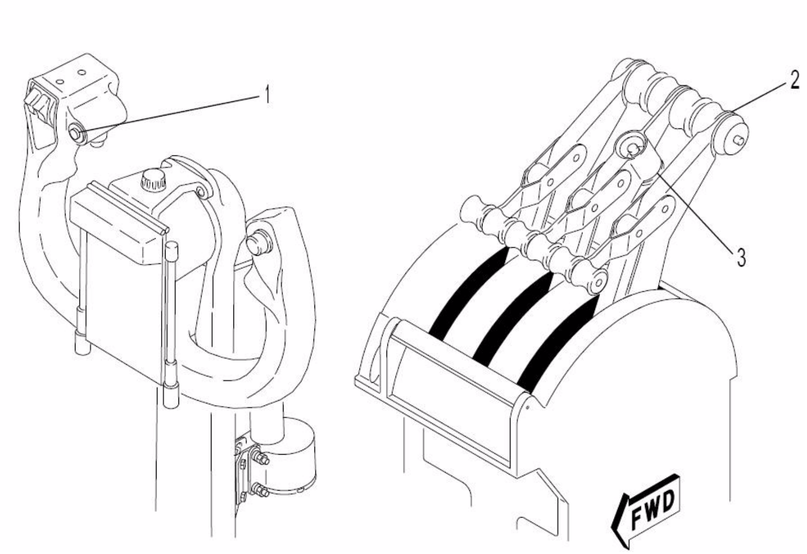


Automatic Flight System Functions Chart



Controls and Displays

AP, ATS Disconnect and GA Switches



1. AP Disconnect Switches (2)

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

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

2. ATS Disconnect Switches (2)

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

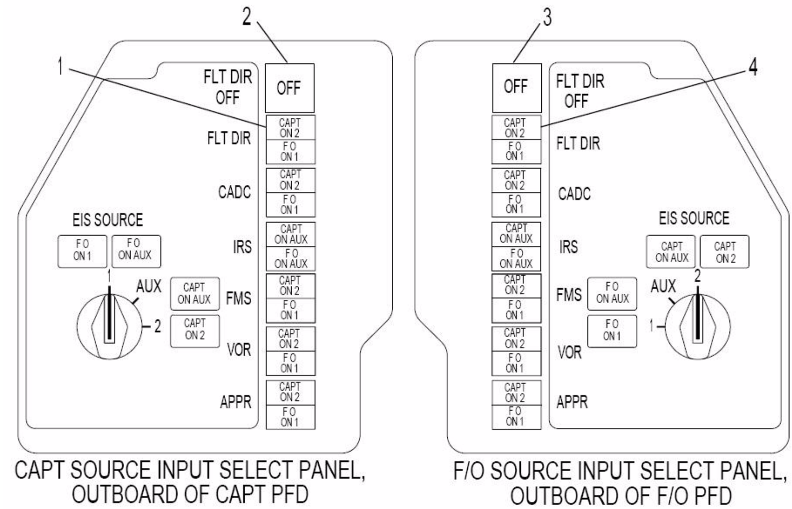
3. GA Switch

- Pushing during approach conditions (RA less than 2500ft and flaps or slats down) causes:
- FDs pop up to go-around mode even if selected off
- If AP on, AP will follow FS commands
- ATS Goes to go-around limits
- Parallel rudder active (in case of engine failure)
- Bank angle limited to 10 degrees
- Reference speed and PITCH appears on FMA
- GO-AROUND appears in altitude window
- Exits LAND mode (if engaged or armed)
- Windshear pitch guidance provided if windshear warning active. WINDSHEAR will appear in FMA speed and altitude windows.

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

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

Flight Director Switches



1. Captain's FLT DIR Switch - amber

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

2. Captain's FLT DIR OFF Switch - amber

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

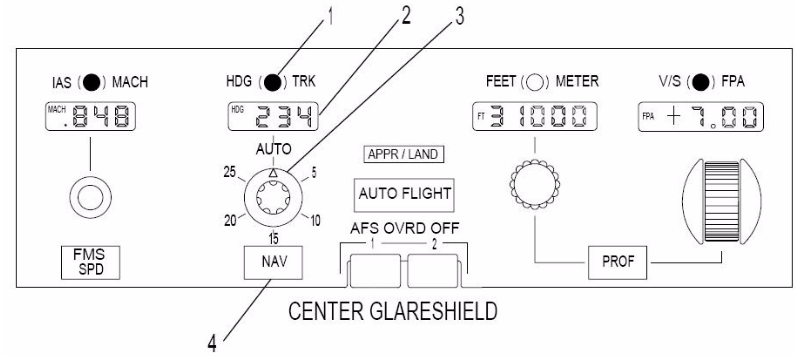
3. First Officer's FLT DIR OFF Switch - amber

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

4. First Officer's FLT DIR Switch - amber

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

Heading/Track Controls and Display



1. HDG/TRK Changeover Button

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

2. HDG/TRK Display Window

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

3. HDG/TRK and Bank Angle Limit Selectors

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

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

Pull to select:

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

Push to hold:

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

Bank Angle Limit Selector (Outer Knob) -

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

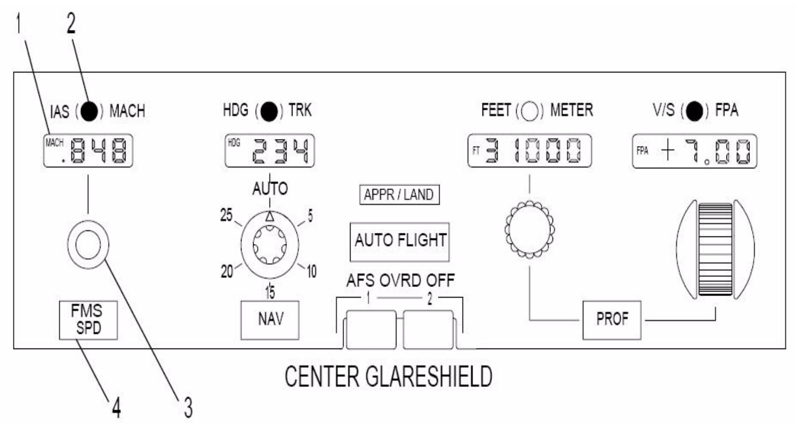
4. NAV Switch

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

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

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

Speed Controls and Displays



1. IAS/MACH Display Window

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

2. IAS/MACH Changeover Button

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

3. IAS/MACH Select Knob

   Turn to preselect:

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

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

   Pull to select:

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

   Push to hold:

   - Disengages FMS speed mode (if engaged)

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

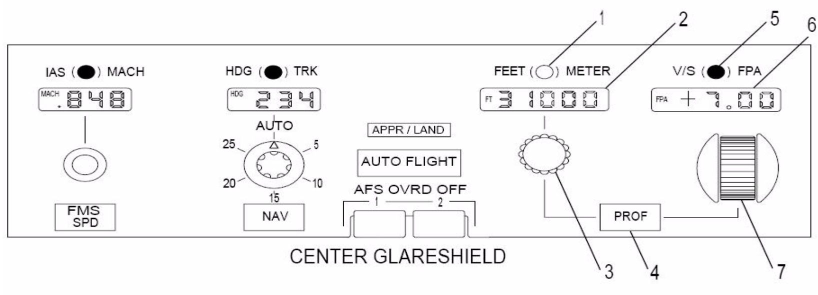
4. FMS SPD Switch

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

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

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

Altitude Controls and Display



1. FEET/METER Changeover Button

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

2. Altitude Display Window

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

3. Altitude Select Knob

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

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

Turn to preselect:

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

Pull to select:

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

Push to hold:

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

4. PROF Switch

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

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

5. V/S-FPA Changeover Button

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

6. V/S-FPA Display Window

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

7. Pitch Wheel

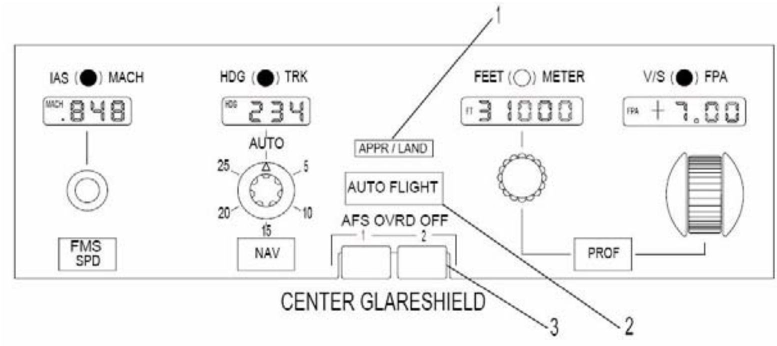
   Rapid rotation results in large changes in the display window. Slow rotation results in 100 fpm (or 0.1 degree) changes per detent. A vertical speed bug is positioned on the PFD vertical speed tape corresponding to the selected vertical speed.

   Roll to select:

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

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

APPR/LAND, AUTO FLIGHT, AFS OVRD OFF Switches



1. APPR/LAND Switch

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

2. AUTO FLIGHT Switch

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

   After AP engagement, each push alternates the AP between AP 1 and AP2. AP mode is always retained. AP1 or AP2 will appear on the FMA (top of PFD).

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

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

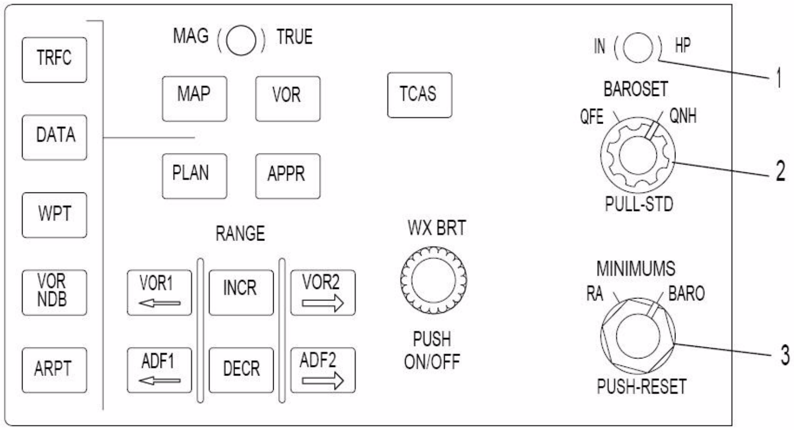
- AP 1 requires HYD system 2 for flight controls and HYD system 3 for auto pitch trim.
- AP2 requires HYD system 1 for flight controls and auto pitch trim.

3. AFS OVRD OFF Switches (2)

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

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

EIS Control Panel



GLARESHIELD, LEFT AND RIGHT SIDE

1. IN/HP Changeover Button

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

2. BARO SET Control Knob

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

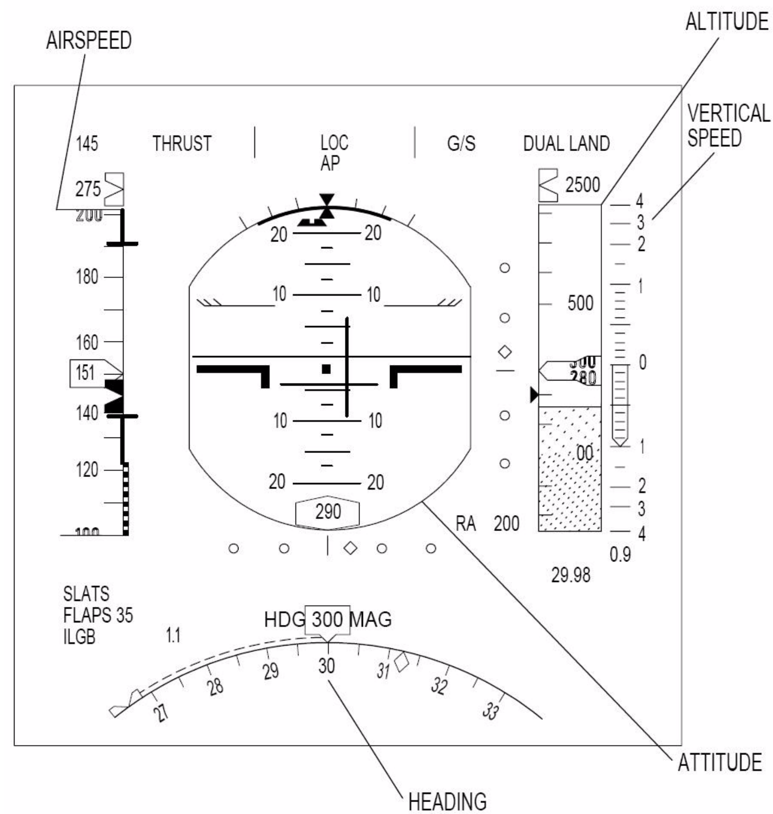
3. MINIMUMS Control Knob

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

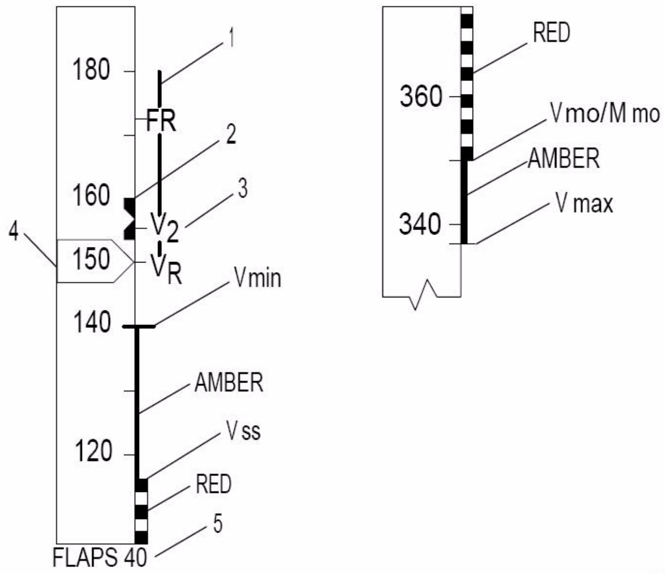
   The baro minimums bug is a solid triangle on the right side of the PFD altitude tape. To set the baro bug, turn the inner collar with the knob in BARO. BARO position during initial climb can cause nuisance aural warnings.

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

EIS Primary Flight Display (Typical)



PFD Airspeed Display



1. Airspeed Trend

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

2. Airspeed Bug

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

   If selected speed is set lower than Vmin, the white bug stops at Vmin and an amber reference bug will be at the selected speed.

   If selected speed is set lower than Vss, a red reference bug will be at the selected speed.

If selected speed is set higher than Vmo/Mmo, the white bug stops at Vmo/Mmo and a red reference bug will be at the selected speed.

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

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

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

3. Speed Bugs

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

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

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

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

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

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

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

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

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

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

4. Airspeed

Shown at the center of tape.

- Box and digits red - A/S below Vs or exceeds Vmo/Mmo
- Box and digits amber - A/S below Vmin or exceeds Vmax

Vss (from FMC) is the end of a red checker column.

Vmin (from FMC) is a line at the end of an amber column extending from Vss.

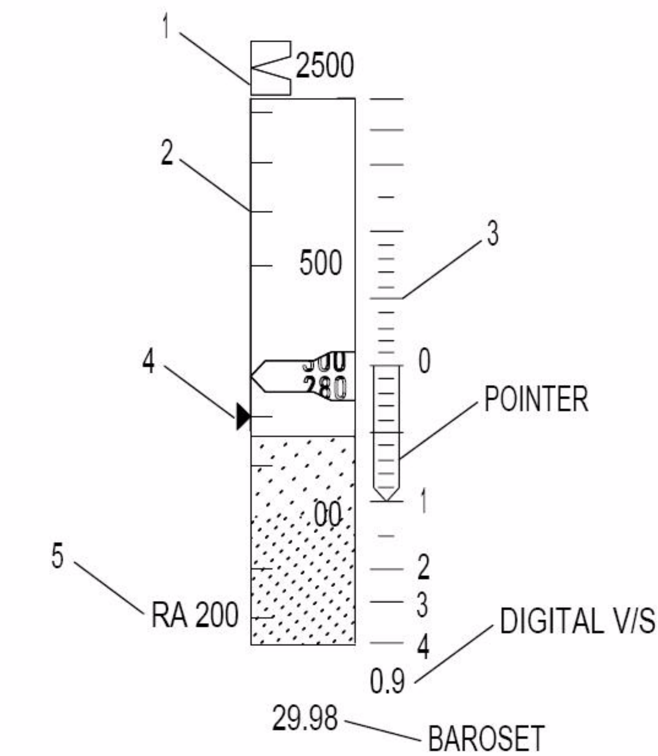
Vmo/Mmo (from ADC) is a line at the end of a red checker column extending from the high end of the tape.

Vmax is a line at the end of a narrow amber column extending down from Vmo/Mmo.

5. Flap/Slat

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

PFD Altitude/Vertical Speed Display



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

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

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

2. Altitude Tape

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

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

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

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

3. Vertical Speed

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

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

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

4. Minimum Bug

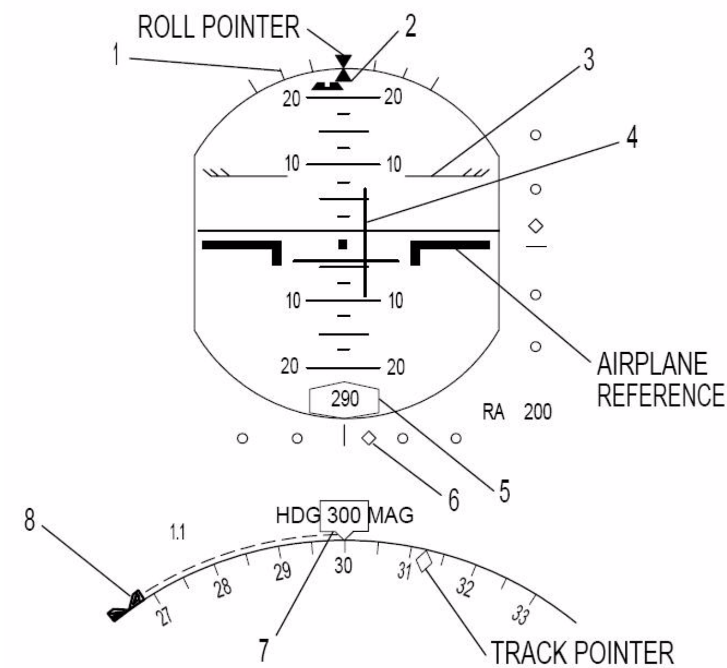
Solid triangle on the left is RA minimum bug. RA is set with the ECP MINIMUMS control knob in the RA position. This bug is white color (above minimum) or amber (below minimum).

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

5. Selected Minimum

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

PFD Attitude Displays



1. Roll Indice

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

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

2. Slip/Skid Indicator

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

3. Pitch Limit Indicator - cyan

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

4. Flight Director - magenta

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

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

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

5. Radio Altitude

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

   - At about 430 feet AGL, the RA box starts to move up so that the top of the box reaches the center of the attitude indicator at 0 feet RA for split-cue FD or bottom of airplane symbol for the single-cue FD.
   - An optional magenta T rising runway symbol for both single and double-cue FDs begins rising at 200 feet AGL and

moves laterally with the localizer. The symbol will flash for excessive localizer deviations (.27 dots). An E symbol on top of the RA box provides localizer deviation alignment.

6. ILS or MLS Deviation Pointer - magenta

   Moves against respective dot scale. Scales are blank until an ILS or MLS is tuned. Respective pointer turns amber and flashes for excessive deviation. Marker beacon passage is shown with a flashing circle I (white), M (amber), or O (cyan).

7. Heading

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

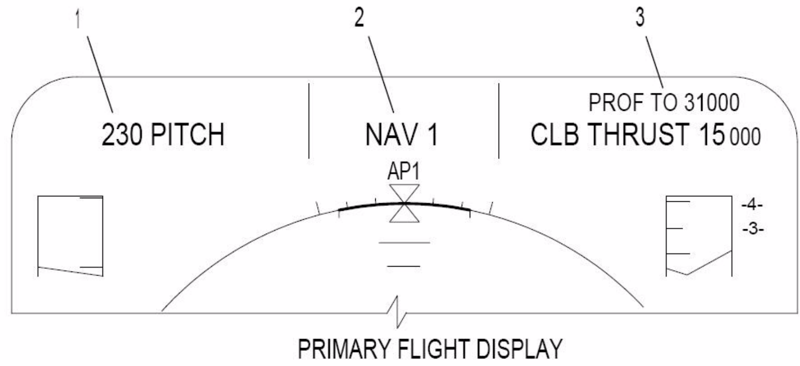
8. Heading Bug

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

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

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

Flight Mode Annunciator



1. Speed Control Window

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

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

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

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

2. Roll Control Window

   Shows what mode is controlling the aircraft roll axis. A digital value is displayed when in HDG or TRK mode. Engaged autopilot (AP1or AP2) is shown.

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

   If the mode changes due to an auto reversion, the new mode flashes 5 times. Armed modes are in small characters above the engaged mode.

3. Altitude Window

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

   If the mode changes due to an auto reversion, the new mode flashes 5 times. Armed modes are shown above the engaged mode.

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

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

FMA Control Window Modes

SPEED CONTROL MODES	TYPE	ANNUNCIATION	COLOR
FMS Descent	Engage	IDLE THRUST	Magenta
Speed on Pitch	Engage	PITCH	Magenta/White
Speed on Throttle	Engage	THRUST	Magenta/White
Throttle Retard	Engage	RETARD	White
Windshear FPA Control	Engage	WINDSHEAR	White
Lo Speed Protection	Armed/Engaged	LO SPEED PROTECTION	White
Hi Speed Protection	Armed/Engaged	HI SPEED PROTECTION	White

ROLL CONTROL MODES	TYPE	ANNUNCIATION	COLOR
Capture/Track VOR	Engage	VOR1 or VOR2	White
Capture/Track LOC	Engage	LOC ONLY	White
FMS Nav	Engage	NAV1 or NAV2	Magenta
Heading Hold or Select	Engage	HEADING _____	White
Track Hold or Select	Engage	TRACK _____	White
Landing Rollout	Engage	ROLLOUT	Green/White
Localizer	Engage	LOC	Green/White
Runway Alignment	Engage	ALIGN	Green/White
Takeoff Ground Roll	Engage	TAKEOFF	White
Over VOR	Engage	VOR 1 (or 2) CRS	White
FMS Nav Armed	Armed	NAV ARMED	Magenta
Land Armed	Armed	LAND ARMED	White
LOC Armed	Armed	LOC ARMED	White
VOR Armed	Armed	VOR ARMED	White

ALTITUDE CONTROL MODES	TYPE	ANNUNCIATION	COLOR
Takeoff Thrust	Engage	T/O THRUST	White/Magenta
Throttles Clamp	Engage	T/O CLAMP	White/Magenta
Climb w/Climb Thrust	Engage	CLB THRUST	White/Magenta
Altitude Hold	Engage	HOLD	White/Magenta
CLIMB w/MAX Contin Thrust	Engage	MCT THRUST	White/Magenta
Vertical Speed	Engage	V/S	White/Magenta
Flight Path Angle	Engage	FPA	White
FMS Prof Descent	Engage	PROF	Magenta
GA Thrust Mode	Engage	GO AROUND	White
Glideslope	Engage	G/S	White/Green
Dual Autoland	Engage	DUAL LAND	Green
Single Autoland	Engage	SINGLE LAND	White
No Land Mode	Engage	APPR ONLY	White
IIIA/B Autoland Flare	Engage	FLARE	White/Green
IIIA/B Autoland Rollout	Engage	ROLLOUT	White/Green
Level Change Descent	Engage	IDLE CLAMP	White
FMS Speed On Elevators	Engage	IDLE	Magenta
Next FMS Prof Alt	Armed	PROF TO	Magenta
PROF Armed On Ground	Armed	PROF ARMED	Magenta
Alt Chnge in Prof Mode	Armed	VERT ALERT	Magenta
Armed to Capture G/S	Armed	LAND ARMED	White
Windshear (GA Thrust) Mode	Engage	WINDSHEAR	White
CLIMB w/GA Thrust	Engage	GA THRUST	White/Magenta
CLIMB w/Cruise Thrust	Engage	CLB THRUST	White/Magenta

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

Alerts

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

Amber Alerts (Level 1)

- AUTOPILOT SINGLE (MISC) - Only one AP is valid.
- NO AUTOLAND (MISC) - Autoland mode is not available.
- ROLL CWS FAIL (MISC) - (If installed) Roll CWS is inoperative.
- SINGLE LAND (MISC) - Autoland availability is reduced from dual land to single land.

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Description and Operation

General

The MD-11 communications system consists of the following:

- VHF communications system
- HF communications system (not modeled)
- Communication Radio Panels (CRP)
- Audio Control Panels (ACP)
- Flight interphone system
- Service interphone/call system
- Passenger address (PA) system
- Selective Calling System (SELCAL) (not modeled)

Static dischargers on the trailing edges of the wing and tail surfaces dissipate static electricity that could interfere with communications and navigation. The wingtip and winglet dischargers also protect the aft wingtip lenses from lightning strike.

VHF Communications System

The VHF communications system consists of three separate, identical systems, designated VHF1, VHF2 and VHF3.

All of the three systems operate separately or simultaneously. The systems provide short-range line-of-sight communications in the 118.000 to 1 36.975-MHz frequency range. This allows communications between the airplane and ground and/or other airplanes.

The selection for the VHF communications system is controlled from any of three.

Communication Radio Panel

Three Communication Radio Panels (CRP) are installed on the aft pedestal to provide tuning of the communications systems.

The interface between CRPs allows tuning of the communications radios from any panel. Pushing one of the five radio select switches on the panel (VHF1, VHF2, VHF3, HF1 or HF2), illuminates the selected switch, and the associated ACTIVE and STBY frequencies are displayed. New frequencies are placed in the STBY memory and transferred to the ACTIVE mode by use of the transfer button.

The three CRPs can be used simultaneously, provided radio selection (VHF1, VHF2, VHF3, HF1, HF2) differs from another CRP. Only one radio may be selected on an individual CRP.

Audio Control Panel

Two Audio Control Panels (ACP) are installed on the aft pedestal and one is installed at the observer station.

The ACPs provide the following functions:

- Communication radio transmit and volume control
- Navigation radio ident and volume control
- Flight/service interphone transmit and volume control
- PA transmit and volume control (passenger and combi configurations)

Transmitting can be done using a handheld or boom microphone.

Flight Interphone System

The flight interphone is controlled by three ACPs.

Jacks for the boom and handheld microphone are installed at the Captain's, First Officer's, and right Observer's stations. A flight interphone jack is installed at the ground power receptacle and the nose landing gear.

Service Interphone/Call System

The service interphone/call system allows communications between the cockpit and cabin attendant/courier's stations and between the cockpit and maintenance service areas.

The service interphone/call panel is installed on the forward overhead panel in the cockpit.

The following service interphone operations are possible through the handset:

- The cockpit can call either a selected cabin attendant station, all cabin attendant stations, the courier station (freighter) or the maintenance service area.
- Each cabin attendant station can call a selected cabin attendant station or the cockpit. The courier's station (freighter) can call the cockpit.

Switches (AFT ATTND, FWD ATTND, MID ATTND, OWING ATTND, and ALL) on the forward overhead panel (passenger and combi configurations) permit calling a selected cabin attendant station pair or all cabin attendant stations simultaneously. Switches at each cabin attendant station permit calling a selected cabin attendant station pair or the cockpit. A button is installed at the external ground power receptacle to permit the mechanic to call the cockpit.

A call from the cabin attendant/courier's station to the cockpit causes the following:

- Actuation of a call chime in the cockpit
- Illumination of CALL on the ACP CAB MIC/CALL switch
- Illumination of a light on the service interphone/call panel identifying the calling station pair

A call from the ground power panel to the cockpit causes the following:

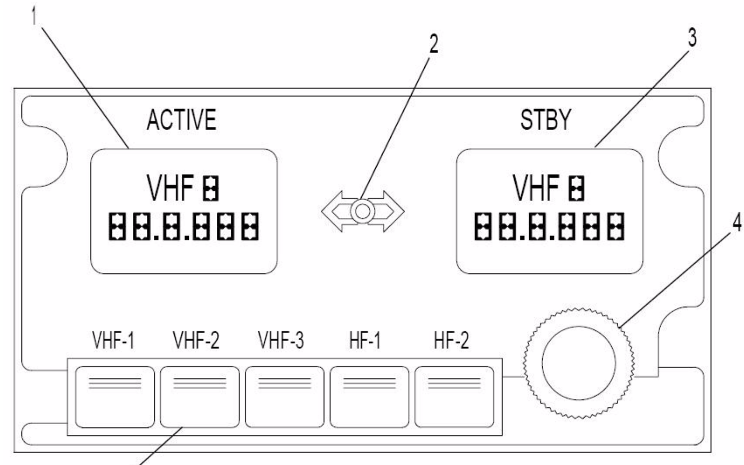
- Actuation of a bell in the cockpit
- Illumination of MECH on the ACP MIC/MECH switch

- Illumination of CALL on the service interphone/call panel MECH/CALL light

The call system can be reset from any station or the cockpit by pushing the CALL RESET button. The system resets automatically when the handset is returned to its hanger or a microphone is keyed on the appropriate interphone.

Controls and Displays

Communications Radio Panel



AFT PEDESTAL, 2 ON LEFT 1 ON RIGHT

1. ACTIVE Window

   Displays the active frequency and selected radio.

2. Transfer Button

   Push to transfer the STBY frequency to the ACTIVE window for transmission. STBY frequencies cannot be transmitted until transferred to ACTIVE window.

3. STBY Window

   Displays the standby frequency and selected radio.

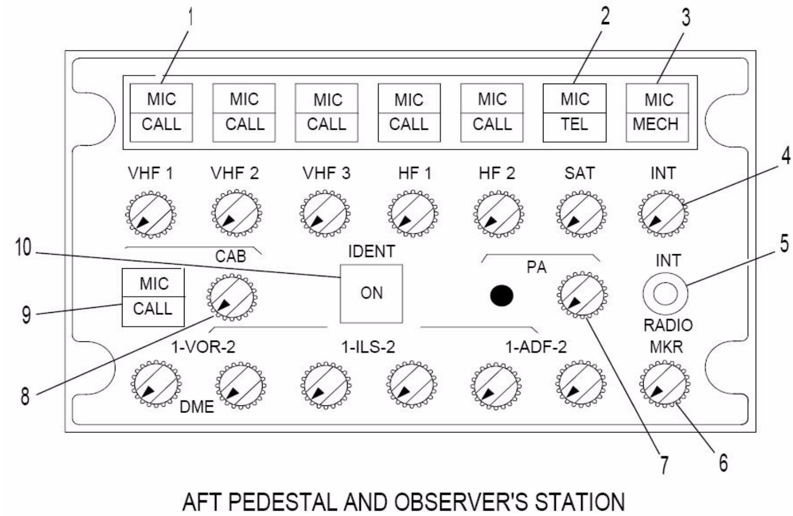
4. Frequency Selector

   Turn knobs to select frequency in STBY window only

5. Radio Selector Switches (5) - white

   Push to select respective radio. Switch illuminates white. Selected radio is displayed in the STBY/ACTIVE window

Audio Control Panel



1. Navigation Radio MIC/CALL Switches (5) - white
   - MIC - Illuminates white when a navigation radio system MIC/CALL switch is pushed. Radio transmission is enabled for that system.
   - CALL - If flashing, a call is being received on the radio system indicated below the flashing light.
2. MIC/TEL Switch - white
   - MIC - Illuminates white, with SATCOM installed and voice enabled, when pushed to transmit via SATCOM.
   - TEL - Flashes blue and a tone sounds when an incoming/ outgoing SATCOM transmission is initiated. With MIC pushed to transmit, air to ground transmission is connected, TEL illuminates steady blue. When transmission is disconnected, TEL extinguishes.

   Pushing either RADIO PTT switch enables transmission through either the boom microphone or the oxygen mask microphone.

3. MIC/MECH Switch - white
   - MIC - Illuminates white when pushed, enabling communication with outside maintenance personnel through the external flight interphone jacks.
4. Communication Receiver Volume Control Knobs (7)

   All volume control knobs on the ACP are illuminated and protrude out with a white band at the base when pushed on. The knobs are used to control the volume of the selected radio.
5. INT/RADIO Switch

   Not modeled
6. Navigation Receiver Volume Control Knobs (7)

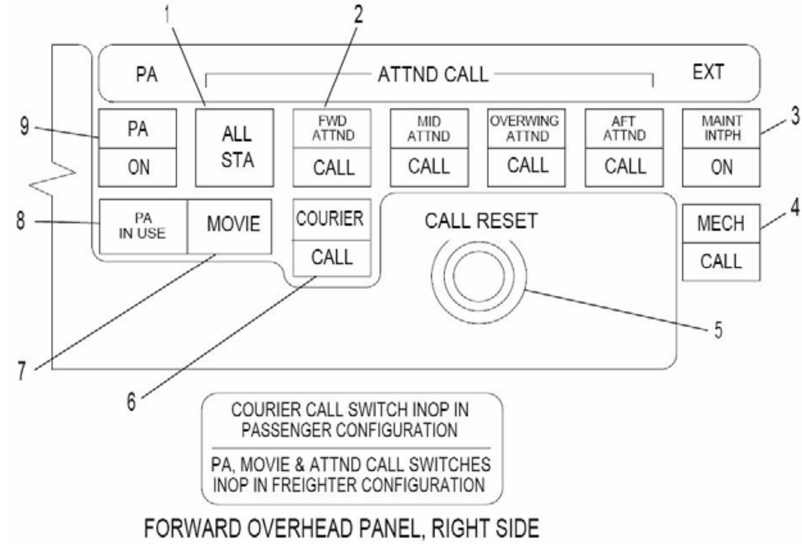
   The knobs control the audio of the NAV systems designated above or below the selected knob. For an operational description of the VOR 1/2, ILS 1/2, ADF 1/2, MKR, and DME systems refer to the Instrumentation and Navigation chapter.
7. PA Button

   Not modeled
8. CAB Volume Control Knob

   Controls cabin/service interphone volume.
9. CAB MIC/CALL Switch - white

   Not modeled
10. IDENT Switch - white
    - ON - Illuminates white when pushed. Enables voice and coded identification of DME, VOR, ADF, and ILS navigation receivers.

Service Interphone Call Panel - Passenger and Combi



1. ALL STA Switch - white

   Switch illuminates white when the system is powered.

   Push to call all cabin attendant stations. Use aft pedestal handset to talk.

2. CALL Switches - white/blue

   - CALL - Illuminates blue when a call is made to the cockpit. Station identifier illuminates white when the system is powered.

   Push the respective switch to call a station. Use aft pedestal handset to talk.

3. MAINT INTPH/ON Switch - white/amber

   - MAINT INTPH - Illuminates white when the system is powered.
   - ON - Illuminates amber when the switch is pushed to connect the maintenance interphone jacks to the service interphone system.

4. MECH/CALL Switch - white/blue

   Pushing the switch momentarily sounds the mechanic call horn. MECH - Illuminates white when the system is powered.

   - CALL - Illuminates blue when ground personnel push the PILOT'S CALL button on the ground service panel.

5. CALL RESET Button

   - CALL RESET - Push to extinguish the CALL light on all attendant switches.

6. COURIER/CALL Switch - white/blue

   The placard and the COURIER/CALL switch are installed in the combi configuration only. Pushing the switch illuminates the CALL light at the courier station.

   - COURIER - Illuminates white when the system is powered.
   - CALL - Illuminates blue when a call is made from the courier station. The aft pedestal handset is used for communication.

7. MOVIE Light - blue

   The MOVIE light operates only on airplanes with an installed video system. MOVIE - Illuminates blue when a video movie is in progress.

8. PA IN USE Light - blue

   - PA IN USE - Illuminates blue when the PA system is in use on the airplane.

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Description and Operation

General

The AC and DC electrical systems are normally powered by three engine driven Integrated Drive Generators (IDG). They may also be powered by an Auxiliary Power Unit (APU) generator, or an external source through two external power receptacles (main and galley).

The main external power plug connects external power to the main aircraft buses. The galley external power plug connects external power to the galley buses.

During emergency operation the Captain's and First Officer's flight essential equipment may be powered by a battery and by an Air-Driven Generator (ADG).

Distribution and control is normally done automatically by the Generator Control Units (GCU) and the Electrical Power Control Unit (EPCU). In case of failure of the automatic system the flight crew can control the electrical system manually with controls on the forward overhead panel.

Due to the design of the electrical system, there are no special procedures for operation in the manual mode.

The EPCU transmits system status and alerts to the Engine and Alert Display (EAD) and the System Display (SD).

AC Power

Integrated Drive Generator (IDG)

During ground operations, ac power is supplied by two external power sources, the APU generator, or by one or more of the three engine driven IDGs.

Each IDG is attached to each engine accessory gearbox by means of a Quick Attach/Detach (QAD) adapter.

The IDG consists of a hydromechanical Constant Speed Drive (CSD) and an oil cooled generator mounted side by side in a common housing. The CSD portion of the IDG converts variable input speed from the engine accessory gearbox to a constant output speed. This constant output speed drives the generator portion of the IDG producing a constant 400-Hz frequency output.

The IDG will function paralleled or isolated.

Each IDG is able to supply sufficient power for operation of all essential electrical systems.

APU Generator

The APU generator is installed in the tail section and provides electrical power for ground operations. The APU also serves as a supplemental electrical power source when required in certain flight phases.

The APU generator does not have a CSD. The APU is governed to drive the generator at the correct speed.

External Power

The main external power receptacle is on the ground power panel near the nose of the aircraft. It connects external power onto the ac generator buses through the Bus Tie Relay-External Power (BTR-EP), the External Power Relay (EPR) and associated Bus Tie Relays (BTR). Main external power will not power the galley buses.

Additionally, on passenger and combi aircraft, a galley external power receptacle (on ground power panel) connects external power onto the galley buses through galley transfer relays (GTR) 1, 2, and 3.

AC Distribution

Three independent ac generator buses distribute power to the aircraft ac buses and Transformer Rectifier (TR) units. Each IDG assumes the loads on its respective ac generator bus through its own independent supply network.

Paralleling of the ac generator buses is accomplished automatically through the ac tie bus. This allows assumption of electrical loads by any functioning IDG.

The APU generator can power any of the ac buses through its own independent supply network.

A time limited emergency ac source is available to the left emergency ac bus through the battery/inverter combination. The ADG may be used to power the right emergency ac bus. The left emergency ac bus may also be powered by the ADG for long term use.

The ac generator buses and the ac ground service bus supply most of the centrally located and/or high current loads (hydraulic pumps, most fuel pumps, ac buses, and galley power). Power for lower current, non-centrally located loads and essential loads is supplied through the three ac buses, cabin ac buses, ground service buses, and the two ac emergency buses. Instrument buses supply their respective component loads.

The ac ground service bus distributes power to those components essential to ground servicing operations. The APU generator or main external power can be connected to the ac ground service bus without energizing any of the other ac generator buses. This allows ground servicing of the aircraft without having to energize the whole electrical power distribution system. The ac ground service bus is powered by ac generator bus 2 in flight.

No Break Power Transfer (NBPT) and Parallel Operation

A complete NBPT system is provided on the aircraft. Power transfers between external power, APU generator, and IDG electrical power will normally occur without a power interrupt. If the two power sources cannot be synchronized closely, a break power transfer will occur.

Non-interrupted electrical power is supplied to the aircraft buses by momentarily paralleling alternate electrical power sources before the power transfer occurs. The power source with the highest priority (or selection) momentarily parallels with the lower priority power source before the lower priority power source is disconnected from the bus.

When the electrical power source is available and selected on, the power source priority for the ac generator bus is as follows:

- Associated IDG
- APU generator
- The ac tie bus (external power or IDG)

When the electrical power source is available and selected on, the power source priority for the ac tie bus is as follows:

- External power
- Any IDG

For example, no break power transfer will occur automatically when the IDGs can no longer power the buses after engine shutdown. If both APU and EXT power are available, the APU has the higher priority and will supply electrical power to the buses. On APU shutdown, external power, if available, will take over.

Momentary paralleling between IDG, APU generator, and external power is completely automated through the GCUs and EPCU once the flight crew has selected the respective power source on or off.

Except for dual land operation and external power on the tie bus, the IDGs will normally operate in the parallel mode. Parallel operation of the IDGs is also completely automated through the GCUs and the EPCU.

Generator Control Units (GCU)

The respective GCU (1, 2, 3, and APU) controls the following:

- GR 1, 2, and 3
- BTR 1, 2, and 3
- IDG disconnect (crew command)

- DC ties 1 and 3
- NBPT from APU generator to external power
- NBPT from APU generator to IDG
- NBPT from IDG to EXT power across BTR 1, 2, and 3
- NBPT from external power to IDG

The respective GCU (1, 2, 3, and APU) regulates the following:

- IDG and APU generator voltage
- IDG frequency and current limit
- IDG load control

Each GCU (1, 2, 3, and APU) protects its respective generator from electrical faults.

The respective GCU (1, 2, 3, and APU) provides automatic operation of:

- IDG reset due to generator protective trips
- AC generator bus 1, 2, and 3 fault reset
- Maintaining IDG oil temperature and pressure indication for IDG fault indicating.

Electrical Power Control Unit (EPCU)

The EPCU controls the following:

- EPR
- BTR-EP
- Ground Service Relay (GSR) - external power position
- Auxiliary Power Relay (APR) 1, 2, and 3
- Load shedding
- APU N2 speed for APU NBPT operation
- NBPT from external power to APU generator
- NBPT from IDG to external power across BTR-EP
- NBPT from IDG to APU generator
- DUAL LAND mode electrical system configuration
- Electrical Power System (EPS) operating mode
- EPS parameter transmission to EIS
- EPS fault transmission to the CFDS
- Frequency reference for GCU 1, 2, and 3
- If galleys are installed, Galley Transfer Relay (GTR) 1, 2, and 3

The EPCU provides protection for the following:

- Main external power phase sequence
- Main external power over/under voltage
- Main external power over/under frequency
- Main external power feeder fault
- ac tie bus fault
- If galleys are installed, galley external power voltage, frequency and phase sequence

The EPCU provides automatic operation of the following:

- APU generator reset for incorrect voltage, frequency or feeder faults
- Emergency power transfer
- Smoke procedure

Protection for ac bus, galley bus, and equipment feeder faults is provided by individual Remote Control Circuit Breakers (RCCB), Circuit Breakers (CB), or fuses.

If galleys are installed, feeder fault and overload protection for the galley buses is also provided by the Galley Load Control Units (GLCU).

DC Power

Transformer Rectifier (TR) Units

Four 75-amp TRs provide dc power to the aircraft dc buses (includes the battery bus). The TRs convert 115-volt ac power into 28-volt dc power. The battery and/or the ADG (through TR 3) may be used as emergency dc power sources.

DC Distribution

Four dc tie RCCBs are normally closed for parallel dc operation. This ensures all dc loads are supplied power during start up, normal operation, shutdown, and abnormal conditions.

An RCCB is used to connect each of the TRs to a common tie bus. This dc bus arrangement allows supplying any single load from any one of the TRs.

If isolated, the four TRs receive ac power from the following ac buses:

- TR 1 receives power from ac generator bus 1
- TR 2A receives power from ac generator bus 2
- TR 2B receives power from the flight compartment ac ground service bus

- TR 3 receives power from the right emergency ac bus

Emergency Power

The emergency power system consists of one main battery, a battery charger, a manually deployed ADG, and a static inverter.

The main battery is a 28-volt dc battery consisting of two 14-volt dc halves.

The battery charger converts ac input into a controlled dc output to keep the battery fully charged. Battery power is supplied directly to the battery direct bus. The battery can provide power to the left emergency ac and dc buses whenever the left emergency ac or dc bus loses power. The battery direct bus is powered at all times.

The ADG is an air cooled, turbine generator that consists of an air turbine unit, brushless generator, and voltage regulator.

A static inverter inverts battery dc power into ac emergency power for the left emergency ac bus.

With the EMER PWR selector in the ARM position and the BAT switch in the ON position (emergency power armed), the left emergency ac and dc buses will automatically transfer to main battery power when either the left emergency ac or dc bus is de-energized (emergency power on).

With emergency power on and the ADG deployed, the ADG will supply electrical power to:

- The left emergency ac bus and auxiliary hydraulic pump 1 when the ADG ELEC switch is in the OFF position (battery supplies the left emergency dc and battery bus).
- The left emergency ac bus, left emergency dc bus, right emergency ac bus, right emergency dc bus, battery bus, and the battery charger when the ADG ELEC switch is in the ON position (battery is charged by the battery charger).

This arrangement will allow the battery and ADG to provide emergency electrical power to the Captain's flight essential equipment during an all engines failed situation, or it will allow the ADG to provide non-time limited emergency power to the Captain's and First Officer's flight essential equipment during an all generators failed situation.

During an all engines failed situation, or an all generators failed situation, the battery alone (without the ADG) will supply approximately 15 minutes of emergency electrical power to the Captain's flight essential equipment.

EIS Test Display

All ELECTRICAL synoptic data digits will be crossed out with amber Xs when all of the conditions are met as follows:

- The aircraft is on the ground
- The aircraft is operational
- The ANNUN LT TEST button on the forward overhead panel is pushed
- The ELECTRICAL synoptic has been selected to appear on the SD

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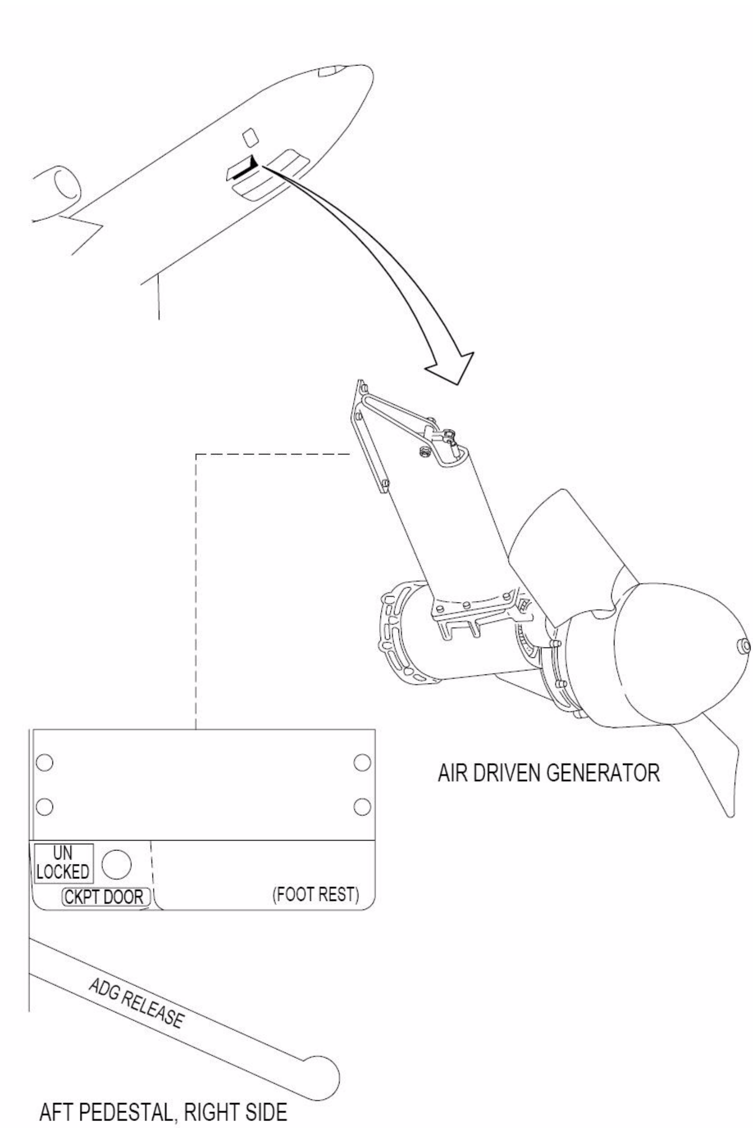
Components

Air Driven Generator



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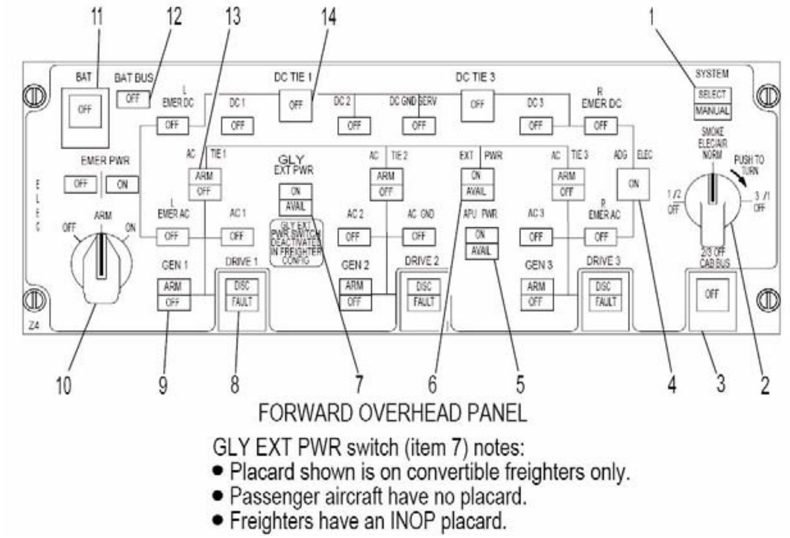
Controls and Displays

Electrical Control Panel



1. SYSTEM SELECT/MANUAL Switch - amber

   This is an alternate action switch that allows selection between manual and auto modes.

   - SELECT illuminates amber if the electrical system reverts from auto to manual. In this case, the SEL ELEC SYS MAN alert will be on the EAD and the crew should push this switch to extinguish the SELECT light.
   - MANUAL illuminates amber if the system is in manual.
   - MANUAL flashes amber if the system is in auto and a switch on the ELEC control panel has been pushed that has no effect in auto.

2. SMOKE ELEC/AIR Selector

   This selector controls the electrical and air smoke isolation functions when the system is in auto or manual mode.

- NORM - All gen relays, aux pwr relays, bus tie relays, and dc tie RCCBs are in normal auto or manual mode. Air system operation is normal.
- 3/1 OFF - Gen relay, aux pwr relay, bus tie relay and dc tie 3 are open. Gen channel 3 is unpowered, ECON mode and galley bus 3 is unpowered. Pack 1 and air supply 1 turn off and EIS CRTs go full bright.
- 2/3 OFF - Gen relay, aux pwr relay, bus tie relay, and dc tie 3 return to state prior to SMOKE switch operation. When gen channel 3 is again powered, gen channel 2 becomes unpowered. Galley bus 3 is again powered and galley bus 2 is unpowered. Gen relay, aux pwr relay, and bus tie relay 2 are open. Pack 1 and air supply 1 are reinstated. Pack 3 and air supply 3 are turned off.
- 1/2 OFF - Gen relay, aux pwr relay, bus tie relay 2 return to state prior to SMOKE switch operation. When gen channel 2 is again powered, gen channel 1 becomes unpowered. Galley bus 2 is again powered and galley bus 1 is unpowered. Gen relay, aux pwr relay, bus tie relay, and dc tie 1 are open. Automatic transfer or emer pwr is inhibited. Pack 3 and air supply 3 are reinstated. Pack 2 and air supply 2 are turned off.
- NORM - Gen relay, aux pwr relay, bus tie relay, and dc tie 1 return to state prior to SMOKE switch operation. Turns on pack 2 and air supply 2. Returns ECON mode and galley bus 1 to normal operation. EIS CRTs return to auto brightness control.

3. CAB BUS OFF Switch - amber

   This switch is a guarded alternate action switch that opens the RCCB bus feeds to the following buses when the system is in auto or manual.

   Passenger and Combi

   - Cabin ac buses 1 and 3.
   - Fwd and mid cabin ground service buses.

- Overwing and aft cabin ground service buses.

Freighter

- Cabin ac ground service bus.
- Cargo loading bus.

With the CAB BUS OFF light illuminated, power is removed from all cabin buses, including galley buses.

4. ADG ELEC ON Switch - amber

   This switch is an alternate action switch that is used after ADG deployment. Operation is the same in auto or manual.

   - OFF - electrical power is supplied to the aux hydraulic pump. If emergency power is on, power will also be supplied to the left emergency ac bus.
   - ON - electrical power is supplied to the right and left emergency ac buses, right and left emergency dc buses, battery charger, and battery bus.

5. APU PWR ON/AVAIL Switch - blue/green

   The APU PWR switch is a momentary contact switch that starts the APU from the ELEC panel and supplies electrical power to any generator bus. Switch operation is the same in manual or auto mode. Pushing the APU PWR switch starts the APU. If the APU was started by the APU START/STOP switch, it cannot be stopped with this switch.

   When this switch is used to start the APU, AVAIL will flash green until APU reaches 95 percent N2. AVAIL will illuminate steadily when APU power is correct. If APU power is not correct, AVAIL light will extinguish.

   - ON illuminates blue when any APR is closed.

6. EXT PWR ON/AVAIL Switch - blue/green

   The EXT PWR switch is a momentary contact switch that supplies external power to the main aircraft buses when the system is in the auto or manual mode.

- AVAIL illuminates green when external power is available. Main external power plug must be correctly seated to receptacle and correct signal must be received by the electrical power control unit.
- ON illuminates blue when the bus tie relay-external power is closed. If an incorrect signal is received by the electrical power control unit, power receptacle is improperly seated, or switch is pushed while in the ON position, external power is disconnected and ON extinguishes.

7. GLY EXT PWR ON/AVAIL Switch - blue/green

   The GLY EXT PWR switch is a momentary contact switch that supplies external power to the galley buses when the system is in the auto or manual mode. This switch is inoperative on freighters.

   - AVAIL illuminates green when galley external power is available. Galley external power plug must be correctly seated to receptacle and correct signal must be received by electrical power control unit.
   - ON illuminates blue when galley external power is selected on. If an incorrect signal is received by the electrical power control unit, power receptacle in improperly seated, or switch is pushed while in the ON position, galley external power is disconnected and ON extinguishes.

8. DRIVE 1/2/3 DISC/FAULT Switch - amber

   The generator DRIVE switch (guarded) is a momentary contact switch that disconnects the IDG through the generator control unit when the system is in auto and manual mode.

   - FAULT illuminates amber when a situation requiring an IDG disconnect has occurred.
   - DISC illuminates amber when an IDG disconnect has taken place. DISC extinguishes when the light illumination logic is reset through the CFDS interface with the EPCU or after the IDG input spline is mechanically reconnected and the engine is run up to about ground idle.

CAUTION: Do not disconnect an IDG with engine speed less than ground idle. Disconnecting an IDG with engine speed less than ground idle will cause damage to the IDG input shaft and seal.

9. GEN 1/2/3 ARM/OFF Switch - blue/amber

   The GEN switch is a momentary contact switch that resets the respective generator when the electrical system is in the manual mode. Switch has no effect if system is in auto mode.

   - OFF illuminates amber when the generator control relay is tripped open.
   - ARM illuminates blue by pushing the GEN switch from the off position. This initiates a generator control unit to close the generator relay when the generator power is correct. Switch position automatically reverts to OFF when a protective trip of the generator relay occurs in the ARM/reset position. When ARM is illuminated, the generator control relay is closed and the generator relay is open.

   The GEN switch is blank when the generator relay is closed.

10. Emer Pwr OFF/ARM/ON Selector and OFF/ON Light - amber

    The EMER PWR selector is a three position selector. It operates when the system is in the auto or manual mode as follows:

    With the selector in the OFF position the main battery is not allowed to supply power to the left emergency ac and/or dc bus. OFF will illuminate amber.

    With the selector in the ARM position the main battery is automatically transferred to the left emergency ac or dc bus when the system conditions are correct. ON will illuminate amber upon transfer. Conditions required for an automatic transfer are:

    - BAT switch in ON position.

- SMOKE ELEC/AIR Selector not in 1/2 OFF position (Generator channel 1 de-energized).
- Left emergency ac or dc bus de-energized.

With the selector in the ON position, the left emergency ac and dc buses are transferred to battery power. ON will then illuminate amber.

If this selector is in ARM when the aircraft electrical power is shutdown, the emergency circuits will remain activated, resulting in depletion of the aircraft batteries.

NOTE: If emergency power automatically transfers ON and then normal power is restored, this selector must be cycled OFF and back to ARM to allow the L emer buses to be powered by the main generator bus. If this is not done, the L emer buses will continue to be powered by the aircraft batteries.

11. BAT OFF Switch - amber

The BAT switch is a guarded, alternate action switch that disconnects the battery from the battery bus and battery charger. This switch is normally on and operates the same when the system is in the auto or manual mode.

When the switch is on, battery charger is allowed to charge the main battery if:

- Battery power is not supplying the left emergency dc bus or (through the static inverter) the left emergency ac bus.
- Inverter powered ground refueling is not taking place.
- Transformer rectifier bus 2A or transformer rectifier bus 2B is energized or the ground service relay is closed into the APU or EXT PWR position.
- Ac power is present at battery charger input.

When the switch is on, battery is connected to the battery bus if:

- Transformer rectifier bus 2A and transformer rectifier bus 2B are not energized.

- Ground service relay is not closed into APU or EXT PWR position.

The switch illuminates amber when pushed into the OFF position. The battery is then disconnected from the battery bus and is not allowed to be charged by the battery charger. Automatic transfer of emergency power to the left emergency ac or dc buses is inhibited.

12. BAT BUS OFF Lights (13) - amber

Illuminates amber when associated ac or dc bus is deenergized. There is one light for each ac or dc bus.

13. AC TIE 1/2/3 ARM/OFF Switch - blue/amber

The AC TIE switch is a momentary switch that controls the respective bus tie relay when the system is in manual mode. Switch has no effect when the system is in auto mode.

- OFF illuminates amber when the respective bus tie relay is open and the AC TIE switch is in the OFF position. Related buses are then isolated from the ac tie bus.
- ARM illuminates blue when the respective bus tie relay is open and the AC TIE switch is in the ARM position. In ARM, bus tie relay is controlled automatically by the generator control unit.
- OFF and ARM extinguished indicates that the respective bus tie relay is closed.

Switch illumination is inhibited during dual land operation.

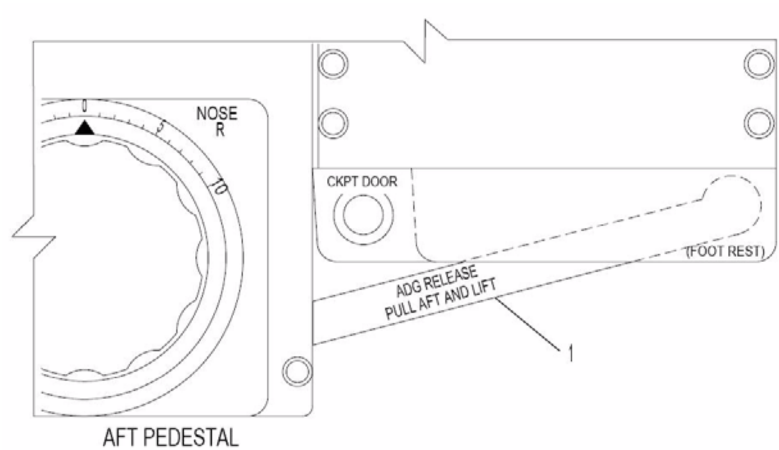
14. DC TIE 1/3 OFF Switch - amber

The DC TIE switch is a momentary switch that controls the respective RCCBs when the system is in the manual mode. Switch has no effect when the system is in auto mode.

- OFF illuminates amber when the respective RCCBs are open and the generator control unit is inhibited from closing the RCCBs. Pushing switch from the OFF position places it in the ON position and returns control to the generator control unit. Switch position will revert to OFF if the switch is pushed or a protective trip of the RCCBs occurs.

- OFF extinguishes when the RCCBs are closed.

ADG Handle



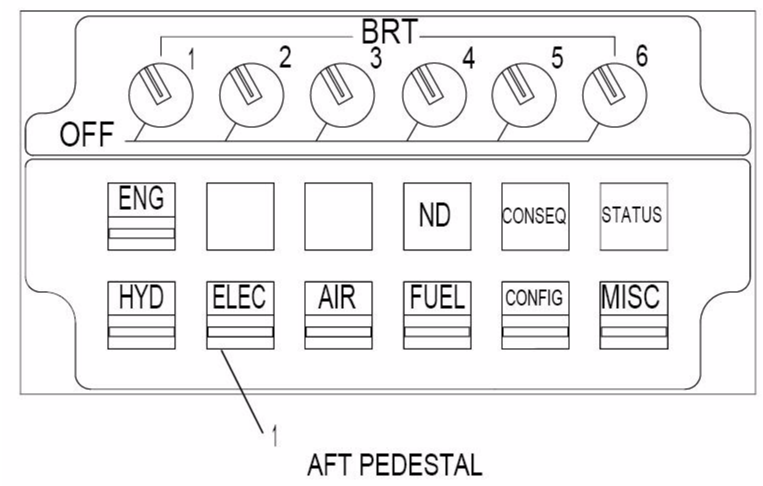
1. ADG Release Handle

   This handle deploys (by cable) the ADG. The handle is safety wired in the stowed position. Pulling the handle aft will break the safety wire. A swift upward motion will unlatch and deploy the ADG.

   When the ADG is fully out, an overcenter link locks the ADG in the deployed position and locks the handle in the up position.

   The handle operates in one direction only, to deploy the ADG. The ADG can only be retracted on the ground by maintenance personnel.

ELEC Cue Switch - white



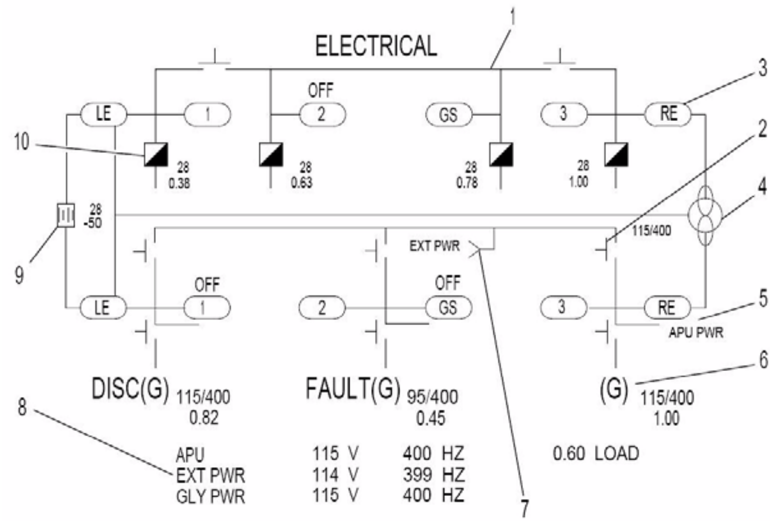
1. ELEC Cue Switch - white

   Illuminates white when an ELEC alert is displayed on the EAD. When pushed:

   - MASTER CAUTION or MASTER WARNING lights will extinguish.
   - Reminder message will replace EAD alert.
   - Synoptic and consequences come into view on SD.

   Some level 1 alerts are maintenance alerts that appear on the SD STATUS page only. These maintenance alerts will not illuminate the cue witch or the MASTER CAUTION lights

SD Synoptic



1. Schematic Lines

   Schematic lines representing power buses are shown as solid white lines at all times.

2. Relays

   Relays are shown green when closed and are white when open during normal operation. Relays are amber when open due to a fault.

3. Buses

   Buses are shown in green with the bus name inside in white. If off, the buses turn amber and OFF will appear in amber above the bus.

4. Air Driven Generator (ADG)

   The ADG and all connecting lines are shown in white. When in use, the ADG symbol is shown in green with its voltage and frequency shown to the left of the ADG symbol in white. If ADG voltage and/or frequency are out of limits, the associated parameter will be boxed and amber. If no valid data is available, the data will be removed.

5. APU Power

   APU PWR is shown only when APU power is available. APU PWR will be white with white lines connecting to the three bus lines receiving APU power. When APU power is in use on any bus, the text will turn green. APU voltage, frequency, and load are shown in white digits below the schematic. The APU voltage, frequency, and load parameters will be white during normal operation. The APU voltage and frequency parameters will be boxed and amber when any abnormal APU GEN OFF condition exists. The APU load parameters will be amber and boxed when an APU GEN LOAD HI condition exists. If no valid data is available it will be removed.

6. Generator (3)

   The ac generators are shown in green with their voltages, frequencies, and loads in white. The generator will turn amber and associated parameters will turn amber and boxed when a GEN OFF condition exists. The generator load parameters will be amber and boxed when a GEN LOAD HI condition exists. The ac generator symbol is shown in white when engines are off or during engine start-up or shutdown. If a fault requiring disconnect occurs, FAULT is shown at the side of the symbol in amber. When the generator is disconnected, FAULT is replaced by DISC. If no valid data is available, the data will be removed and replaced with an amber X.

7. Main External Power

   External power is available when a white EXT PWR is shown and it is connected to the buses receiving external power with white lines. When in use, EXT PWR will turn green. The external power voltage and frequency are shown in white below the APU data. If no valid data is available, the associated data will be removed from the screen. If external power is not available all associated displays are removed.

8. APU and EXT PWR

Associated voltage, frequency, and status are shown in white. If voltage and/or frequency are out of limits, the numbers are boxed and turn amber. If no valid data is available, it will be removed. GLY PWR not applicable on freighters.

9. Battery

The battery symbol is normally white with associated lines in white. The battery becomes green when emergency power is on. Battery voltage with the current load is shown in white next to the battery. The voltage turns amber and boxed, when out of limits. When emergency power is on, the battery load (amps) is shown next to the battery in white. If no valid data is available, the data will be removed and replaced with an amber X.

10. Transformer Rectifiers (TR)

Transformer rectifiers are normally shown in green but become amber when the TR fails. TR voltage and load digits are shown next to the TR symbol in white. If no valid voltage or load data is available, the associated data will be removed from the screen and replaced with an amber X.

Alerts

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

Amber Boxed Alerts (Level 2)

- BUS L EMER AC OFF (ELEC) - The left emergency ac bus is unpowered. BUS L EMER DC OFF (ELEC) - The left emergency dc bus is unpowered.
- GEN 1/2/3 OFF (ELEC) - Generator 1/2/3 fault (manual mode). A protective trip has occurred.
- GEN ALL OFF (ELEC) - No engine driven generator or APU generator is supplying electrical power. Fuel pressure to engine 2 may not be available. Without fuel tank pump pressure, engine 2 will probably flameout. If the ADG is deployed and ADG ELEC is on, the left aft pump in tank 2 can supply fuel pressure to engine 2. This pump will be powered from the right emergency ac bus. The tail tank alt pump can also be powered when the right emergency ac bus is powered.
- GEN BUS 1/2/3 FAULT (ELEC) - The respective generator bus has been de-energized. Fault exists.
- GEN DRIVE 1/2/3 FAULT (ELEC) - The respective generator drive oil temperature is high or pressure is low or oil differential temp is out of limits.

Amber Alerts (Level 1)

- AC TIE 1/2/3 OFF (ELEC) - If the respective AC TIE switch ARM light is illuminated, the relay has opened due to a fault. The system may be in auto or manual. If the respective AC TIE switch OFF light is illuminated, the relay has been commanded open by overhead panel switch action. The system may only be in manual. The OFF light will not illuminate in auto.
- AC TIE FAULT (ELEC) - The ac tie bus is inoperative. Relays are locked out.

- ADG ELEC SW ON (ELEC) - The ADG ELEC switch on the ELEC control panel has been selected ON.
- BAT CHARGING (ELEC) - The battery is being charged. Normally displayed for a short time following an APU start.
- LOW (ELEC) - Battery voltage is below limit.
- BAT SWITCH OFF (ELEC) - The BAT switch has been manually selected to OFF.
- BUS AC 1/2/3 OFF (ELEC) - The respective ac bus is unpowered or the associated sensing circuit has failed.
- BUS AC GND OFF (ELEC) - Ground ac bus is unpowered.
- BUS DC 1/2/3 OFF (ELEC) - The respective dc bus is unpowered or the associated sensing circuit has failed.
- BUS DC CABIN OFF (ELEC) - The cabin dc bus is unpowered or the associated sensing circuit has failed.
- BUS DC GND OFF (ELEC) - The ground dc bus is unpowered or the associated sensing circuit has failed.
- BUS R EMER AC OFF (ELEC) - The right emergency ac bus is unpowered or the associated sensing circuit has failed.
- BUS R EMER DC OFF (ELEC) - The right emergency dc bus is unpowered or the associated sensing circuit has failed.
- CABIN BUS SW OFF (ELEC) - The CAB BUS switch has been manually selected to OFF. This removes power from the cabin buses.
- DC TIE 1/3 OFF (ELEC) - When system is in auto, the associated relay has opened due to a fault. When the system is in manual, the relay has opened due to a fault or the relay has been commanded open by overhead panel switch action.
- ELEC SYS MANUAL (ELEC) - The electrical system is in manual mode.
- EMER PWR ON (ELEC) - Emergency power has been automatically commanded or manually selected on.

- EMER PWR SW OFF (ELEC) - EMER PWR selector has been manually selected to OFF.
- EMER PWR TST FAIL (ELEC) - The emergency electrical power preflight test has failed.
- GALLEY BUS OFF (ELEC) - One or more galley buses are not powered. To select galley bus power, the electrical system must be in manual mode. Does not apply on freighters.
- GEN 1/2/3 OFF (ELEC) - The respective generator is off. In auto mode, a protective trip and one auto reset attempt has occurred, or the generator has been commanded on but the generator relay has not closed or the generator is failed. In manual mode, the respective generator has been turned off by the flight crew.
- GEN DRIVE DISC (ELEC) - One or more of the generators has been disconnected.
- SEL ELEC SYS MAN (ELEC) - GCU or EPCU does not agree with position of select switch or there is a failure in the auto system.
- SMOKE SW IN USE (ELEC) - SMOKE switch on the ELEC control panel is out of the NORM position.
- TR 1/2A/2B/3 FAIL (ELEC) - The respective transformer rectifier is unpowered.

Cyan Alerts (Level 0)

- EXT POWER AVAIL - External electrical power is connected and available for use.
- EXT POWER ON - External electrical power is powering the ac tie bus.
- GLY EXT POWER ON - External electrical power is connected to the galley buses. Not applicable on freighters.
- GLY EXT PWR AVAIL - Galley external electrical power is connected and available for use. Not applicable on freighters.

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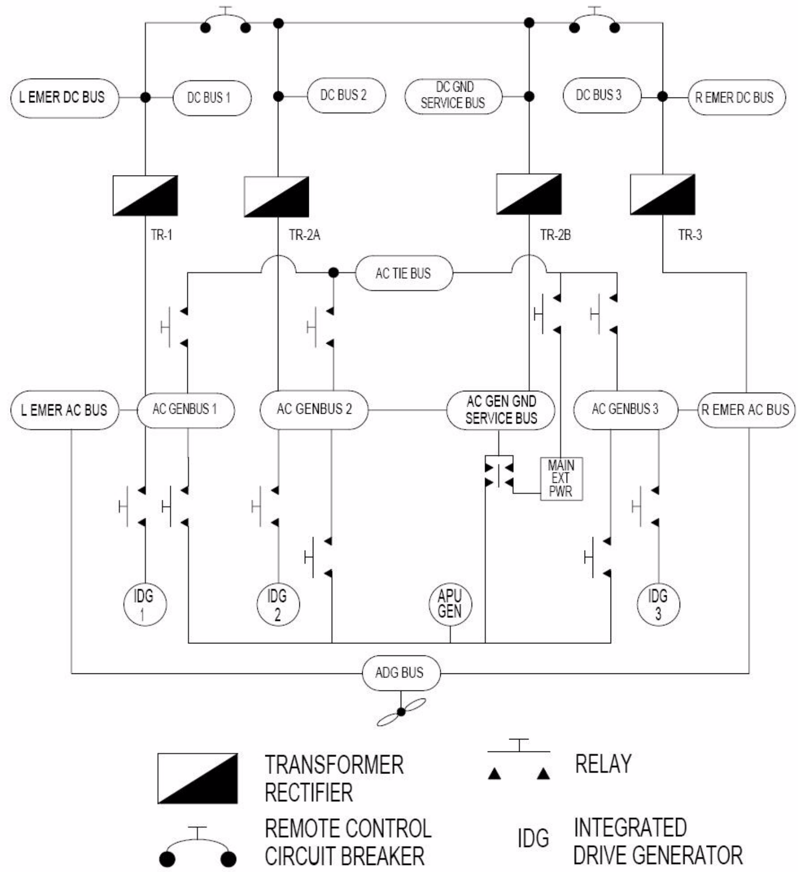
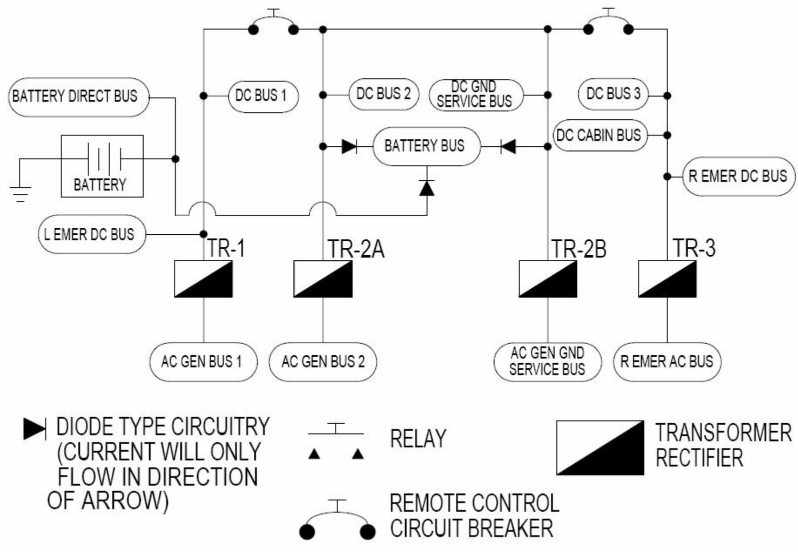
Functional Schematic

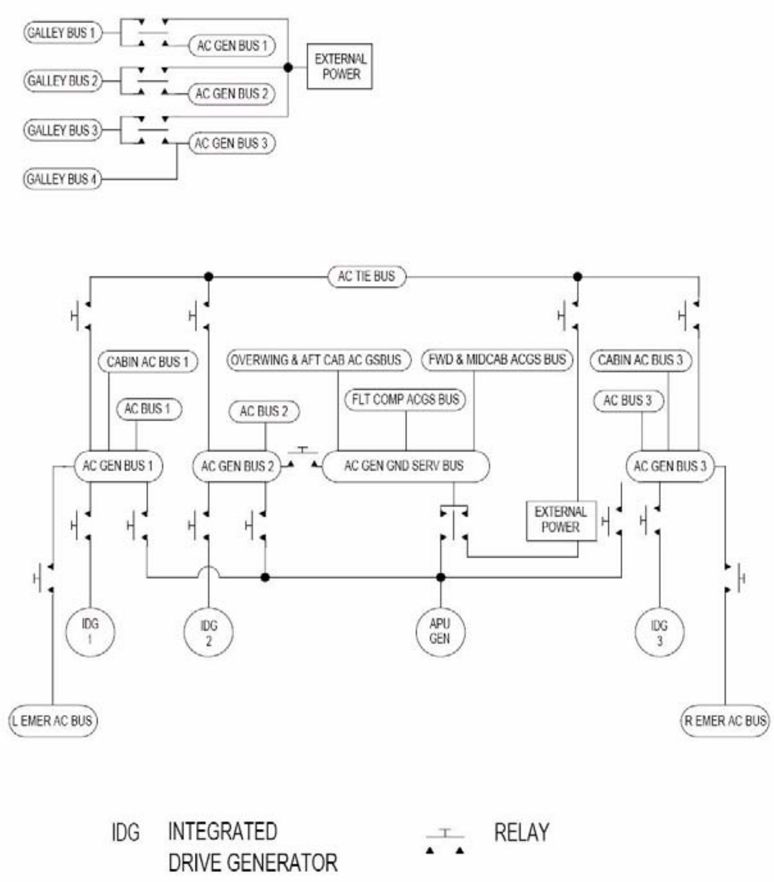
System Diagram



DC Distribution



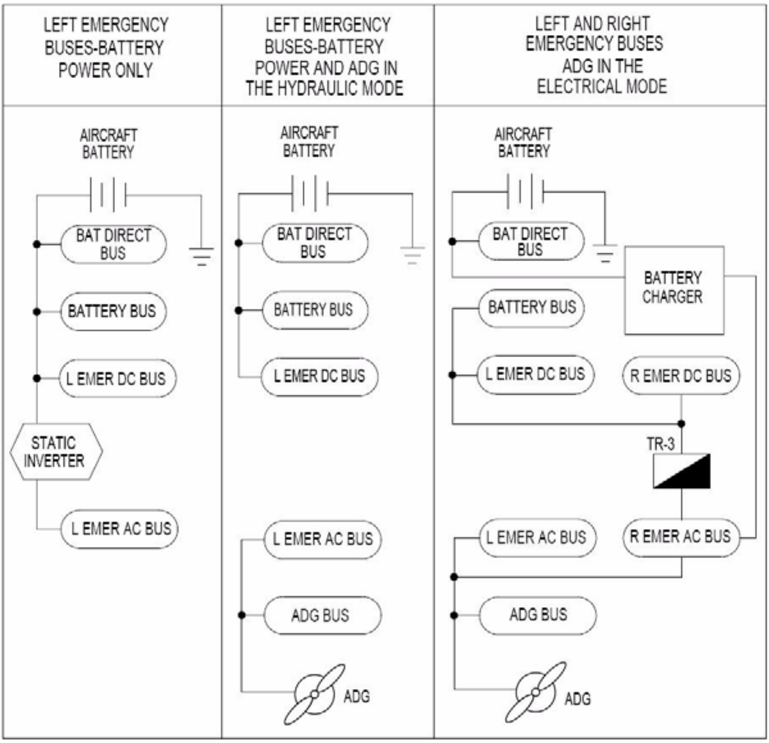
AC Distribution



On freighter aircraft note the following:

- GALLEY BUSES not installed.
- CABIN AC BUS 1 and 3 deleted.
- OVERWING & AFT CAB AC GSBUS replaced with CARGO LOADING BUS.
- FWD & MIDCAB ACGS BUS replaced with CABIN AC GS BUS.

Emergency Power



ADG - AIR-DRIVEN GENERATOR
TR - TRANSFORMER RECTIFIER

Description and Operation

General

The aircraft is equipped with three GE CF6-80C2 engines or three P&W PW4460 or PW4462 engines.

Each engine has dual rotors, a Low Pressure Compressor (LPC) (N1) incorporating a high bypass ratio turbofan, and a High Pressure Compressor (HPC) (N2).

A multiple stage (low and high pressure) turbine drives the compressors and fan. The fan exhaust cowl contains a fan thrust reverser.

The accessory drive section extracts energy from the core engine rotor to drive accessories and sends core engine speed signals to the Full Authority Digital Electronic Control (FADEC) system. The accessory gearbox is installed in the core engine compartment. Mounted on the gearbox are:

- Starter
- Electrical N2 sensor
- Fuel pump
- Lube and scavenge pump
- Integrated Drive Generator (IDG)
- Hydraulic pumps
- Alternator (powers the FADEC computer)

Engine controls are on the forward and aft overhead panel and forward pedestal.

Primary engine indications are shown on the upper 2/3 of the Engine and Alert Display (EAD). The lower 1/3 of the EAD is used for alert presentation.

Secondary engine indications are shown on the System Display (SD) secondary engine page. The secondary engine page is a default page and is presented automatically if any parameter on this page exceeds limits.

Full Authority Digital Electronic Control (FADEC)

FADEC is an engine control system that includes the following functions:

- Engine acceleration to idle speed during start
- Acceleration and deceleration limiting
- Automatic control of available thrust
- Minimum/approach idle speeds during descents
- Compressor airflow control
- Selection of alternate modes from cockpit
- Thrust control as a function of throttle position and thrust reverser lever
- Protection from exceeding N1, N2, internal pressures, and maximum thrust limits

For GE, FADEC is controlled by an Engine Control Unit (ECU). For P&W, FADEC is controlled by an Electronic Engine Control (EEC).

The two channels (A and B) of the ECU or EEC are housed in one assembly but are physically separated.

The ECU or EEC has dual channel control (A and B). This allows normal engine control and operation with the total failure of one channel. The failure of any sensor results in cross-channel data exchange so that dual-channel capability is retained.

Primary power for each channel is obtained from a dual-output Permanent Magnet Alternator (PMA) driven by the N2 gearbox. The PMA has two independent sets of windings. Each set of windings supplies power to its respective ECU or EEC channel. Aircraft 28-volt input power is required for ground starting, testing. For GE, 28-volt input power is also required for ECU backup power.

The ECU or EEC is the primary interface between the aircraft and the engines. The ECU or EEC operates in response to pilot commanded thrust settings that are transmitted to the ECU or EEC by dual electrically isolated position sensors. The position sensors are mechanically linked to each throttle. Each position sensor is dedicated to one channel of the ECU or EEC and provides independent analog signals to each ECU or EEC channel proportional to the throttle angle.

The ECU or EEC interfaces with two Air Data Computers (ADC) through two ARINC 429 data buses. Each ECU or EEC channel receives parameters from both ADCs. These parameters include:

- Pressure altitude
- Total pressure
- Total air temperature

FADEC MODE switches on the forward overhead panel allow the flight crew to select the alternate control mode of the ECU or EEC. Selection of the alternate mode is required when a primary air data parameter is not available to the ECU or EEC. The alternate mode can also be selected by pushing the throttles past the normal forward stop.

Reverting to the alternate mode will never result in a decrease in thrust, but may result in an increase in thrust.

Reset switches are activated by the engine FUEL switches on the forward pedestal. When the engine FUEL switches are moved to OFF, the ECU or EEC will sense fuel shutoff and reset the system.

For engines 1 and 3, the ECU or EEC controls a thrust reverser interlock within the Thrust Control Module (TCM) based on reverser position. The interlock prevents the reverse throttle levers from moving past the reverse idle position. For GE, the ECU releases the interlock when the reverser is 60 percent deployed and relocks it when the reverser is within 20 percent of being stowed. For P&W, the EEC releases the interlock when the reverser is 87 percent deployed and relocks it when the reverser is within 20 percent of being stowed.

The ECU or EEC interfaces with the two Flight Control Computers (FCC). Each channel of the ECU or EEC interfaces with both FCCs. FCC parameters transmitted to the ECU are:

- N1 trim and autothrottle (GE) or EPR trim and autothrottle (P&W)
- Bleed configurations
- GMT
- DATE
- Flap/slat position (for idle selection)
- Weight on nosewheel (for reverser 2 operation and idle selection)

The ECU or EEC will transmit digital data to the aircraft. The transmitted data is as follows:

- Engine rating parameter data
- Parameters used for engine control
- ECU or EEC status and fault data
- ECU or EEC system maintenance
- Engine condition monitoring parameters

The engine has two idle modes as follows:

Minimum Idle - Minimum idle is the minimum operating speed of the engine and is intended to minimize thrust, fuel use, noise, and jet blast. Minimum idle is automatically provided in flight during descent when the throttles are positioned to idle.

Approach Idle - Approach idle provides an increased idle rpm which permits rapid response to throttle advancement. All engines will revert to approach idle when any one of the following occurs:

- Any engine cowl anti-ice on
- Appropriate configuration of flaps or slats

Both idle modes are controlled by the ECU or EEC.

Thrust Control Module (TCM)

General

The TCM is installed in the forward pedestal and contains all the mechanisms to provide completely electronic signaling (fly-by-wire) between the throttles and the engines. Pilot controls on the TCM include:

- Throttles
- ENG START switches
- Engine FUEL switches

Throttles

Thrust is set by N1 for GE or EPR for P&W.

The three throttles are driven manually by the pilot or automatically by the autothrottle system (ATS). The ATS operation can be overridden by the pilot at any time.

Ignition System

Each engine ignition system consists of two independent ignitors (A and B). The ignitors ignite the fuel/air mixture during starting and provide continuous ignition during takeoff, landing, and when using engine anti-ice. The ignitors use 115 volt, 400 Hz power.

Only one ignitor is required to start the engine. During a ground start, either ignition (A or B) may be selected with the ENG IGN switches on the forward overhead panel. When either ENG IGN A or B switch has been pushed, moving the respective FUEL switch to ON will turn on the corresponding ignitor.

With A or B selected, continuous ignition is provided automatically during takeoff, landing, and engine anti-ice on (60 seconds only). The selected engine ignitors automatically shut off when flaps/slats are retracted.

The ignition system indicating lights are integral with the ENG IGN switches and the ENG START switches. The Miscellaneous Systems Controller (MSC) provides automatic control of the ignition system.

An ENG IGN OFF light on the forward overhead panel will illuminate if neither system A or B or the OVRD switch is selected. This indicates that no power is being supplied to either ignition system.

Selecting ignition system A or B with the ENG IGN switch will:

- Supply 28-volt dc power to each ENG START switch.
- Arm ignition system A or B.
- Send a signal to the APU for 100 percent N1.
- Configure the air and fuel systems for engine start.

With an ignition system selected, the ENG START switch can then be pulled out. This energizes a coil that holds the switch in that position. The ENG START switch also energizes the start valve to open and supplies 28-volt dc power to the ECU or EEC.

The Fuel System Controller (FSC) automatically turns on the aft fuel pumps in fuel tanks 1, 2, or 3 when the respective ENG START switch or engine FUEL switch is moved to ON.

When the start valve opens, a light in the ENG START switch will illuminate. When the engine FUEL switch is moved to on, the MSC supplies 115-volt ac power to the exciter. A lightning symbol will appear on the EGT display of the EAD and will remain until 45 percent N2 for GE or 47 percent N2 for P&W.

As the N2 speed accelerates to 45 percent for GE or 47 percent for P&W, the MSC causes the ENG START switch to pop in. Then the start valve will close, the light in the ENG START switch will extinguish, and the ignition system will automatically remove power from the ignitors. The MSC controls the start sequence. If the ENG START switch latching function in the MSC fails, the switch must be held out until the engine reaches 45 percent for GE or 47 percent for P&W.

The ignition override function can be used for emergency conditions (engine flameout), for simultaneous failure of ignition systems A and B, or when flying in heavy turbulence or precipitation.

Actuation of the ENG IGN OVRD switch will bypass the MSC to simultaneously provide power to both the A and B ignition systems for as long as the override is selected. Selection of the ENG IGN OVRD switch provides power to the ENG START switches to allow starter assisted air starts.

The ignition system has no time limit although excessive use will reduce ignitor service life.

If optional automatic relight is installed, and the engine flames out, the MSC will turn on the respective ignitor for an engine relight attempt. The ignition lightning symbol will be displayed during the auto relight attempt.

Starting System

The starting system consists of an air turbine starter and a starter air valve.

The starter air valve is a butterfly valve that controls the flow of air (supplied by APU, engine crossbleed, or ground power unit) to the engine air turbine starter. It is powered from the battery bus.

The starting system is energized by pulling the ENG START switch on the forward pedestal. Pulling out the ENG START switch will:

- Energize a coil that holds the switch out.
- Energize the engine starter valve open which will illuminate the light in the switch.
- Supply power to the ECU or EEC.

Normal engine starts can be done with pneumatic pressure greater than 25 psi. Optimum engine acceleration to idle and lowest EGT peak is obtained with a pressure of 40 psi and above. Conditions may necessitate the use of pressure below 25 psi. Extended time to idle and higher EGT peaks may result. Under these conditions, the start cycle must be closely monitored so that action can be taken to prevent a hung or hot start.

If starter air pressure drops during start, the START AIR PRES LO alert will appear at 25 psi for GE or 20 psi for P&W.

When the engine has attained about 45 percent N2 for GE or 47 percent N2 for P&W, the starter air valve closes and shuts off air to the starter turbine. As the engine continues to accelerate, a starter clutch automatically disengages the starter.

An amber light in the respective ENG START switch will remain illuminated when the valve is not closed.

Fuel Control System

Fuel flow is controlled by the ECU or EEC.

For GE, the engine FUEL switch supplies electrical power directly to the Hydromechanical Unit (HMU). The HMU then operates the High Pressure fuel Shutoff Valve (HPSOV). For P&W, the engine FUEL switch supplies electrical power directly to the Fuel Metering Unit (FMU). The FMU then operates the fuel shutoff valve.

A red light in the engine FUEL switch will illuminate if an engine fire condition occurs. The light will also illuminate during the ENG/APU FIRE test.

Moving the engine FUEL switch to ON starts ignition and fuel provided the ENG START switch is out and the ENG IGN switch is selected A or B.

The FSC automatically turns on the fuel pumps in tanks 1, 2, or 3 when the respective ENG START switch is pulled to ON.

Moving any FUEL switch to ON initiates a test of the cargo door indicating system sensors. The TEST light on the forward overhead panel will illuminate during the test. If the test is satisfactory, TEST will extinguish. If the test fails, a CRG DOOR TEST FAIL alert will be displayed.

Fuel flows through the following components:

- Fuel-oil heat exchanger
- Fuel filter
- Fuel flow meter (GE) or fuel flow transmitter (P&W)
- IDG fuel-oil heat exchanger (GE)
- Fuel metering valve (GE)
- Fuel nozzles (30) (GE) or fuel injectors (P&W)

Fuel flowing through the fuel/oil heat exchanger cools the engine oil and heats the fuel.

A pressure differential switch is installed across the main fuel filter and will display an appropriate alert when an impending filter clogging situation exists. If the filter clogs to a predetermined degree, fuel will bypass the filter to maintain flow to the engine.

P&W engines have an air/oil heat exchanger installed upstream of the fuel/oil heat exchanger. Fan air is used to cool the oil. If the valve controlling this fan air is failed open, the oil may not be hot enough to warm the fuel in the fuel/oil heat exchanger.

Emergency Shutdown

In case of an engine fire, the fire detector system actuates the red MASTER WARNING lights and the fire bell. Emergency shutdown is accomplished with individual ENG FIRE handles on the aft overhead panel. Pulling the ENG FIRE handles down actuates the generator field disconnect and shuts off electrical, fuel, and hydraulics. The associated air system is depressurized when the air system is operating in the automatic mode.

Fire agent discharge is accomplished by exerting a force forward against the forward stop, while simultaneously twisting the handle in the agent position. The turning action in one direction will activate one discharge switch, opposite motion will activate the other switch.

If the pilot pulls one of the ENG FIRE handles down, a warning (disagreement) light in the related engine FUEL switch is illuminated.

The light will be extinguished when the engine FUEL switch is placed in the OFF position.

Oil System

Each engine oil system is self-contained. Oil for engine lubrication is supplied from an oil tank. Oil is pumped under pressure to the engine and returns to the tank.

An oil pressure indicating system is installed on each engine to indicate current oil pressure to the flight crew. An oil pressure transmitter senses the differential pressure.

For P&W, a low oil pressure switch will sense pressure in the oil supply line and a strainer clog switch will sense pressure drop across the scavenge oil strainer.

The ENG (1, 2, or 3) OIL FILTER alert indicates a clogged or an impending clogging of the oil filter. The filter bypass valve will open when the oil filter is clogged. All contaminated oil will then bypass the filter and go directly to the engine.

ENG (1, 2, or 3) OIL FILTER alerts are accompanied by the MASTER CAUTION lights and are inhibited when the oil temperature is below 35°C.

For GE, an oil quantity sensor is installed in the oil tank. It contains a magnetic float supported by the oil level in the tank. As the oil level changes the float causes switches to close.

All oil indications will be shown on the secondary engine page of the SD. Appropriate alerts will appear on the EAD and the SD.

A conflict between oil pressure displays on the SD and related alerts indicates a sensor failure.

Compressor Control System

The compressor control system controls performance through the range of engine operation. A Variable Bleed Valve (VBV) system controls the amount of air into the high pressure compressor.

At low engine speeds, the low pressure compressor supplies more air to the core than is necessary for operation. This excess air goes into the fan discharge airstream and around the high pressure compressor.

The VBV system valves close when the engine speed is sufficient to use the air. A Variable Stator Vane (VSV) system controls the airflow through the high pressure compressor.

The VSV system changes the direction of this airflow to the best angle for compressor performance. This prevents compressor stalls and improves engine operation during acceleration and deceleration. The ECU controls the operation of the VBV and the VSV systems.

Engine Vibration Monitoring System (EVMS)

The EVMS consists of the following:

- One Engine Vibration Signal Conditioner (EVSC)
- Accelerometers (1 or 2)
- N1 and N2 tachometer signals wired to the EVSC from each engine (6 total)

The EVSC is powered by 115-volt ac/400-Hz electrical power. All EVMS data is displayed on the secondary engine display. When engine vibration exceeds a preset value, the digits will turn amber and will be boxed in amber, and an alert will be displayed.

Compressor (N1) and turbine (N2) vibration signals for all three engines are displayed on the secondary engine page of the SD. The secondary engine page is one of many pages that can appear on the SD. If the secondary engine page is not on the SD it can be selected with the ENG cue switch on the aft pedestal. The secondary engine page will appear automatically if there is an engine vibration alert on the EAD.

An engine may experience normal momentary peaks in vibration levels lasting between 5 to 30 seconds during certain throttle transients or engine inlet air entry angles.

Engine Failure Detector System

An N1 difference detector alerts the flight crew of engine N1 loss on any of the three engines during takeoff ground roll by illuminating the ENGINE FAIL lights on the glareshield.

During takeoff between 80 knots and V1 the ENGINE FAIL lights will illuminate when any engine N1 rpm differs by 11 percent or more with any other engine N1 rpm.

Thrust Reversing System

The reverse thrust system is designed for ground use only.

Reverse thrust is accomplished by aft movement of a section of the engine cowl to expose fixed cascades and operate blocker doors that rotate across the fan exhaust stream. Normal fan exhaust flow is then blocked and forced through cascades at a forward angle.

Reversers are most effective at high speeds, however, some slowing force remains at low speeds.

If a failure occurs, aerodynamic forces and mechanical loads on the reverser tend to hold the reverser in the last selected position.

When airborne, engine power will be reduced to idle by the FADEC system whenever throttle position disagrees with its reverser position.

For GE, the engine thrust reversers are powered by regulated pneumatic pressure from the respective engine. For P&W, the engine thrust reversers are powered by hydraulic pressure from the respective hydraulic system.

The thrust reversers are armed when the FCC software receives input that either the Radio Altitude (RA) is seven feet or wheel spinup is greater than 80 knots. A compressed nose gear strut will also arm the thrust reversers in case of an FCC fault.

Each system is operated by movement of the associated reverser lever. Reverser levers cannot be operated unless the throttle is at the idle stop. To deploy the reverser, the reverser levers must be moved to the reverser interlock position.

As the reverser levers are raised to reverse idle, each N1 display for GE, or each EPR display for P&W, on the EAD will show an amber U/L (reverser unlocked). When the reversers are fully deployed and available, a green REV will appear on the N1 displays for GE or the EPR displays for P&W.

The reversers are stowed by movement of the reverser levers through the reverse idle detent to the forward idle stop position.

The EAD displays U/L in each N1 display for GE, or each EPR display for P&W, as each reverser is being stowed. The U/L message will be removed when forward thrust is restored.

Thrust reverser override switches are installed on the cockpit maintenance panel. These switches allow maintenance checks of the reverse thrust range of the throttle resolvers. When pushed, these switches cancel the ECU or EEC signals to the wing engine reverser interlocks in the pedestal. This releases the reverser levers so that they can be moved without operating the thrust reversers.

Test Display

EAD

Engine EAD failure indications are amber Xs over the thrust limit, TAT, and fuel flows, and larger amber Xs over the dials (or tapes). These failure indications will appear when all of the following conditions are met:

- The aircraft is on the ground
- The aircraft is operational

- The ANNUN LT TEST button on the forward overhead panel is pushed.

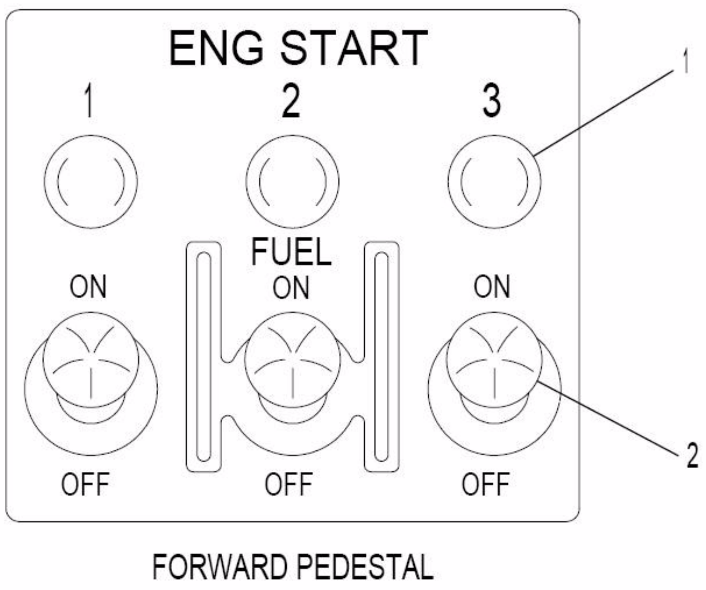
SD

SD secondary engine display power failure indications are amber Xs over the digital readouts. In the case of the oil PRESS, TEMP, and QTY the amber Xs are over the dial (or tape). These failure Xs will appear when all of the following conditions are met:

- The aircraft is on the ground
- The aircraft is operational
- The ANNUN LT TEST button on the forward overhead panel is pushed
- Secondary engine display is on the SD

Controls and Displays

ENG START switches and FUEL



1. ENG START Switch (3) - amber Pulling this switch will:
    - Energize a coil that holds the switch out.
    - Energize the engine starter valve open.
    - Illuminate the switch amber.
    - Supply power to the FADEC computer.

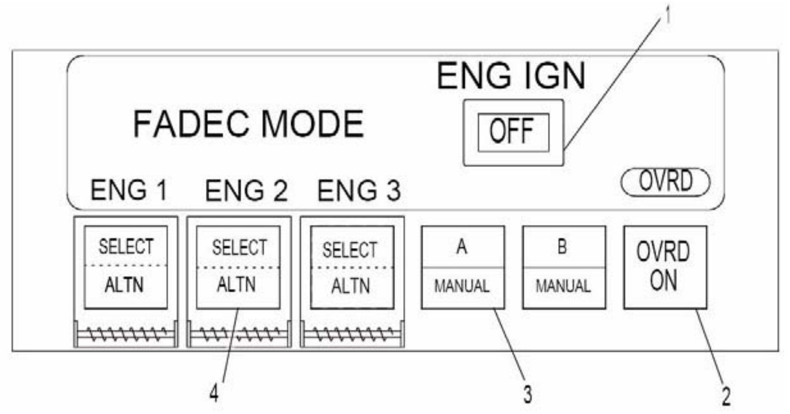
    At about 45-52 percent the ENG START switch will pop in and the light will extinguish indicating that the starter air valve has closed. The MSC controls the start sequence. This switch cannot illuminate until the appropriate electrical bus is powered.

2. FUEL Switch (3) - red

    This switch supplies electrical power to a fuel metering device. The fuel metering device then operates the fuel shutoff valve.

This switch illuminates red during engine fire and ENG/APU FIRE test. Moving the switch to the ON initiates ignition and fuel if the ENG START switch is out and the ENG IGN switch is selected A or B. The FSC automatically turns on the fuel pumps in tanks 1, 2, or 3 when the respective ENG START switch or FUEL switch is moved to ON.

FADEC MODE Panel



FORWARD OVERHEAD PANEL, LEFT SIDE

1. ENG IGN OFF Light - amber

   Illuminates amber when no ignition system has been selected and no power is being supplied to the ignitors.

2. OVRD ON Switch - amber

   Push switch to select ignition override. Direct power to both ignitors on each engine is provided for in-flight use. Normal ignition control is bypassed.

   Illuminates amber when ignition override is selected on.

3. ENG IGN Switch (A & B) - white/blue

   Selecting ignition with these switches will signal the Automatic System Controllers (ASC) that the engines are about to be started. The ASC will then configure the interfacing aircraft systems for engine start.

Once an ignition selection has been made (A, B, or both), the selection will remain until engine shutdown.

A or B illuminates white when the respective ignition system has been selected with the switch. When A or B is illuminated, the APU N1 will increase to about 1 00 percent rpm to provide greater pneumatic capability for starting.

In the normal mode of operation, the auto-ignition feature will provide continuous power to ignition system A or B (whichever has been selected) during takeoff and landing, and for the first 60 seconds after one of the engine cowl anti-ice systems has been commanded on.

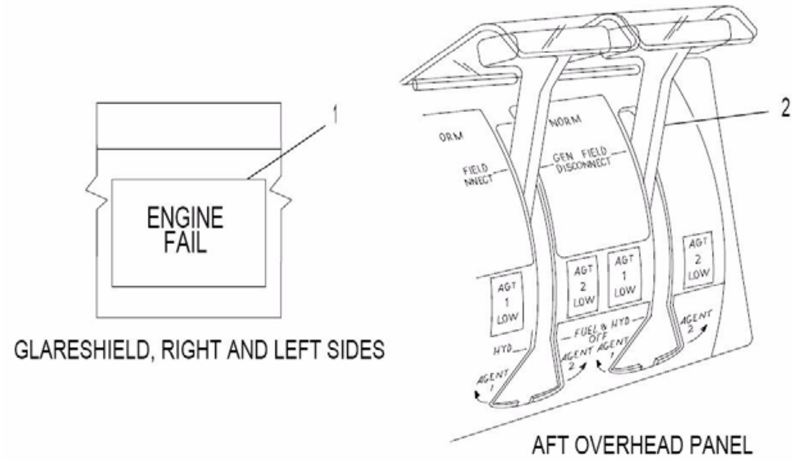
MANUAL illuminates blue to indicate that power is being supplied continuously to the selected ignition. This occurs when the ignition has reverted to the manual mode (auto-ignition failure). In this case the ignition system will remain powered until the pilot turns it off by pushing ENG IGN switch.

4. FADEC MODE ENG 1/2/3 Switch (3) - amber

   SELECT ALTN illuminates amber when the respective FADEC cannot operate in the primary mode. The crew can then push this switch to select the backup alternate mode. When the alternate mode is selected, ALTN will remain illuminated.

   With P&W engines, autothrottle is not available when operating in the alternate mode.

ENGINE FAIL Lights and ENG FIRE Handles



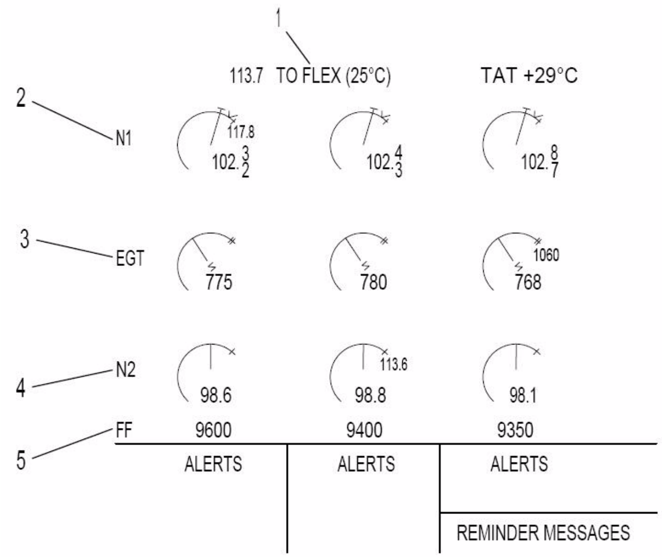
1. ENGINE FAIL Light (2) - red

   This light illuminates red if the aircraft is in takeoff between 80KTS and V1 and any engine N1 differs by 11% or more with any other engine. The MASTER WARNING or MASTER CAUTION lights will not illuminate.

2. ENG FIRE Handle (3) - red

   Pulling the ENG FIRE handle full down will shutoff fuel and hydraulic supply to the associated engine, deenergize associated generator field, and turn off fire bell. The associated FUEL shutoff lever light on the forward pedestal will be illuminated red if it is not off.

EAD Primary Engine Display (GE Dials)



1. Thrust Rating and TAT

   FMS N1 limit and modes are magenta. Manually set modes are white. Available modes are: CLB (climb), CRZ (cruise), GA (go-around), MCT (max contin thrust), TO (takeoff), and TO FLEX (takeoff flex). In TO FLEX, the assumed temp is also shown. Optional ALT TO (alternate takeoff thrust), TO 1, TO 2 (10%, 20% derated takeoff thrust), CLB 1, CLB2 (10%, 20% derated climb thrust), GA 1, GA 2 (1 0%, 20% derated go-around thrust) are displayed if selected. Total air temperature is in the upper right corner in white.

2. N1

   The display is white, but the pointer and digits turn red (digits boxed in red) if N1 exceeds the redline limit. Throttle position is a white T riding along the scale and computed N1 thrust rating is a magenta V. When the throttle is set to a computed thrust, the T will fit in the V. The thrust reverser display is above the digital value. It is blank for reverser stowed, amber U/L for in transit, and green REV for reverser fully deployed. Maximum redline exceedance, if any, is shown in amber at the high end of the scale. This exceedance can be reset with the ENG MAX POINTER RESET button on the forward overhead panel.

3. EGT

   The display is white but the pointer and digits turn amber (digits boxed in amber) if EGT exceeds the amber line for more than 5 minutes. The pointer and digits turn red (digits boxed) if EGT exceeds the redline. A cyan lightning symbol appears over the digits when ignition for that engine is on. Maximum redline exceedance, if any, is shown in amber at the high end of the scale. This exceedance can be reset with the ENG MAX POINTER RESET button on the forward overhead panel.

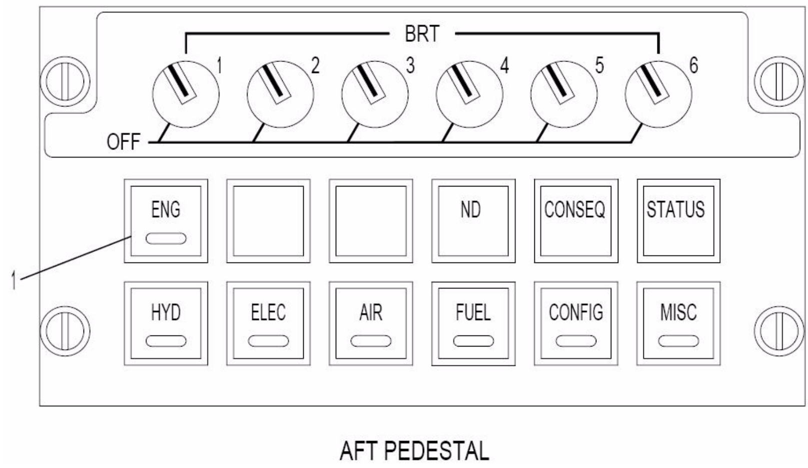
4. N2

   The display is white, but the pointer and digits turn red (digits boxed in red) if N2 exceeds the redline limit. During start, a cyan line appears to indicate the N2 at which fuel should be turned on. Maximum redline exceedance, if any, is shown in amber at the high end of the scale. This exceedance can be reset with the ENG MAX POINTER RESET button on the forward overhead panel.

5. Fuel Flow

   Fuel flow is in white digits. Unit of measurement is pounds per hour. When the engine fuel valve is closed, a cyan FUEL OFF appears above the digits.

ENG Cue Switch



1. ENG Cue Switch - white

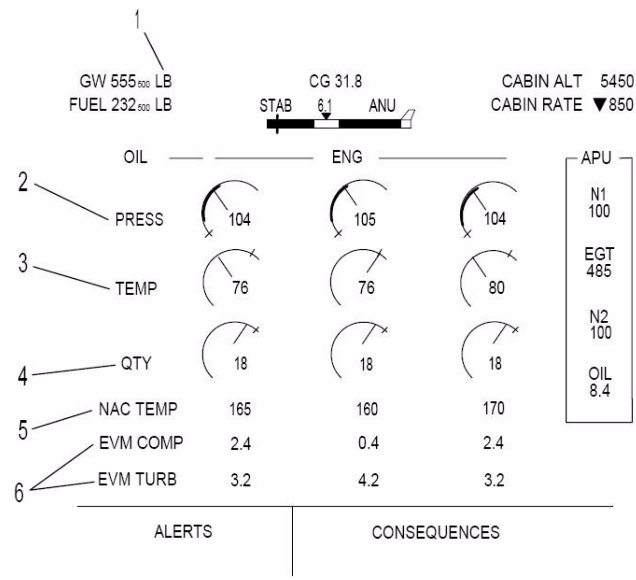
   Illuminates white when an ENG alert is displayed on the EAD. When pushed:

   - MASTER WARNING or MASTER CAUTION lights will extinguish.
   - Reminder message will replace the alert.
   - Secondary engine display comes into view on the SD.

   The secondary engine page is a default page and is presented automatically if any parameter on it exceeds limits.

   Some level 1 alerts are maintenance alerts that appear on the STATUS page only. These maintenance alerts will not illuminate the cue switch or the MASTER CAUTION lights.

SD Secondary Engine Display (Dials)



1. Gross Weight and Fuel

   Gross weight and fuel are in white. Invalid data is marked with an amber X. Unit of measurement is pounds.

2. OIL PRESS Display

   A green arc shows the valid operating range. The digits are normally white. If the pointer moves out of the green band, the digital display and the pointer turn amber and the digits are boxed in amber. The pointer, digits, and box will turn red when the pointer moves below the red line. During engine starts under extreme cold conditions, oil pressure may reach maximum indication due to low oil viscosity. Normal ranges are 10 to 120 psi for GE and 70 to 400 psi for P&W.

3. OIL TEMP Display

   The white digits (°C) and pointer will turn amber and digits will be boxed in amber if oil temperature exceeds the high amber line or below the low amber line. The white digits and pointer will turn red and digits will be boxed in red if red line is exceeded. There is a band below red line in which operation is allowed for 15 minutes for GE and 20 minutes for P&W. After the allotted time the pointer and digits will turn amber and will be boxed in amber.

4. OIL QTY Display

   When the engine reaches minimum idle (on ground), each scale is marked with a cyan line showing initial oil quantity for oil consumption reference. Pointer and digits (quarts) turn amber and digits are boxed in amber when oil quantity is below 4 quarts. An amber X is displayed when signal is lost.

5. NAC TEMP Readouts

   Nacelle temperature (NAC TEMP) is shown below the vibration readouts. If data is not available, an amber X will appear.

6. EVM COMP and EVM TURB Readouts

   Compressor (COMP) and turbine (TURB) vibration levels are shown in white. The digits will turn amber and will be boxed in amber if they exceed limits. If data is not available, an amber X will appear.

Intentionally Left Blank

Alerts

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

Amber Boxed Alerts (Level 2)

- ENG 1/2/3 EGT HI (ENG) - Engine 1/2/3 EGT over redline limit.
- ENG 1/2/3 OIL PRES LO (ENG) - Engine 1/2/3 oil pressure is low.
- ENG 1/2/3 OIL TEMP HI (ENG) - Engine 1/2/3 oil temperature is high.
- ENG 1/2/3 RPM HI (ENG) - Engine 1/2/3 (N1 or N2) rpm is high.
- ENG 1/2/3 RPM LO (ENG) - Engine 1/2/3 N2 is below idle.
- SELECT FADEC ALTN (ENG) - One or more engines are operating in ALTN mode, a degraded automatic mode.

Amber Alerts (Level 1)

- ENG 1/2/3 FADEC ALTN (ENG) - Engine 1/2/3 FADEC MODE switch is in the ALTN position, or the throttle has been pushed through the overboost stop. The FADEC is operating in a degraded mode and care should be taken to avoid exceeding thrust limits.
- ENG 1/2/3 FADEC FAULT (ENG) - FADEC 1/2/3 has detected an internal fault or loss of redundancy. Engine operation is not affected.
- ENG 1/2/3 FUEL FILTER (ENG) - The respective engine fuel filter is clogged and engine fuel may be bypassing the filter. In flight, monitor engine operation.
- ENG 1/2/3 NAC TEMP HI (ENG) - Respective engine nacelle temperature is significantly higher than the other 2 engines. Optional.

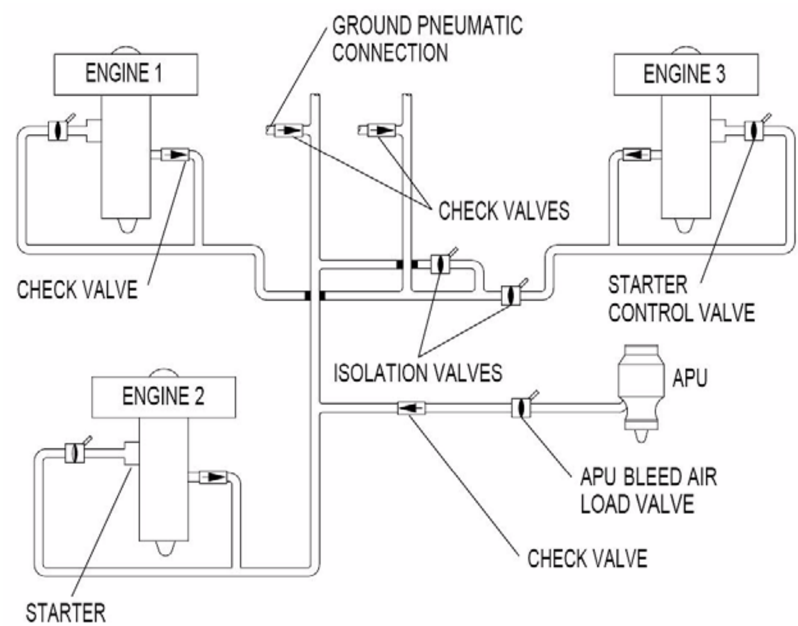
- ENGINE 1/2/3 VIB HI (ENG) - Engine 1/2/3 vibration 4.0 units or greater. Optional.
- ENGINE IGN MANUAL (ENG) - Automatic control of the engine ignition system is inoperative.
- ENG IGN NOT ARMED (ENG) - Engine ignition is not armed.
- START AIR PRES LO (AIR) - Insufficient air pressure for engine start.

Cyan Alerts (Level 0)

- ENG IGN OVRD ON - The engine ignition override function has been selected.
- ENGINE IGN ON - Automatic control of the engine ignition system is inoperative and ignition is on.

Functional Schematics

Start System



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Description and Operation

General

The fire protection system is a dual function system. The two functions are detection and extinguishing.

The detection system detects fires in the engine nacelles, APU compartment, and cargo compartments. It also detects smoke in the cargo compartments. The extinguishing system will extinguish fires in any of these fire zones.

The detection system includes the following:

- Dual sensing elements in the engine nacelles and APU compartments.
- Separate heat and smoke detectors in the cargo compartment.
- Fire Detection Control Units (FDCU) (Engine 1, 2, 3, and APU).
- Control switches and lights on the aft overhead panel.
- EAD alerts, AIR synoptic smoke/heat symbology, engine fire bells, aural and voice warnings.

The extinguishing system includes pressurized agent storage bottles installed near the fire zone they protect. Discharge of the extinguishing agent is accomplished with controls located in the cockpit.

The cargo area is divided into two class C compartments, forward and center/aft. The center/aft compartment is considered a single compartment for fire protection purposes.

Fire protection system alerts are displayed on the EAD. MASTER WARNING lights on the glareshield illuminate when a fire detection system is activated.

Engine and APU Fire Detection

The system includes dual sensing elements, control units and circuits, MASTER WARNING lights, control switches, aural fire warning accompanied by alerts on the EAD for the engines, and an external alarm horn for the APU.

An FDCU for each engine and the APU contains dual channels in a single unit. Each channel operates from a single sensing element or loop. The loops are mounted in close proximity on the same support structure along the routing. The outputs of the channels are integrated so that fire signals from both operative loops must be received to result in a fire alarm.

If one of the loops is inoperative, a fire signal from the remaining operative loop can provide a valid signal. The outputs are also integrated through a logic circuit to differentiate between a fault signal and a fire signal.

Engine and APU fire detection and extinguishing is available during battery starts.

Main Engine Sensing Elements

The sensing elements consist of a stainless steel tube filled with pressurized helium gas. The tube also contains a hydrogen impregnated gas core.

One end of the tube is sealed and the other end has an assembly containing the pressure switches (alarm and integrity).

During overheat conditions, an increase in temperature from normal to a specified average will cause thermal expansion of the helium gas with an increase in pressure until an electrical contact is made to trigger the alarm system.

During a fire condition, hydrogen gas is released from the core material when a section of the sensing element is heated to a preset temperature. This release of hydrogen will activate the alarm switch.

The expansion of gases in the sensing element is reversible. The sensing element will detect the extinguishing of a fire as well as the presence of a fire.

A single break in the element casing or wiring will cause a loop FAULT alert and will not cause false fire alarms.

The main engine fire detector sensing elements are located in the engine core compartment.

The sensing elements detect the following types of fire or overheat conditions:

- Fires caused by flammable fluids leaking on hot surfaces or ignited by electrical sparks.
- Fire/overheat caused by burn through of the combustor case.
- Ruptured bleed ducts (during certain operating conditions only).

APU Sensing Elements

The APU is installed in the aft fuselage. The dual fire detector sensing elements for the APU are routed along the sides of the compartment wall. There are three dual segments connected in parallel.

The system is designed to detect flammable fluid fires and hazardous overheat conditions from ruptured pneumatic ducts.

Besides the APU duct, this compartment also contains the pneumatic duct from engine 2 (aft). Thus, an APU FIRE warning could also mean that pneumatic duct 2 has ruptured. The flight crew action for an APU FIRE warning includes manually shutting off pneumatic system 2. The APU sensing elements are activated by a uniform temperature of about 218 °C (425 °F).

Since the bleed air temperature from engine 2 can vary over a wide range depending on engine operating conditions, and since the fire detection alarm temperature is above the nominal bleed air temperature expected, a ruptured duct will be detected only if it is hazardous.

Fire Detection Control Unit (FDCU)

One FDCU for each main engine and the APU is located in the avionics compartment directly below the cockpit. The four FDCUs are identical, however, the external circuitry for the engines is different than for the APU.

The FDCU contains circuits that will:

- Detect signals from the sensing elements.
- Differentiate between a fire signal and a fault.
- Receive inputs from the LOOPS A/B and LOOPS A/B TEST switches.
- Energize the MASTER WARNING lights, LOOP A/B lights, alerts, and aural fire warning or APU horn.

The FDCU incorporates two loop circuits (loop A and loop B) which provide continuous monitoring of the detectors. These loop circuits provide warning signals to the flight crew in the event of any fire/overheat alarms, or loop faults.

The FDCU continuously receives and analyzes both fire detection loops signals and is capable of detecting one or more failures in the fire detection loops.

In the event of a failure, the FDCU will:

- Isolate the failure to an LRU.
- Provide alerts regarding the system status including failures.
- Enable single loop fire detection capability on the remaining good loop when a single loop fails.

When a fire condition is sensed, the FDCU will generate two fire outputs. Fire output 1 is powered by the loop A power source, and fire output 2 is powered by the loop B power source.

The two fire outputs eliminate the possibility of a single point failure preventing an alarm during a fire condition.

In addition to the two fire outputs, a third output is also provided for cockpit aural warning. The fire outputs will be activated in response to any one of the following conditions:

- (Fire loop A) and (Fire loop B).
- (Fire loop A) and (Fault loop B).
- (Fault loop A) and (Fire loop B).
- (Fault loop A) and (Fault loop B) - AND both faults occurring within 5 seconds of each other.

If any of the following conditions exist, the FDCU will generate a FAIL output signal for the affected loop:

- Loss of power for that loop.
- Fault in a detector for that loop.
- A failure within that loop's fire detection circuit.
- Detection of fire by single loop for greater than 15 seconds while the other loop is indicating normal (no fire and no fault).

The fire bell has the following characteristics:

- Sounds when a fire condition (engine) is detected.
- Sounds during pilot initiated fire test.
- Will stop sounding when the fire output clears.
- Is inhibited during maintenance test.

The FDCU contains two redundant control channels (loop A and loop B) in a single enclosure, with each channel operated by one of the sensing element loops. Alerts are activated as follows:

LOOP A	LOOP B	ALERT
Fire	Fire	ENGINE (1, 2, 3, or APU) Fire
Fire	Normal	FIRE DET (1, 2, 3, or APU) FAULT
Normal	Fire	FIRE DET (1, 2, 3, or APU) FAULT
Fire	Fault	ENGINE (1, 2, 3, or APU) Fire
Fault	Fire	ENGINE (1, 2, 3, or APU) Fire
Fault	Fault	ENGINE (1, 2, 3, or APU) Fire (if both loops were good before control unit detected dual fault within 5 seconds)
Fault	Fault	FIRE DET (1, 2, 3, or APU) FAIL (if control unit detects dual fault occurred outside 5 seconds)

Fire Indications

A main engine fire or overheat condition is indicated by:

- Illumination of MASTER WARNING lights.
- Sounding of fire bell.
- Illumination of ENG FIRE handle.
- Illumination of engine FUEL switch.
- Alert on the EAD.

The red MASTER WARNING light, located on both the Captain's and First Officer's glareshield, is actuated by the relays of the FDCU. This light is a push-to-reset light used to turn the aural warning and MASTER WARNING light off after a fire warning. This enables the system to indicate another warning if necessary.

A red light in the ENG FIRE handle and the associated alert on the EAD will indicate which ENG FIRE handle to pull for fire extinguishing. A red light in the engine FUEL switch indicates which engine FUEL switch to turn off. With the ENG FIRE handle pulled and the engine FUEL switch on or off, the FUEL switch remains illuminated if the fire warning still exists.

With the ENG FIRE handle pulled and the fire warning terminated, the engine FUEL switch will remain illuminated until the FUEL switch is moved to the OFF position.

An APU fire or overheat condition is indicated by:

- Illumination of MASTER WARNING lights.
- EAD alert.
- Aural warning in cockpit.
- Illumination of APU FIRE light on the external APU control panel.
- Illumination of APU FIRE handle on the APU control panel.

The APU FIRE handle and the alert on the EAD will continue to stay on as long as the warning exists

Engine and APU Fire Extinguishing

The engine/APU fire extinguishing system is a chemical (Halon 1301) high rate discharge system used to extinguish fires in the engine and APU compartments. The system is powered by the battery direct bus.

Each extinguishing system consists of two stainless steel agent bottles, discharge heads, discharge cartridges with electrical connectors, agent distribution system, cockpit controls and displays, and warning lights.

Agent discharge is not automatic.

Two bottles located in the rear fuselage provide agent for the aft engine (engine 2) and APU fire zones. Each bottle has two outlets, allowing discharge to the selected fire zone, with provision for the second bottle to discharge to the same fire zone, if necessary.

When both engine 2 fire agents have been discharged to the APU, none remains for engine 2.

Two identical bottles are located in each wing inboard of the pylon near the front spar. They provide agent for each of the pylon mounted engine fire zones.

The ENG FIRE handles allow the crew to discharge fire agent to an engine from one of two bottles installed for each engine. Moving the handle to the first position turns off the generator field. The second position shuts off fuel and hydraulics. The handle can then be rotated clockwise to discharge bottle 1 and counterclockwise for bottle 2. When a fire is extinguished, the handle light will extinguish, however, the engine FUEL switch will remain illuminated if FUEL switch is still on.

The APU FIRE handle allows the crew to discharge fire agent to the APU. Pulling the handle turns off the APU if not already off. The handle can then be rotated clockwise to activate bottle 1 and counterclockwise for bottle 2. Switches on the external APU control panel allow discharge from the wheel well area. Normally, the APU will shutdown automatically if a fire is detected. With the aircraft on the ground a horn will sound. This horn will stop when the fire signal is no longer received.

Lower Cargo Fire Detection

The aircraft has class C forward and center/aft lower cargo compartments which require detection and fire extinguishing provisions.

The center and aft compartments are considered a single class C cargo compartment.

The lower cargo fire detection system consists of photoelectric smoke detectors, overheat detector, smoke detector annunciation, heat detector annunciation, FWD and AFT flow DISAG/OFF lights, and CRT displays.

The aircraft has five smoke detectors installed in the forward cargo compartment and five in the center/aft cargo compartment area.

In addition, one overheat detector is installed in the ventilation exit duct of the ventilated forward cargo compartment area and two overheat detectors are installed in the exhaust ducts of the ventilated center/aft cargo compartment area. Any one of the smoke or overheat detectors will activate the warning system.

Both the forward and aft cargo compartments are ventilated. Ventilation of these areas is controlled by the FLOW switches on the CARGO FIRE control panel. In the event of heat or smoke, the HEAT or SMOKE lights on the CARGO FIRE control panel illuminate and an alert will be displayed.

When smoke or heat is detected in the cargo compartment, heating and ventilation of that compartment will automatically shut off and the respective cargo flow DISAG light on the CARGO FIRE control panel will illuminate. The auto shutoff of heating and ventilation continues as long as the smoke signal exists. Once the smoke stops, the MSC will return the cargo heating and ventilation to normal operation. Pushing the DISAG/OFF switch will illuminate the OFF light, and prevent automatic restoration of the heating and ventilation without pilot intervention. Turning FWD/AFT CARGO HEAT selector to OFF prevents automatic restoration of heating without pilot intervention.

The cargo fire detection and extinguishing system is automatically tested when the first of 3 IRUs is turned on. It is manually tested with the CARGO FIRE MANUAL TEST switch on the CARGO FIRE control panel.

Any failure in the system will cause a CRG FIRE TST FAIL alert to be displayed.

If the alert MSC AUTO FAIL appears on the status page of the SD, a manual cargo fire test must be performed.

The air synoptic on the SD informs the flight crew of specific failures in the systems. For a description of the air synoptic refer to the Air chapter.

Lower Cargo Fire Extinguishing

The cargo fire extinguishing system uses Halon to extinguish fires in the lower class C cargo compartments.

Each system consists of two different sized, agent bottles, agent distribution system, cockpit controls and warning lights.

The normal discharge time prior to the LOW light illumination on the CARGO FIRE control panel is about 28 seconds for bottle 1 and about 15 seconds for bottle 2.

Agent discharge is not automatic. The primary discharge is initiated manually by the flight crew upon fire indication. The second bottle, (make-up) is discharged by the fight crew into the lower cargo compartment after 1.5 hours.

Agent from the fire extinguishing bottles is discharged into the appropriate cargo compartment (fwd or aft) when the corresponding AGENT DISCH switch on the CARGO FIRE control panel is pushed.

When heat and/or smoke is detected in a forward or aft cargo compartment the appropriate AGENT 1 light on the CARGO FIRE control panel will flash to indicate the proper agent to discharge. The DISCH CARGO AGENT alert will be displayed on the EAD. The AGENT 2 light will flash immediately if AGENT 1 LOW light was illuminated due to a low pressure condition.

Approximately 90 minutes after the agent 1 bottle has been discharged, DISCH AGENT 2 light will flash to indicate that agent 2 bottle should be discharged.

The agent 2 fire extinguishing bottle is considerably smaller than the agent 1 fire extinguishing bottle.

If smoke or heat is detected in the forward or aft compartments, ventilation airflow to the compartments automatically shuts off. This isolates that compartment prior to agent discharge.

Main Deck Fire Detection

On F and CF(F) the main deck is a class E cargo compartment which requires fire detection.

F - Eighteen smoke detectors are installed in the main deck. There is no automatic extinguishing. The smoke detectors will activate the glareshield MASTER WARNING lights, aural tone, the CABIN AIR SMOKE light on the AIR control panel, AIR cue switch, and the CABIN SMOKE alert. An auto test of the cargo fire detectors (main deck and lower) will occur when one of the three IRS mode selectors is placed from OFF to NAV. A manual test can be performed with the CARGO FIRE MANUAL TEST switch on the CARGO FIRE control panel. Power for main deck smoke detection comes from the 28-volt dc left emergency bus.

CF(F) - Eighteen smoke detectors are installed in the main deck. The smoke detectors will activate the glareshield MASTER WARNING lights, aural tone, CABIN SMOKE alert, CABIN AIR SMOKE light on the AIR control panel, and AIR cue switch. An auto test of the cargo fire detectors (main deck and lower) will occur when one of the three IRS mode selectors is placed from OFF to NAV. A manual test can be performed with the CARGO FIRE MANUAL TEST switch on the CARGO FIRE control panel. After initiation of an auto test or manual test of the system, the following indications associated with the main deck smoke detection will remain on for about 20 seconds after the lower cargo fire test indications have disappeared: MASTER WARNING light, CABIN SMOKE alert on the EAD, CABIN SMOKE alert and consequences on the AIR SD, CABIN AIR SMOKE light on the AIR control panel, and triangles for the good main deck smoke detectors on the AIR SD. CARGO FIRE TEST on the EAD and CARGO SMOKE TEST on the AIR SD will remain on for about 30 seconds during the test. Power for main deck smoke detection comes from the 28-volt dc right emergency bus.

Combi - Smoke detectors and heat detectors are installed in the main deck cargo compartment. The smoke detectors will activate the glareshield MASTER WARNING lights, aural tone, HEAT and SMOKE lights on the CABIN CARGO FIRE control panel, and the CABIN CARGO FIRE alert. An audio test of the cargo fire detectors (main deck and lower) will occur when one of the three IRS mode selectors is placed from OFF to NAV. A manual test can be performed with the CARGO FIRE MANUAL TEST switch on the CARGO FIRE control panel. Power for main deck smoke detection comes from the 28-volt dc left emergency bus.

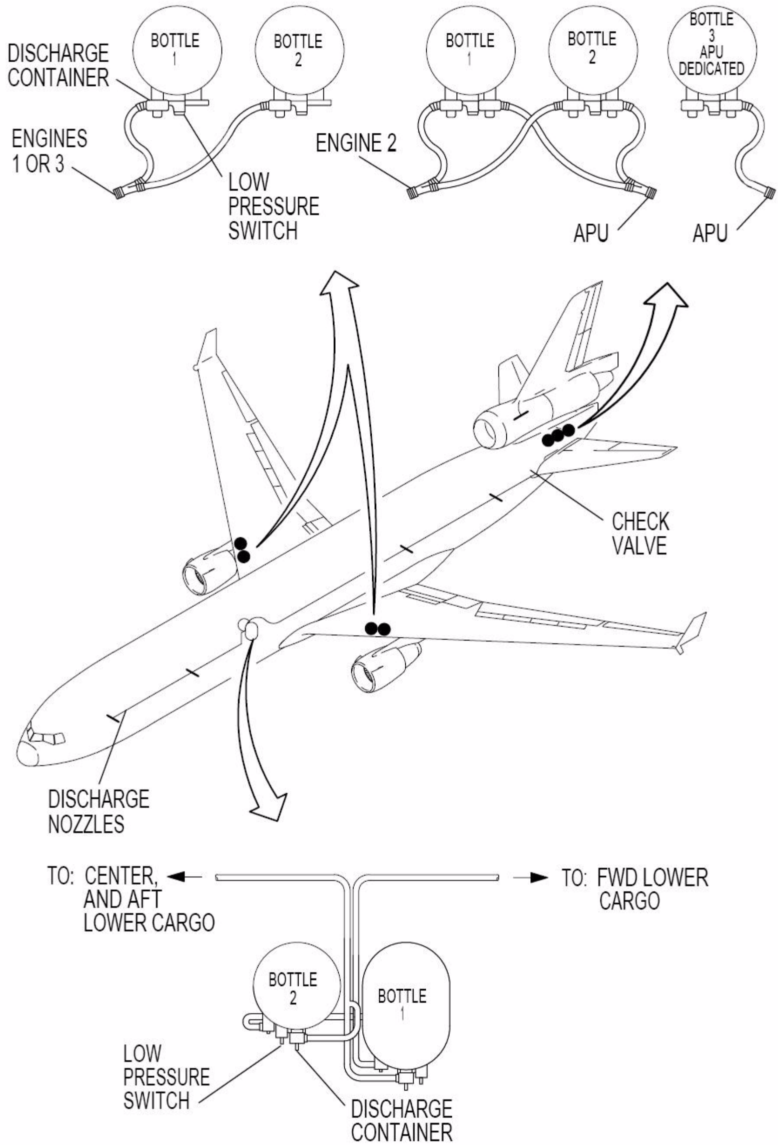
Main Deck Fire Extinguishing

P, F, CF(P), CF(F) - Not installed.

Combi - Four firex bottles are installed in the cabin cargo compartment. These bottles are connected with the two lower cargo firex bottles in the lower center accessory compartment. This makes six bottles available. The bottles are discharged with AGENT DISCH switches on the CABIN FIRE control panel. The systems cab be tested automatically or manually.

Components

Fire Protection - Extinguisher Locations



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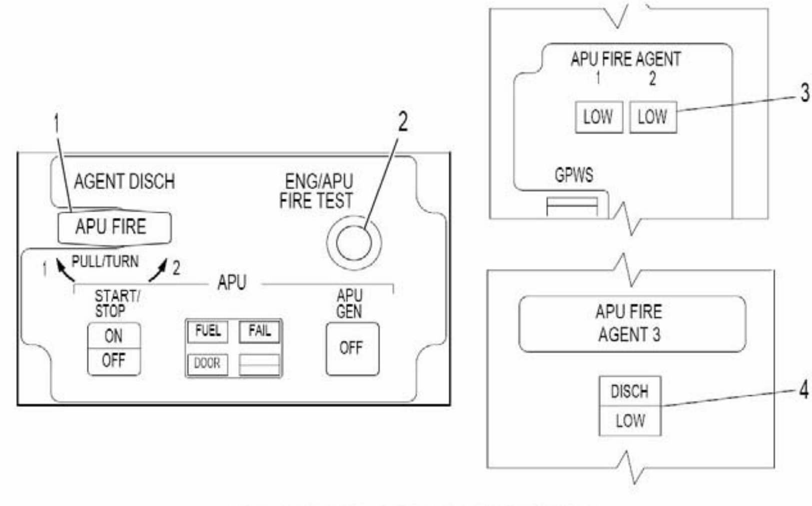
Controls and Displays

APU Controls/Indicators



AFT OVERHEAD PANEL, RIGHT SIDE

1. APU FIRE Handle

   Illuminates red when the APU fire warning circuit is activated. At the same time, the following actions will take place automatically:

   - MASTER WARNING lights illuminate red.
   - Alert appears on EAD.
   - APU FIRE illuminates red on the external APU control handle.
   - Fire horn sounds near the external APU control panel.
   - APU shuts down.
   - Aural warning will sound.

   When the handle is pulled:

   - APU goes to emergency shutdown.

- Fire extinguishing agent is armed.
- APU generator field is deenergized.
- APU fuel valve closes.

After handle has been pulled, rotating handle clockwise will discharge bottle 1 agent. Counterclockwise rotation will discharge bottle 2 agent.

2. ENG/APU FIRE TEST Button
3. When pushed:

- ENGINE FIRE handles, APU fire handle, and engine FUEL switches illuminate.
- Both MASTER WARNING lights flash, fire bell, and aural tone sound.
- ENG 1, 2, 3, and APU FIRE alerts are displayed.
- ENGINE FIRE voice warning (optional) sounds.

MASTER WARNING lights, fire bell, and FIRE alerts will not activate unless aircraft power or emergency power is available.

4. APU FIRE AGENT LOW Lights - amber

When the ENG/APU FIRE TEST switch is pushed, a low electrical current goes to all FIREX discharge cartridges. This current tests the cartridges and illuminates the following:

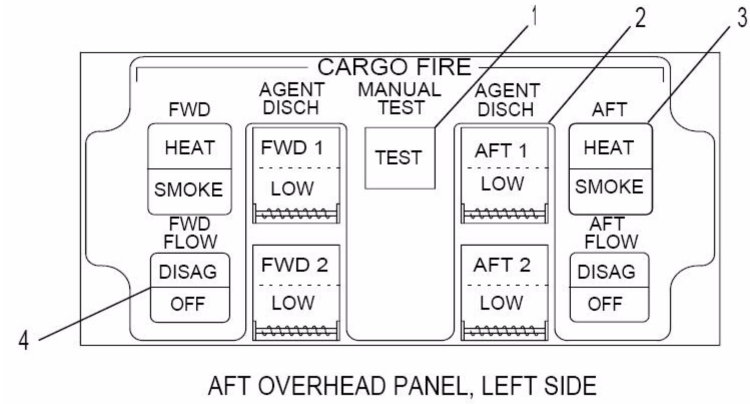
- 6 ENG FIRE AGT LOW lights (2 for each ENG FIRE handle) and
- Both APU FIRE AGENT LOW lights.

If a cartridge fails the test, the associated ENG FIRE AGT LOW or APU FIRE AGENT LOW light will not illuminate.

When an engine 2 bottle is discharged:

- The associated ENG FIRE AGT LOW light (1 or 2) next to engine fire handle illuminated and
- Associated APU FIRE AGENT LOW light (1 or 2) illuminates.

Cargo Fire Panel



1. MANUAL TEST Switch - blue

   Push to test lower cargo smoke and heat detectors and agent discharge squibs. MASTER WARNING, HEAT/SMOKE, FLOW DISAG, AGENT DISCH LOW, and MANUAL TEST lights illuminate. Aural tone sounds. Related alerts appear on the EAD and SD AIR synoptic.

2. AGENT DISCH Switch (4) - amber

   If FWD1 or AFT1 flashes, the flight crew should push to discharge bottle 1 to the respective lower cargo compartment. The DISCH CARGO AGENT alert is displayed. After discharge, LOW illuminates amber (FWD1 or AFT1 extinguishes). After 90 minutes, FWD2 or AFT2 flashes and the flight crew should push to discharge bottle 2. After discharge, LOW illuminates amber (FWD2 or AFT2 extinguishes).

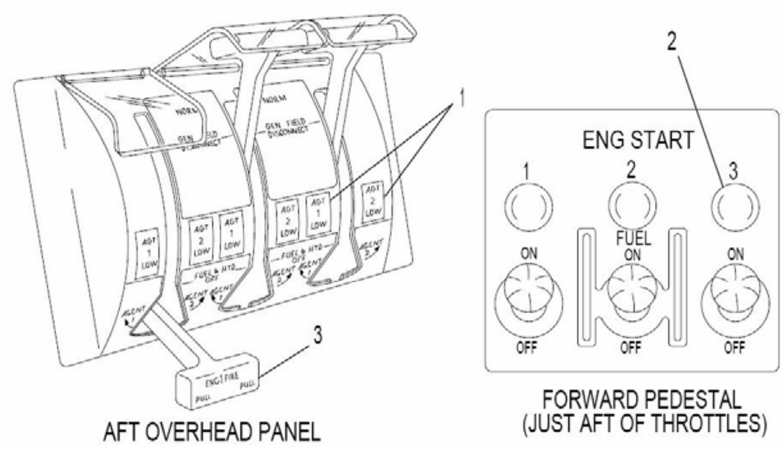
3. HEAT/SMOKE Light (2) - red

   SMOKE or HEAT illuminates red when smoke or heat is detected in the respective lower cargo compartment. Ventilator airflow to respective compartment shuts off. MASTER WARNING lights, EAD alert, and aural tone come on.

4. Cargo FLOW Switch (2) - amber

Flow (ventilation fan) to the lower cargo area shuts off automatically if smoke or heat is detected. DISAG then illuminates amber (flow does not agree with switch position). OFF illuminates amber if flow is commanded off with this switch. Auto control is prevented when OFF is illuminated.

Fire Protection Controls/Indicators



1. AGT LOW Light (2) - amber

   Illuminates amber when fire extinguishing agent in respective bottle has been discharged. Engine 2 (and APU) AGENT LOW lights 1 and 2 are powered by the battery bus.

2. FUEL Switch (3) - red

   Illuminates red when respective ENG FIRE handle illuminates. Indicates which FUEL switch to shut off. With ENG FIRE handle pulled and FUEL switch on or off, the switch will remain illuminated if the fire warning still exists. With the ENG FIRE handle pulled and fire warning terminated, this switch will remain illuminated until it is moved to OFF.

3. ENG FIRE Handle (3) - red

Illuminates red when an overheat or fire has been detected in respective engine nacelle. At the same time, the following actions will take place automatically:

- MASTER WARNING lights illuminate.
- Alert appears on EAD.
- FUEL switch illuminates red.
- Fire bell sounds.

GEN FIELD DISCONNECT position shuts down the generator and stops the alarm (if not already stopped by pushing MASTER WARNING light). FUEL & HYD OFF position shuts off fuel and hydraulics and allows handle rotation. Pulling forward and rotating handle discharges agent into the engine nacelle. Respective engine FUEL switch on pedestal will illuminate red if it is ON and the ENG FIRE handle is actuated.

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Alerts

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

Red Boxed Alerts (Level 3)

- APU FIRE (ENG) - APU fire is detected.
- CRG FIRE LWR AFT (AIR) - Heat and/or smoke detected in lower aft cargo compartment.
- CRG FIRE LWR FWD (AIR) - Heat and/or smoke detected in lower forward cargo compartment.
- ENGINE 1/2/3 FIRE (ENG) - Respective engine fire.

Amber Alerts (Level 1)

- CARGO FIRE AGT LO (AIR) - Pressure in one or more cargo fire agent bottles is low.
- CARGO FLO AFT OFF (AIR) - The CARGO FIRE AFT FLOW switch has been manually selected OFF.
- CARGO FLO FWD OFF (AIR) - The CARGO FIRE FWD FLOW switch has been manually selected OFF.
- CRG FLO AFT DISAG (AIR) - The aft cargo compartment ventilation flow is in disagreement with the commanded position of the switch on the CARGO FIRE panel.
- CRG FLO FWD DISAG (AIR) - The forward cargo compartment ventilation flow is in disagreement with the commanded position of the switch on the CARGO FIRE panel.
- ENG FIRE AGENT LO (ENG) - One or more of the engine fire agent bottles has low pressure. Observing the overhead panel AGT LOW lights will indicate the affected bottle.

Cyan Alerts (Level 0)

- CARGO FIRE TEST - Cargo fire test in progress.

Description and Operation

General

All primary and secondary flight controls are hydraulically powered, each by at least two, and in some cases, by all three airplane hydraulic systems.

Primary flight controls consist of the ailerons (inboard and outboard), the elevators (inboard and outboard), and the upper and lower two-segmented (forward and aft) rudders.

Secondary flight controls consist of the trailing edge flaps (inboard and outboard), leading edge slats (inboard and outboard), combination speed brakes/spoilers, and an adjustable horizontal stabilizer.

Flight control positions are displayed on the System Display (SD) by selecting the configuration page with the CONFIG cue switch. In addition to the SD, flap and slat positions are also shown on the Primary Flight Display (PFD). Alerts will appear on the Engine And Alert Display (EAD) and SD.

Lateral Control System

The lateral control system consists of inboard and outboard ailerons, augmented on the downward moving wing by spoilers operating in proportion to control wheel displacement and/or spoiler input.

The lateral control system is a full power system. Pilot control wheel motion is transmitted to hydraulic actuators by a closed cable system.

The left-hand inboard aileron and the outboard ailerons of both wings are powered by hydraulic systems 2 and 3. The right-hand inboard aileron is powered by hydraulic systems 1 and 3.

When the flaps, slats, and landing gear are retracted, a lockout mechanism keeps the outboard ailerons faired (neutral) to avoid wing twist. In this case lateral control is provided by the inboard ailerons and the lateral function of the spoilers. As the airplane slows down, the outboard ailerons unlock with flaps extended to 15 degrees, or with slats extended, or with landing gear down and locked.

Longitudinal Control System

The longitudinal control system consists of inboard and outboard elevators. Each surface is powered by two of the three hydraulic systems. The elevator segments respond to commands from the flight crew, the Longitudinal Stability Augmentation System (LSAS), and the autopilot.

A tandem hydraulic actuator, powered by two independent hydraulic systems, combines in pairs to provide full flight envelope hinge movement in the event any single hydraulic system failure occurs. Sufficient power capability to maintain flight is available with the loss of any two systems.

Elevator Load Feel System

The Elevator Load Feel (ELF) system is a self-monitored, dual channel system. A spring-type, variable load-feel mechanism provides a simulated feel of elevator aerodynamic loads. The ELF mechanism acts as a centering device to return the control columns to neutral when released from an off-neutral position. ELF functions are performed by the Flight Control Computers (FCCs). In the event of failure, a brake is applied to the ELF actuator in the failed channel. The remaining channel of the dual channel system maintains uninterrupted EFL system control.

With the ELEV FEEL selector in the AUTO position, the ELF system regulates the control column force per degree of column rotation as a function of airspeed.

The ELF actuator may be operated in the manual mode by pulling the ELEV FEEL selector out and holding the selector in either HI or LO until the desired ELF speed appears on the configuration page of the SD. The ELEV FEEL MANUAL amber light illuminates.

The SEL ELEV FEEL MAN level 2 alert will be displayed to indicate failure of the dual channels of the ELF system. The ELEV FEEL

MANUAL level 1 alert will be displayed to indicate manual selection of the ELEV FEEL selector. In the case of ELF dual channel failure, the SEL ELEV FEEL MAN level 2 alert will be replaced by the ELEV FEEL MANUAL level 1 alert upon ELEV FEEL selection to manual.

Directional Control System

The directional (yaw) control system consists of an upper and lower rudder, each having a forward and an aft segment. The aft segment of each rudder is hinged to the forward segment and is mechanically bused in such a manner that it deflects in the same direction as the forward segment. The upper rudder is powered by hydraulic system 1 and the lower rudder is powered by hydraulic system 2. The full power rudder control system of the MD-11 requires an artificial load feel since no aerodynamic surface loading is fed back to the pedals.

The rudder mechanical control system is operated with pedals in the cockpit. Each pair of pedals is independently adjustable for pilot comfort. The rudder pedal motion is transferred to the rudder actuators by a closed cable system. The rudder pedals also provide input to the nose wheel steering system for directional control on the ground.

Non-Reversible Motor Pumps (NRMP), installed in the hydraulic systems, automatically provide a standby source of hydraulic power to the upper rudder, stabilizer trim, and lower rudder. A compensator with a low fluid level switch automatically shuts off hydraulic flow to the motor side of the NRMP if a compensator low fluid level is detected.

Alerts warn the flight crew when one or both of the NRMPs are inoperative. With both NRMPs inoperative, rudder standby power is unavailable.

A rudder trim system is installed. Dual yaw damper systems for each rudder provide turn coordination and damping of dutch roll. The system operates the rudder hydraulic control valves.

Appropriate alerts and overhead panel annunciations warn the flight crew of yaw damp failures. If a failure is isolated to a single channel, the associated FAIL light illuminates and an alert is displayed. If the failure cannot be isolated to a single channel, the FCC fails both channels on the corresponding surface. In this case, the other FCC maintains dual control. Whenever a channel is selected off, an appropriate amber alert is displayed. If all channels are selected off, the YAW DAMP ALL OFF alert is displayed. If all channels have failed the YAW DAMP ALL FAIL alert is displayed.

Spoiler System

Five spoiler panels are provided on the upper surface of each wing to assist aileron lateral control, reduce speed during flight, and spoil lift for increased brake efficiency. Each spoiler panel is individually powered by one of the three hydraulic systems. All hydraulic systems are required for full spoiler operation.

When used to assist lateral control, the system extends all five spoiler panels on one wing, to a maximum of about 60 degrees from faired, while maintaining the opposite wing panels retracted. When used as speed brakes for slowdown and emergency descent, the system symmetrically extends all panels simultaneously on both wings, to a maximum of about 30 degrees from faired. With flaps retracted during flight, the spoilers can be manually deployed to a maximum of 30 degrees.

When both functions are used at the same time, the panel extension for speed brake function is a maximum 60 degrees on one wing. On the other wing, lateral control panel extension is subtracted from the speed brake panel extension to retract those panels. Flight spoilers, when used as speed brakes or when deployed as ground spoilers retain lateral control differential motion capability.

Spoiler system lateral control assist is active in all modes, extending all spoilers on the downward moving wing in proportion to control wheel movement. All five flight spoilers on each wing are used for lateral control over the flight speed range. The spoiler handle does not move.

Spoiler/speed brake extension and retraction is controlled by the position of the SPOILER handle. The SPOILER handle consists of a T-handle with a latch. Detents in the pedestal allow latching at the 0, 1/3, 2/3, and FULL positions. At the FULL position, a positive (lower) gate prevents further spoiler deployment. This gate, at full speed brake (half ground spoiler) deflection protects against exceeding allowable wing stress levels during flight. The latch is disengaged by squeezing the T-handle or by lifting the handle upward into the ARM position.

The pilot cannot manually deploy symmetrical spoilers with flaps extended 5 degrees or more, except with the autospoiler in transit or the nose gear strut compressed. The maximum available manual spoilers under these conditions is 60 degrees.

With speed brakes deployed and flaps extended, the SPD BRK/FLAP alert is displayed. With flaps or speed brakes retracted, the alert is not displayed.

On the ground, with nose gear strut compressed, pulling the SPOILER handle up and aft to the GROUND SPOILER position extends all ten spoilers to maximum deflection. When in the full aft position, pulling the handle up locks it in that position.

Spoiler extension is accomplished automatically by an Auto Ground Spoiler (AGS) actuator. This provides an increase in drag and a rapid transfer of weight to wheels during landing or Rejected Takeoff (RTO). The FCCs control power to the AGS actuator.

Disarming the SPOILER handle may be initiated at any position during AGS actuation by pushing the T-handle down. The SPOILER handle then moves fully forward to the spoiler retracted (RET) position, drops down to disarmed position, and automatically latches.

After landing, all ten spoiler panels may be extended to maximum deflection by automatic operation of the SPOILER handle. In order for this to occur, the SPOILER handle must be armed and the flaps 31 degrees or more. After main wheel spinup, the SPOILER handle moves to position the full ground spoiler position (GROUND SPOILER) and locks. Maximum ground spoilers are then deployed.

If an RTO is necessary, ground spoilers automatically extend as a function of indicated airspeed when:

- Airspeed is less than 80 knots, with auto spoilers armed, and any two of the three throttles is moved to reverse thrust.
- Airspeed is greater than 80 knots, with auto spoilers armed, and any two of the three throttles is moved to idle.

The SPOILER handle must be armed for automatic deployment of ground spoilers for either landing mode or rejected takeoff mode. Moving the SPOILER handle from the RET position enables the Autobrake System (ABS).

A spoiler bias system extends the spoilers as necessary so that the spoiler panels will not touch the flap/vane surfaces. When the aircraft is on the ground the spoilers may be up a small amount (gap) depending upon slat/flap position, aileron trim knob position, and spoiler cable system temperature.

Flap System

The trailing edge flap system consists of inboard and outboard flap segments on each wing. Each segment is powered by two of the three hydraulic systems. The inboard flap control valve is connected to the cockpit flap handle. The inboard flaps are interconnected by a cable bus system to ensure symmetrical motion. The flap system is mechanically controlled by the FLAP/SLAT handle on the forward pedestal. Each flap is driven by two independently powered hydraulic actuators. The outboard actuator on each flap is driven by hydraulic system 1 and the inboard actuator by hydraulic system 2.

An automatic Flap Limiting system (FL) is installed. There is no automatic flap limiting up to an airspeed of 175 knots. Beyond that airspeed, when the flaps are extended between 22 and 50 degrees, the system provides automatic retraction, and prevents further extension, if flap position airspeed limits are exceeded, by automatically returning the flaps to the originally selected position as airspeed is reduced. A manual override is available in the event of a malfunction.

The SEL FLAP LIM OVRD level 2 alert will be displayed to indicate that both flap limiting channels have failed and manual override is required. The FLAP LIMIT OVRD level 1 alert will be displayed to indicate manual selection of the FLAP LIMIT selector to OVRD 1 or 2. In the case when both flap limiting channels have failed, the SEL FLAP LIM OVRD level 2 alert will be replaced by the FLAP LIMIT OVRD level 1 alert upon manual selection of the FLAP LIMIT selector to OVRD 1 or 2.

The flap indicating system includes the following:

- Position transmitters in the left and right outboard flap follow-up systems that send signals to the FCCs.
- These signals cause flap position to be displayed on the SD. The left outboard transmitter provides a takeoff warning when the flaps are extended 29 degrees or more (not takeoff).
- Also installed is a switch that provides the landing gear warning when the flaps are extended 35 degrees or Position transmitters in the left and right inboard flap drive systems provide position control signals that will display on the SD a 4 degree inboard flap angle disagreement.
- The signals are also used by the autothrottle and flight recorder systems.
- A FLAP/SLAT handle transmitter under the pedestal compares commanded handle position with the outboard flap position transmitters. If the signals disagree by 4 degrees or more, an indication appears on the SD. The flight crew must lift the FLAP/SLAT handle and then position the handle in one of the takeoff detents.

Flaps position may be selected using the dial-a-flap system, a moveable detent for flaps settings. The detent is selected by rotating the dial-a-flap thumbwheel until the required detent flap setting appears in the FLAP T.O. SEL window. Fifteen non-linear divisions are displayed in the window. These divisions represent detent settings between 10 degrees and 25 degrees of flap deflection. Rotation of the thumbwheel drives the indicator and positions the detent.

A moveable detent for takeoff allows setting the flaps at the position which would provide best takeoff performance for a given set of field conditions.

To set takeoff flaps and slats, the flight crew rotates the thumbwheel until the proper takeoff flap setting is displayed in the FLAP T.O. SEL window. The flight crew then lifts the FLAP/SLAT handle out of the 0 degree detent and pulls aft until the handle latches in the detent.

To retract takeoff flaps and slats, the flight crew grasps the FLAP/SLAT handle and lifts up while moving the handle forward. When the 0 degree detent is reached, the handle is pushed down and forward until the handle reaches the retract position.

To extend landing flaps and slats when in the UP/retract detent, the flight crew lifts the FLAP/SLAT handle up and aft past the go-around gate to either the 35 degree or 50 degree landing detent.

To retract landing flaps and slats, the flight crew lifts the FLAP/SLAT handle out of the detent and moves it forward, pushing down and then up to pass the go-around gate. When the 0 degree detent is reached, the flight crew pushes down and forward to the retract position. For electric slats (see next page) the handle has to be lifted over a gate and pushed forward to the UP/RET detent for slat retraction.

Slat System

The slat system is hydraulically actuated. The outboard and inboard slats are positioned automatically by moving the FLAP/SLAT handle on the forward pedestal. An electrically controlled slat system replaces the cable controlled system. With this system FLAP/SLAT handle operation is simplified. The 28 volt right emergency DC bus and the 28-volt DC bus 2 power the system.

Eight leading edge slat segments on each wing are used for lift augmentation. The slats extend during takeoff and again during landing approach to provide maximum lift. The slat positions are retract and land.

The automatic slat extension system extends the outboard slats within 8.5 seconds to 30 degrees when the stall warning system detects 1.05 VS 1 G (1 -G stall speed) prestall logic conditions. When conditions permit, the FCCs automatically retract the slats. The FCCs inhibit activation of the automatic slat extension system for airspeeds more than 0.55 Mach/280 knots.

The auto slat system is not affected by the AFS OVRD switch on the FCP. Auto slat extension begins just after activation of the stall warning stickshaker. The FLAP/SLAT handle does not move during auto slat extension.

Auto slat extension is annunciated by SLATS ASE in the lower left of the PFD. SLATS ASE will override SLAT DISAG during auto slat extension.

The SLAT DISAG alert appears when asymmetric slats are detected or when the FLAP/SLAT handle position disagrees with slat position.

A SLAT STOW switch, located on the forward pedestal, deactivates slat extension and illuminates amber when activated. The flaps operate normally as selected with slats deactivated.

Lateral Trim System

Lateral trim, driving aileron and spoiler actuators through a cable system, is accomplished with the aileron trim knob on the center pedestal.

When the trim knob is moved, the neutral point of the ailerons is repositioned. If more than 5 degrees of aileron trim is commanded, the lateral control spoilers begin to deflect upward, as required, to provide additional trim. Spoiler trim motion is limited to 7 degrees.

Aileron trim is indicated on the aileron trim indicator, the surface position indicator, and by physical displacement of the control wheel.

Directional Trim System

Directional trim is accomplished with the rudder trim knob on the center pedestal. The rudder trim knob repositions the neutral point of the rudders. Rudder trim motion is limited to 13 degrees in both directions.

Rudder trim is indicated on the rudder trim indicator, on the surface position indicator, and by physical displacement of the rudder pedals.

Longitudinal Trim System

Longitudinal trim is provided by a two-speed, hydraulically powered adjustable stabilizer. The stabilizer is actuated by two hydraulic motors powered independently by hydraulic systems 1 and 3. Hydraulic system 2 provides backup hydraulic power to the stabilizer through the 2-1 NRMP.

The stabilizer operates automatically at two different trim rates as a function of airspeed and/or altitude to provide optimum performance. To accomplish smooth and appropriate longitudinal trim operation for all flight conditions, the two trim rates are provided for each mode of operation. The rate change occurs at 250 knots airspeed or at 33,000 feet, and is also dependent upon which stabilizer control input is in use.

A compensator with a low fluid level switch automatically shuts off hydraulic flow from hydraulic system 2 to the 2-1 NRMP if fluid level is low in the compensator.

Four modes of operation are available as follows:

1. Autotrim [longitudinal stability augmentation system (LSAS)]
2. When LSAS is engaged in pitch attitude hold (force on column less than 2 pounds), the automatic pitch trim moves the horizontal stabilizer to trim out steady state elevator commands. The FCC operates one trim motor in this mode. Rate (high or low) is based on altitude and airspeed.
3. Autotrim, using the autopilot.
4. When the autopilot is engaged, the autotrim function controls the stabilizer based on average elevator position offsets. When the AFS OVRD switch on the FCP is pushed to OFF, AP automatic pitch trim turns off.
5. Manual trim, using switches.

6. Full-time actuation of both trim motors is available to the pilot through use of the manual trim switches on both control wheels. These switches move the stabilizer in the commanded direction and disengage the autopilot from any engaged mode (except DUAL or SINGLE LAND).
7. Manual trim, using the LONG TRIM handles.
8. Override of the electrical trim systems is accomplished with a pair of LONG TRIM suitcase style handles on the Captain's side of the forward pedestal. The LONG TRIM handles remain stationary when the control wheel switches operate trim. Use of these handles disconnects the autopilot from any engaged mode (except DUAL or SINGLE LAND).

Longitudinal Stability Augmentation System (LSAS)

The Longitudinal Stability Augmentation System (LSAS) enhances longitudinal stability and provides:

- Pitch attitude hold
- Pitch attitude limiting
- Pitch rate dampening
- Automatic pitch trim
- LSAS speed protection
- LSAS stall protection

LSAS is off when the autopilot is engaged, or when the airplane is below 100 feet AGL. LSAS is not affected by the AFS OVRD switch on the FCP.

With no force on the control column, and bank angle less than 30°, LSAS holds the current pitch attitude. LSAS holds the pitch attitude by deflecting the elevators as much as 5°. The horizontal stabilizer is automatically adjusted to relieve the sustained elevator deflection and maintain a full 5° elevator authority.

Stabilizer motion is displayed on the SD Synoptic, CONFIGURATION page, when the CONFIG cue switch is selected.

LSAS maintains pitch attitude to less than 10° of dive, or less than 30° of climb. Below 1500 feet, if there is more than approximately 2 pounds of force on the control column, LSAS is inoperative. Once the pilot applies about 4 pounds of control column force, the elevators respond to pilot command input.

Above 20,000 feet, LSAS provides pitch rate damping when force is applied to the control column. This damping is gradually reduced to zero, between 20,000 feet and 15,000 feet.

LSAS provides speed and stall protection. This is fully discussed in the autoflight chapter.

Each of the two FCC's has two LSAS channels. Each channel controls one of the four hydraulic actuators at the elevators. If fewer than four channels are available, LSAS is made available by increased gain on the surviving channels. At least one channel must be operational.

Alerts and AFS panel switches warn the flight crew of LSAS failures. If the failure cannot be isolated to a single channel, the FCC fails both channels on the corresponding surface. In this case, the other FCC maintains control. LSAS channels are monitored and turned off by switches on the AFS panel. If a failure is detected, the affected channels shut down automatically. FAIL illuminates on the corresponding LSAS switches.

Following FCC failure, dual control is maintained by the other FCC. The flight crew must deselect the failed channels to extinguish the corresponding FAIL light, and to arm the remaining FCC. This allows single channel operation for any subsequent failures that can be isolated. Following a subsequent failure in one channel of the remaining FCC, if the fault can be isolated, the remaining good channel maintains control.

Whenever a channel is selected off, a corresponding alert is displayed on the EAD. If all channels are selected off, LSAS ALL OFF is displayed on the EAD. If all channels have failed, LSAS ALL FAIL is displayed.

Stall Warning System

The dual stall warning system provides indications of an impending stall.

Stall warning indications can be divided into two categories, alpha-based (angle-of-attack) and speed-based. The two categories will not match unless the airplane is in steady state, level, 1g, non-maneuvering flight.

Stall warning is not affected by the AFS OVRD switch on the FCP.

Alpha-based indications are more accurate than speed-based indications during maneuvering flight. They are generated by the FCC and are the function of alpha, alpha rate, flap position, slat position, and Mach number.

In a slowdown maneuver, prior to stickshaker, alpha-based indications are as follows:

- The PLI on the PFD meshes with the airplane symbol and turns amber.
- PFD airspeed digits turn amber and are boxed in amber.
- LSAS stall protection (nose down elevator) engages if windshear command guidance is off. If windshear command guidance is on, LSAS stall protection engages later (red PLI).

At stickshaker condition:

- PLI feathers mesh with the horizon bar and turns red.
- PFD bank angle limits turn red.
- PFD airspeed digits turn red and are boxed in red.
- Stickshaker actuates (all configurations, to Mach 0.90).
- Outboard slats (autoslats) extend and remain extended for 5 seconds after the condition has been corrected. This applies if in clean configuration with Mach at or below 0.55.
- LSAS stall protection engages if windshear command guidance is on. If windshear command guidance is off, LSAS stall protection should have engaged earlier (amber PLI).

Speed-based indications are accurate only during level maneuvering (bank angle compensated only). They are generated by the FMC.

In a steady slowdown, speed-based indications apply. When the airplane slows to Vmin:

- The airspeed pointer hits the top of the amber column on the PFD airspeed tape.
- The airspeed digits turn amber and are boxed in amber.

As the airplane slows more and reaches Vss:

- The airspeed pointer hits the top of the red column on the PFD airspeed tape.
- The airspeed digits turn red and are boxed in red.

If the airplane has not climbed through the ACCEL altitude (FMS TAKEOFF page and G/A page) and flaps and slats are extended, the Vmin marker on the airspeed display is a function of 1.2 Vs. If flaps are extended with slats retracted, the Vmin marker is a function of 1.25 Vs. Vmin returns to 1.3 Vstall after the airplane has climbed through ACCEL altitude.

Takeoff Deflected Ailerons System

NOTE: TDAS is a customer option on the MD-11. You can enable/disable TDAS in the PMDG Options menu.

A system for takeoff deflected ailerons deflects the inboard and the outboard ailerons for takeoff and allows an additional takeoff flap setting of 28°.

With this system, for takeoff only, the neutral position of the ailerons is as follows:

- 15° trailing edge down on the outboard ailerons.
- 11.5° trailing edge down on the inboard ailerons.

During all phases of flight except takeoff, the neutral (baseline) position of the ailerons is as follows:

- 4° droop trailing edge down on the outboard ailerons.
- 0° (faired) on the inboard ailerons.

With the autopilot engaged, the control wheel moves slightly in roll and returns to neutral when the flap/slat handle is moved to takeoff flap setting, and again when the flap/slat handle is moved from the takeoff flap setting to 0/EXT.

Nose gear strut compression enables the takeoff command for aileron deflection. Once enabled, placing the FLAP/SLAT handle in the takeoff flap range signals the actuator for deflection. Placing the FLAP/SLAT handle in a setting other than the takeoff flap range removes aileron deflection. Repositioning the handle back into the takeoff flap range while the airplane is still on the ground restores the deflected aileron.

MD-11 DEF AIL is displayed on the FMS A/C STATUS page when the airplane is configured for deflected ailerons takeoff.

The AIL DEFLECT DISAG alert is displayed if the ailerons are not in proper position based on selected flap position, phase of flight, and actual aileron position.

During takeoff, the aileron symbols on the SD synoptic CONFIGURATION page droop to show the 15° trailing edge down (outboard ailerons) and 11.5° trailing edge down (inboard ailerons). The baseline 4° droop (non-takeoff flight phases) is not indicated on the SD.

Following takeoff (nose gear strut not compressed) aileron deflection remains until normal wing cleanup when the FLAP/SLAT handle is positioned out of the takeoff flap range. The ailerons return to baseline configuration (4° droop on outboard ailerons and 0° inboard). The deflected aileron position is not enabled again until nosewheel strut compression occurs and the FLAP/SLAT handle is again placed in the takeoff flap range. Landings occur in the baseline aileron configuration.

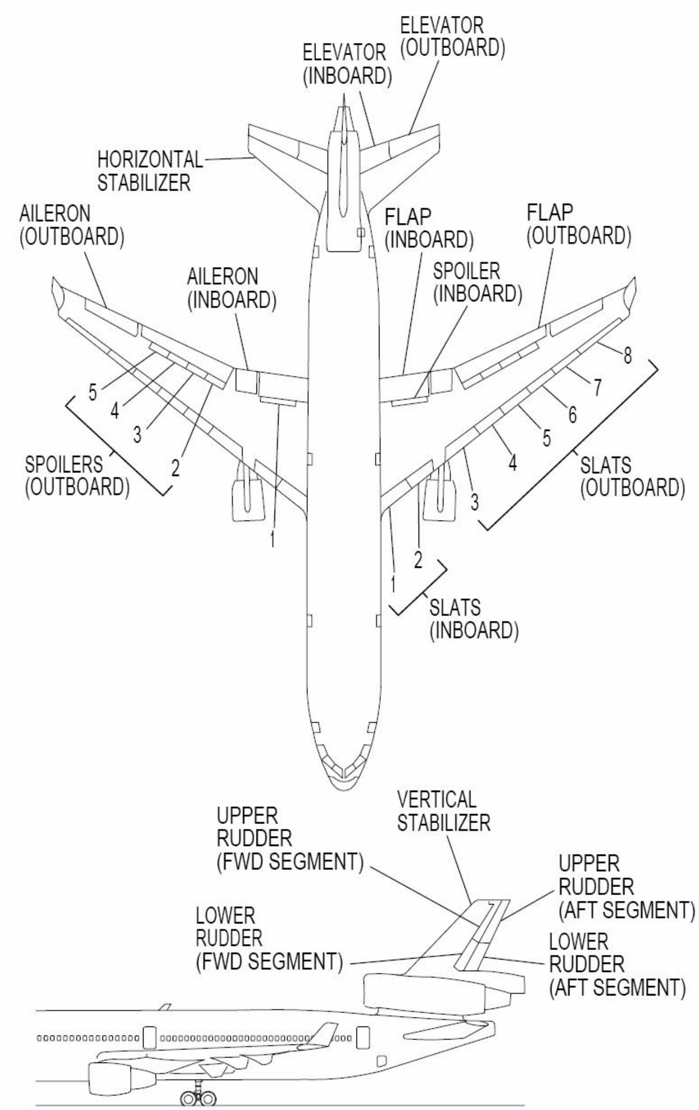
The aileron lockout system is not affected by the deflected aileron system. Outboard ailerons continue to be locked out with slats and flaps not extended and main landing gear retracted. Extension of flaps, slats, or gear unlocks the outboard ailerons.

Spoiler operation is not affected by the deflected aileron system. Spoiler movement on roll command occurs at the same wheel position. When the ailerons are deflected, the aileron position to spoiler position is offset by the amount of aileron deflection commanded.

Aileron trim is not affected by the deflected aileron system. Use of the aileron trim wheel repositions the aileron surfaces whether or not the ailerons are deflected. Deflected ailerons are repositioned from the deflected position. When ailerons are not deflected, trimming repositions the ailerons from the baseline configuration.

When control wheel deflection is more than 45°, control wheel force is approximately double.

Components


ELEVATOR
(OUTBOARD)
ELEVATOR
(INBOARD)
HORIZONTAL
STABILIZER
AILERON
(OUTBOARD)
FLAP
(INBOARD)
FLAP
(OUTBOARD)
AILERON
(INBOARD)
SPOILER
(INBOARD)
5
4
3
2
1
SPOILERS
(OUTBOARD)
8
7
6
5
4
3
2
1
SLATS
(OUTBOARD)
SLATS
(INBOARD)
UPPER
RUDDER
(FWD SEGMENT)
VERTICAL
STABILIZER
UPPER
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(AFT SEGMENT)
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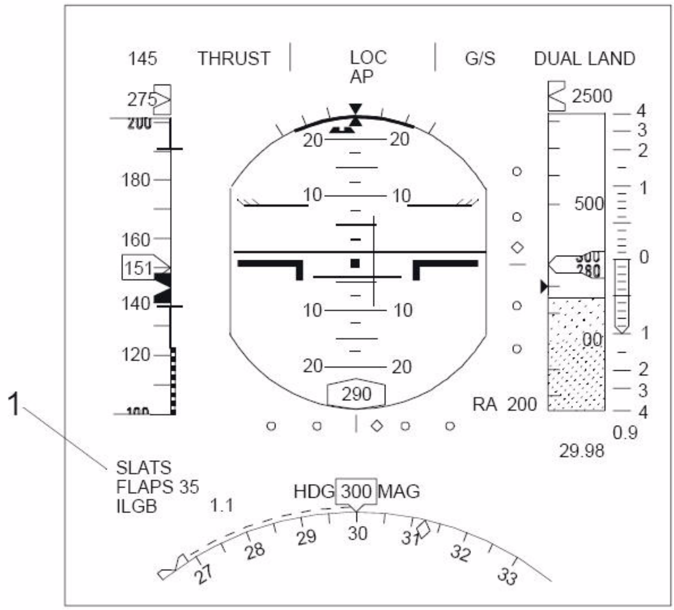
Controls and Displays

EIS Primary Flight Display



INSTRUMENT PANEL

FLAP/SLAT Configurations

Flap/slat configuration affecting mach/airspeed limits is shown below the airspeed tape.

Invalid flap positions are flagged with an amber "X".

Slat messages are amber boxed when in disagreement with the commanded state and flaps are extended.

FLAPS 35 - Flaps down 35°.

FLAPS 35 (with down arrow) - Flaps set at 35° and extending.
FLAPS 10 (with up arrow) - Flaps set at 10° and retracting.
FLAPS (amber) - Inboard flaps are split.

FLAPS 25/35 - Outboard flaps are split.

SLATS (with down arrow) - Slats in transit (down).

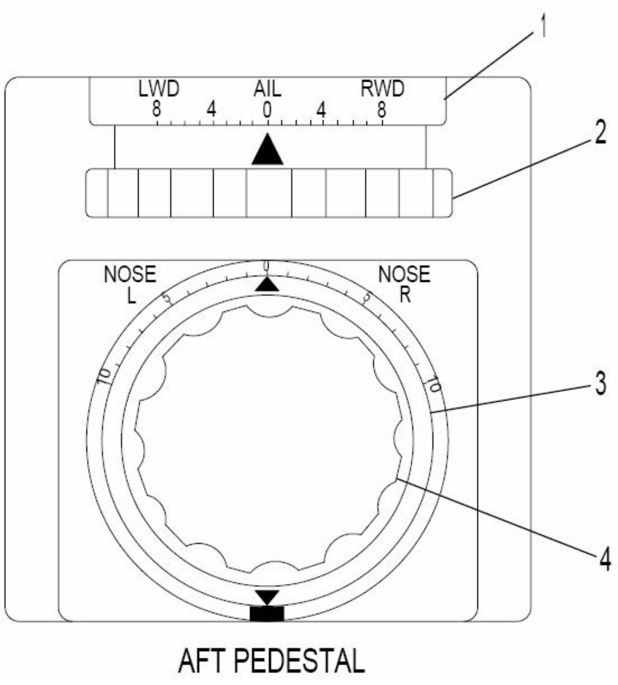
SLATS (with up arrow) - Slats in transit (up).

SLATS ASE - Slats are in auto extension.

SLATS - FLAP/SLAT handle in 0°/EXT and slats are extended.

NO SLATS - SLAT STOW switch or lever is activated and FLAP/ SLAT handle is more than 3°.

Aileron and Rudder Trim



1. AIL Trim Indicator

   LWD - Indicates left wing down as shown in units on scale.
   RWD - Indicates right wing down as shown in units on scale.

2. Aileron Trim Knob

   When rotated, repositions the aileron load feel and override mechanism, which repositions the ailerons and the control wheels to effect lateral trim.

   If more than 5 units of aileron trim is selected, spoilers are activated. Full aileron trim extends spoilers 6°.

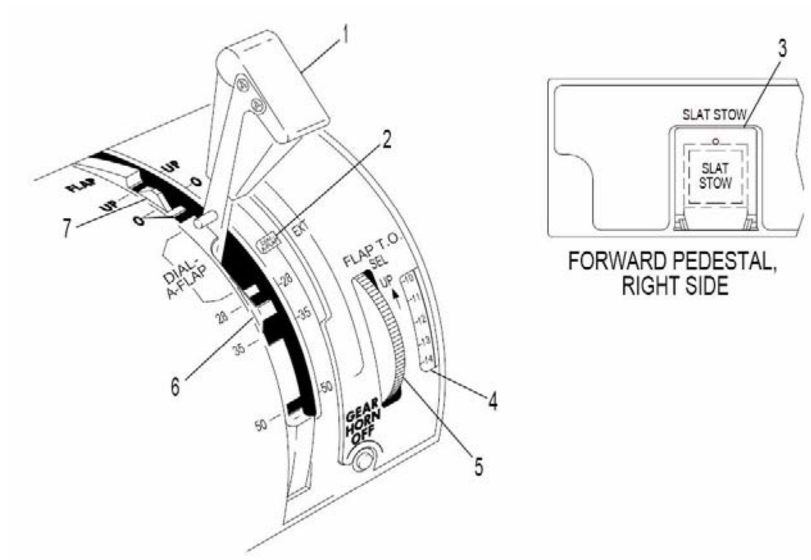
3. Rudder Trim Indicator

   The pointer indicates the direction of rudder displacement from neutral. NOSE L - Indicates nose left trim as shown in units on scale. NOSE R - Indicates nose right trim as shown in units on scale.

4. Rudder Trim Knob

   When turned, provides manual adjustment to the lower and the upper rudder trim and load feel mechanism, which repositions the lower and the upper rudders.

FLAP/SLAT Handle - Electrically controlled slats



1. 1. FLAP/SLAT Handle

   Lifting FLAP/SLAT handle up and pulling aft to latch in preselected takeoff DIAL-A-FLAP detent, 28° go-around gate, or 35°/50° landing flap detent, extends the flaps and the slats.

   Rotating the FLAP T.O. SEL thumbwheel until the proper takeoff flap setting appears in the FLAP T.O. SEL indicator sets the takeoff DIAL-A-FLAP detent.

   The 28° go-around detent has a gate/stop to prevent inadvertent extension/retraction of the flaps. The handle can be maneuvered past the gate/stop.

   Lifting the handle up and aft past the go-around gate to either the 35° or the 50° landing detent extends landing flaps.

   Lifting the handle out of the detent and moving it forward past the go-around gate retracts landing flaps.

   Positioning the handle at the 0°/EXT detent (flaps retracted/ slats extended) retracts the flaps without retracting the slats.

Maneuvering the handle from the 0°/EXT detent gate to positively engage it in the FLAP UP/SLAT RET detent retracts the slats.

2. DIAL-A-FLAP Detent Indicator

   Indicates position of DIAL-A-FLAP detent. The detent position varies with the DIAL-A-FLAP setting.

3. SLAT STOW Switch - amber

   SLAT STOW - With the FLAP/SLAT handle in retract position, pushing the SLAT STOW switch deactivates the slat extend function. Switch illuminates amber. With the FLAP/SLAT handle positioned greater than 3°, NO SLATS is displayed on the PFD.

   With DEU-908 and subsequent installed, a SLAT STOW alert is displayed on the SD CONFIGURATION page. A SLAT DISAG alert is displayed when operating the SLAT SSpoilersTOW switch with slats extended.

   NOTE: Pushing the SLAT STOW switch with slats stowed and flaps extended extends the slats.

4. FLAP T.O. SEL Indicator

   Indicates the preselected DIAL-A-FLAP takeoff flap setting.

5. FLAP T.O. SEL Thumbwheel

   When rotated, sets the DIAL-A-FLAP takeoff flap setting for any flap setting between 10° and 25°.

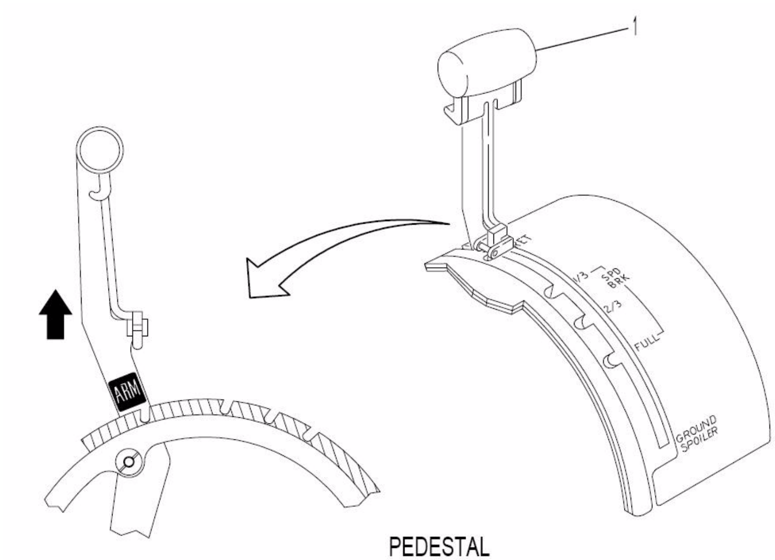
6. Go-Around Gate

   Prevents retraction of the flaps to less than 28° until lifting pressure is released (the handle drops into the 28° detent) and then reapplied (the handle passes through the gate).

7. 0 Degree EXT Detent Gate

   Prevents retraction of the slats with the flap handle at 0 degrees.

Spoilers



1. SPOILER Handle

   The spoiler handle is used to either select automatic operating modes or to control the manual modes of the spoiler system.

   When arming for automatic spoiler operation, the spoiler handle, which is spring-loaded to RET, must be at RET before it can be pulled up to armed. When armed (up), a red placard labeled ARM in white letters, is visible on both sides of the handle.

   When auto spoilers are armed, automatic operation is as follows:

   - During a rejected takeoff, ground spoilers automatically extend when airspeed is less than 80 knots, and any two of the three throttles move into reverse thrust. With airspeed greater than 80 knots, moving any two throttles to idle deploys ground spoilers.

- During landing, with flaps 30° or greater and after main wheel spinup, the spoiler handle moves to approximately the two-thirds position. At nose gear touchdown, the handle moves to full ground spoiler position and the ground spoilers fully extend.

After ground spoiler extension, advancing throttle 2 automatically moves the SPOILER handle to full forward, retracting the spoilers. If the number 2 engine throttle is not at idle at main gear spin-up it is possible that the AGS will initiate deployment and will then immediately retract the spoilers. If this occurs, ground spoilers must be manually extended.

Manual spoiler operation is as follows:

- In flight, the handle controls the speed brake mode when the "T" handle release is squeezed and pulled aft to the 1/3, 2/3, or FULL position. The handle stops at FULL.

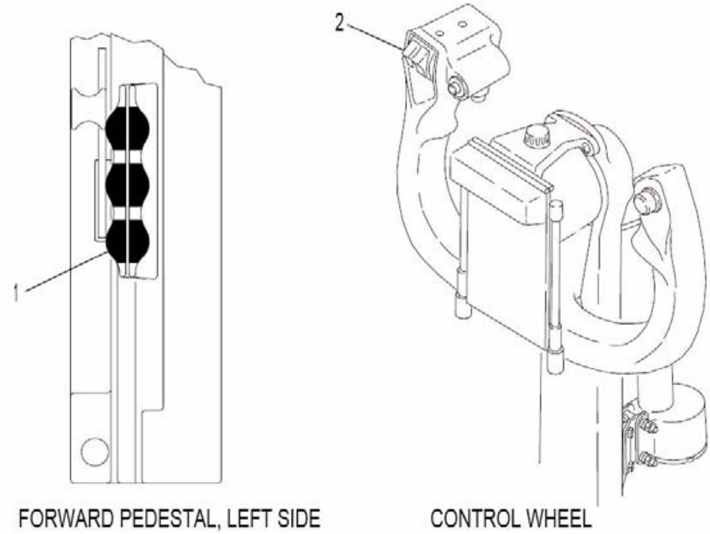
1/3 - all 5 spoilers on both wings extend 10°.

2/3 - all 5 spoilers on both wings extend 20°.

FULL - all 5 spoilers on both wing extend 30°.

- In the ground, the handle controls the ground spoiler mode when pulled up and aft to the GROUND SPOILER position. Pulling the handle up again locks it aft.
- “The handle can inadvertently be placed at the GROUND SPOILER position during flight if deliberately pulled up through the FULL speed brake position, and then aft.

Horizontal Stabilizer Trim



1. LONG TRIM Handles

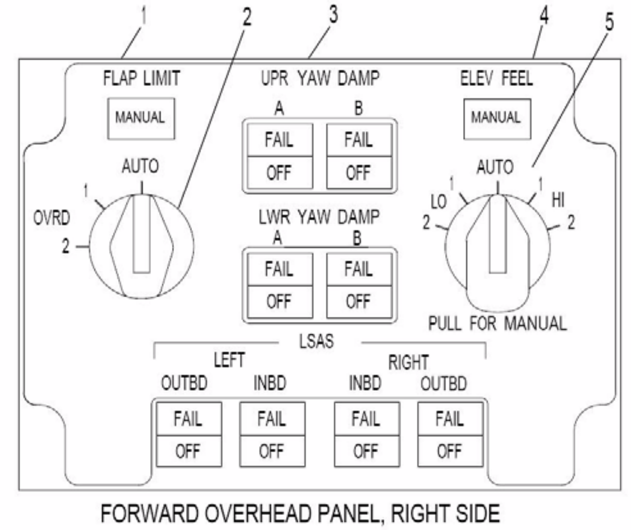
   The handles provide direct mechanical control of the horizontal stabilizer control valves. The trim handles have the same function as the electric control wheel trim switches, except that they have override authority over LSAS or autopilot inputs.

   Moving the handles together provides control of the horizontal stabilizer. Stabilizer movement rate is determined by airspeed and altitude. Both handles must be operated together to move the horizontal stabilizer.

2. Control Wheel Trim Switches (Capt & F/O)

   Stabilizer motion is electrically controlled by dual trim switches on each control wheel. Actuation of the switches engages both horizontal stabilizer trim motors. Both switches on the respective control wheel must be operated simultaneously and in the same direction. Stabilizer motion rate is determined by airspeed and altitude.

Flap limit, Yaw Damp, Elevator Feel and LSAS



1. FLAP LIMIT MANUAL Light - amber

   MANUAL - Illuminates amber when both flap limiter channels fail, or when the FLAP LIMIT selector is in OVRD 1 or 2.

2. FLAP LIMIT Selector

   The FLAP LIMIT selector is used to manually override the auto mode of the flap limiter.

   AUTO - The flap limiter automatically retracts the flaps if the airspeed exceeds limits for flap settings between 22 and 50 degrees.

   OVRD 1 or 2 - Automatic flap limiting is bypassed.

3. YAW DAMP and LSAS Switches - amber

   OFF - When a YAW DAMP or LSAS switch is pushed, the respective control channel shuts off and OFF illuminates amber. With OFF illuminated, pushing a YAW DAMP or LSAS switch engages the respective control channel, if not failed.

FAIL - The respective FAIL light automatically illuminates amber during a failure of a yaw damper or LSAS control channel, and the failed control channel shuts off.

4. ELEV FEEL MANUAL Light - amber

   MANUAL - The ELEV FEEL MANUAL light illuminates amber when both Elevator Load Feel control (ELF) channels fail, or when the ELEV FEEL selector is pulled to MANUAL.

5. ELEV FEEL Selector

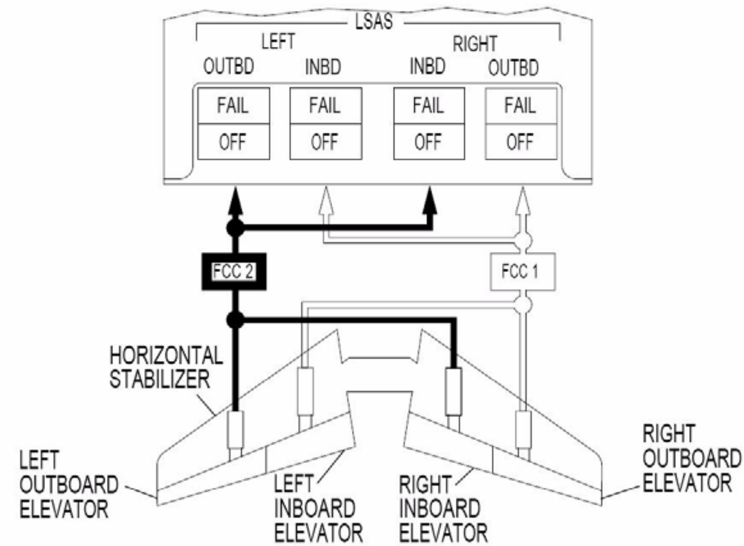
   The ELEV FEEL selector allows manual slewing of the ELF when airspeed is between 120 and 300 knots.

   With the selector in AUTO, the ELF is varied automatically to correspond with the airspeed.

   HI - The MANUAL HI position allows slewing of the ELF to a higher airspeed. The airspeed is displayed on the configuration page of the SD.

   LO - The MANUAL LO position allows slewing of the ELF to a lower airspeed. The airspeed is displayed on the configuration page of the SD.

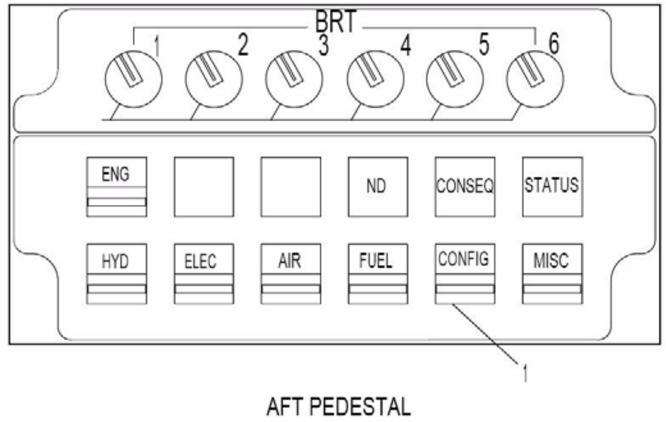
LSAS Channels



LEFT OUTBD/RIGHT INBD - Flight Control Computer 2 (FCC2) controls the left outboard and the right inboard hydraulic actuators at the elevator segments through two of four discreet LSAS channels.

RIGHT OUTBD/LEFT INBD - Flight Control Computer 1 (FCC1) controls the right outboard and the left inboard hydraulic actuators at the elevator segments through two of four discreet LSAS channels.

CONFIG Cue Switch

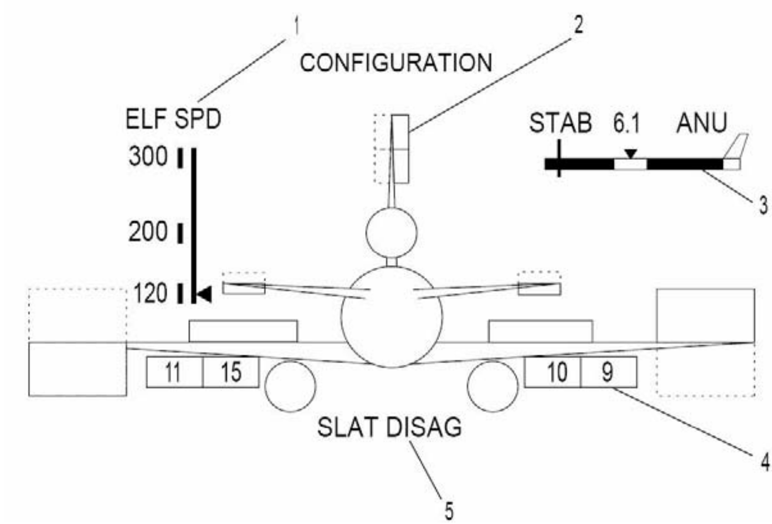


1. CONFIG Cue Switch - white

   CONFIG - Illuminates white when CONFIG alert is displayed on EAD. When pushed:

   - MASTER CAUTION or MASTER WARNING lights extinguish.
   - Reminder message replaces EAD alert.
   - Flight control synoptic and consequences appear on SD.

SD Synoptic- CONFIGURATION



1. Elevator Load Feel Speed

   ELF SPD - The speed is displayed when ELF is in MANUAL by an arrow (reference speed bug) pointing to the current ELF reference speed.

   With ELF in MANUAL and reference speed not available, the ELF arrow (reference speed bug) is not displayed.

2. Rudder, Elevator, Spoiler, Aileron Position - grey, white, green or amber Faired - A grey outline appears.

   Deflected - A white box appears at the respective location. The box size is proportional to the amount of deflection.

   Fully Deflected - A solid green box appears at the respective location.

   Position Not Available - An amber "X" appears in the respective control surface box.

   During takeoff, the aileron symbols deflect to show the 15° trailing edge down of the outboard ailerons and the 11.5° trailing edge down of the inboard ailerons. (Applies only to airplanes with A1 takeoff deflected aileron package installed).

3. Stabilizer Position - green, amber Stabilizer position is depicted inside the schematic fuselage.

   On the ground, stabilizer position is green when within the computed takeoff band.

   If stabilizer trim is more than 2 units different than computed trim setting on the T/O page, the takeoff warning sounds when takeoff power is applied.

   Trim limits are shown when the stabilizer has reached maximum travel. The upper limit is depicted above the stabilizer position by a downward pointing amber triangle. The lower limit is depicted by an upward pointing amber triangle.

4. Flap Position - grey with white or amber

   Flaps are shown under the wing as a fixed-size grey box with white digital readout of the flap position.

   Retracted - Boxes are removed.

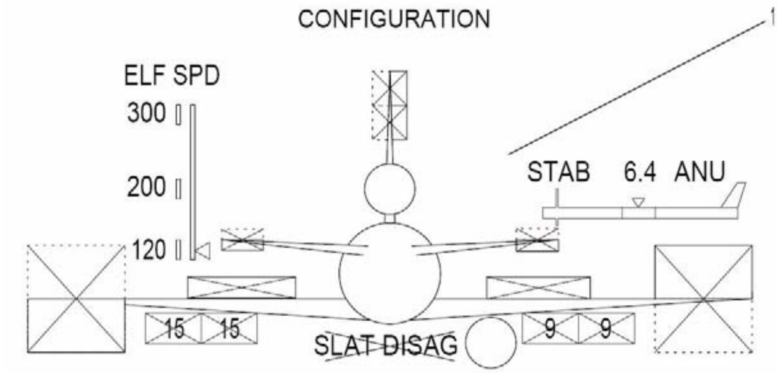
   Position Not Available - An amber "X" appears in the respective left or right (inboard and outboard) flap position box.

5. Slat Position - white, amber

   Slat position is displayed below the schematic fuselage. There is no annunciation when the slats are retracted.

   SLAT EXT - The slat position annunciation appears in white.
   SLAT DISAG - The slat position annunciation appears in amber.

SD Synoptic - EIS Test



1. 1. EIS Test Display - amber, red

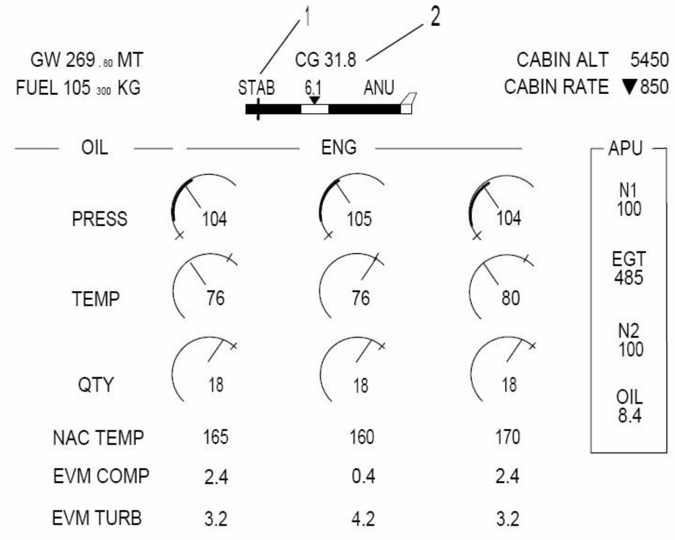
   On the ground, pushing the ANNUN LT TEST switch (forward overhead panel) causes the configuration page SD synoptic and all data failure indications to be displayed.

   SD configuration display failure indications are amber X's over the rudders, elevators, ailerons, spoilers, and flaps. The four gear indicators will each be half green and half red.

   These indications appear when all of the following conditions are met:

   - The airplane is on the ground.
   - The airplane is operational.
   - The ANNUN LT TEST button on the forward overhead panel is pushed.
   - The CONFIGURATION page is displayed on the SD.

Synoptic - Secondary Engine - Dials



1. STAB - green, white

   A horizontal bar represents the stabilizer range. A green band, removed in flight, displays the stabilizer takeoff range. The STAB position is displayed in white digits and with a bug.

2. CG - white, boxed amber

   Center of gravity (CG) is expressed in white digits, in percent MAC. The display flashes when the forward or aft CG limit is reached. The white digits become boxed amber when the CG is out of limits.

Alerts

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

Amber Boxed Alerts (Level 2)

- AIL DEFLECT DISAG (CONFIG) - Aileron(s) not in proper position based on selected flap position and phase of flight.
- FLAP DISAG (CONFIG) - More than 4 degrees position difference between flap handle and outboard flap, or more than 4 degrees position difference between L and R inboard flaps, or more than 4 degrees position difference between L and R outboard flaps exists.
- LSAS ALL FAIL (CONFIG) - All LSAS channels failed.
- SEL ELEV FEEL MAN (CONFIG) - Both elevator load feel transmitters inoperative.
- SEL FLAP LIM OVRD (CONFIG) - Both flap limiter channels have failed. Crew must select OVRD 1 or 2.
- SLAT DISAG (CONFIG) - Slats asymmetric or not in selected position.
- YAW DAMP ALL FAIL (CONFIG) - All yaw damper channels have failed or are off.

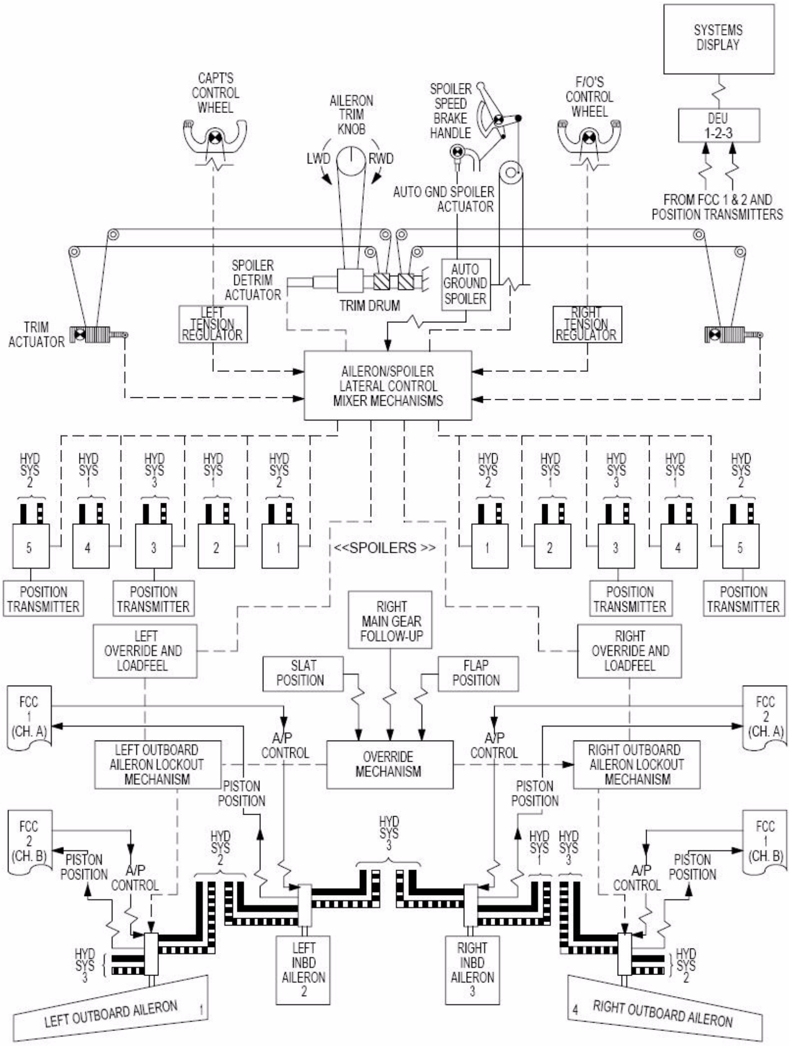
Amber Alerts (Level 1)

- AIL DEFLECT INOP (CONFIG) - Aileron deflection is inoperative.
- ELEV FEEL MANUAL (CONFIG) - ELEV FEEL selector is out of the AUTO in position.
- FLAP LIMIT OVRD (CONFIG) - FLAP LIMIT selector is out of AUTO position.
- LSAS ALL OFF (CONFIG) - All LSAS switches off.

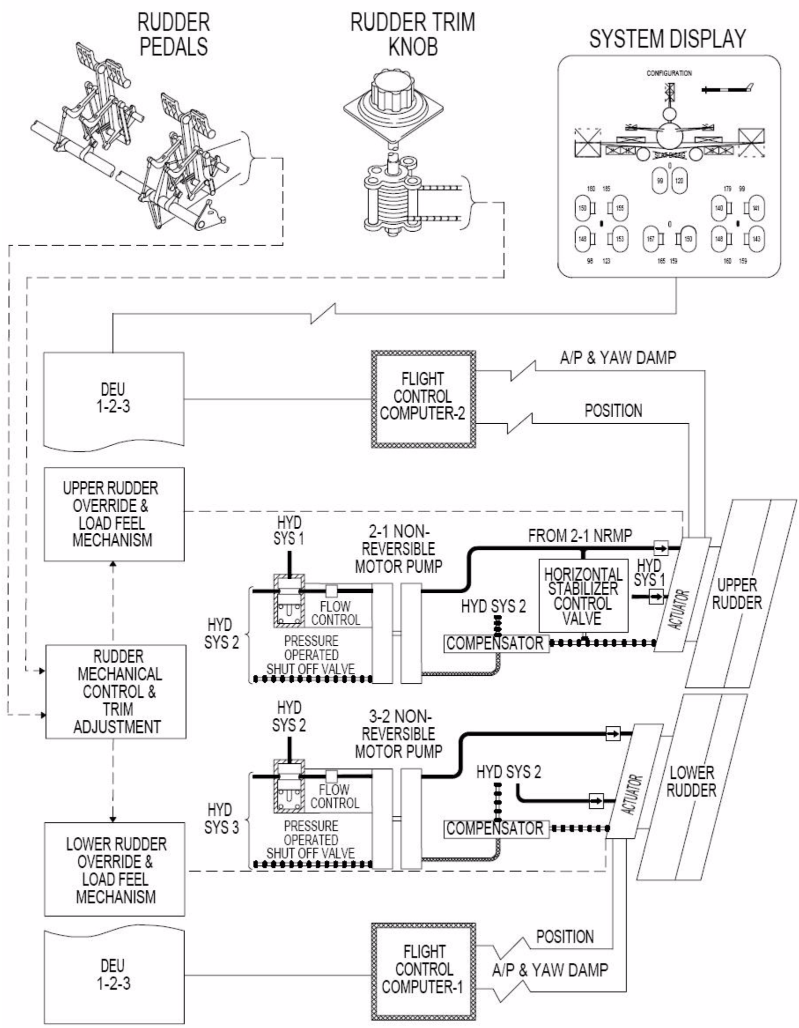
- LSAS L/R INBD OFF (CONFIG) - Left/right inboard LSAS switch OFF. LSAS L/R OUTBD OFF (CONFIG) - Left/right outboard LSAS switch OFF.
- RETRACT SPD BRK (CONFIG) - Speed brakes and flaps are extended in flight.
- SEL ELEV FEEL LO (CONFIG) - Airspeed less than 200 knots and ELF speed indicator more than 200 knots with ELF selected to MANUAL position.
- SEL LSAS (LIB, LOB, RIB, ROB) OFF (CONFIG) - An LSAS channel has failed.
- SEL YAW (UPR A, UPR B, LWR A, LWR B) OFF (CONFIG) - A yaw damper channel has failed.
- SLAT STOW (CONFIG) - SLAT STOW switch is activated. Electrically controlled slats.
- SLATS INHIBITED (CONFIG) - Slat mach inhibit relay is preventing slats from extending. Electrically controlled slats.
- YAW DAMP ALL OFF (CONFIG) - All YAW DAMP switches are in OFF. No autoland modes available.
- YAW DMP LWR A/B OFF (CONFIG) - The respective YAW DAMP switch is OFF.
- YAW DMP UPR A/B OFF (CONFIG) - The respective YAW DAMP switch is OFF.

Functional Schematic

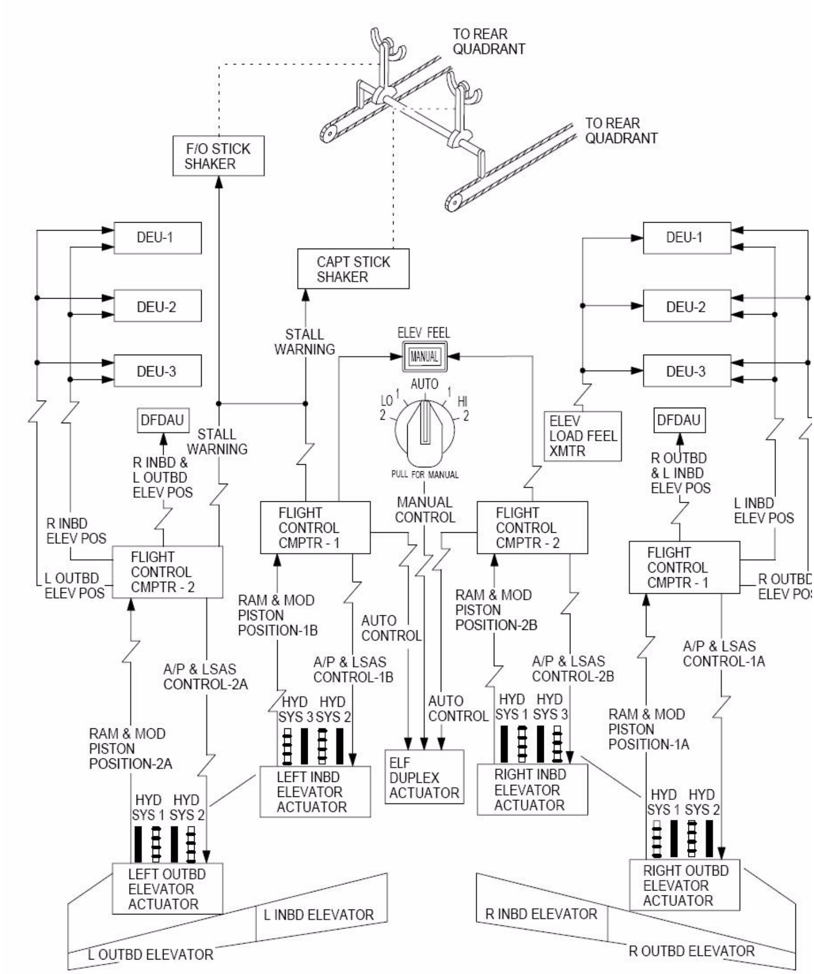
Lateral Control System



Directional Control System



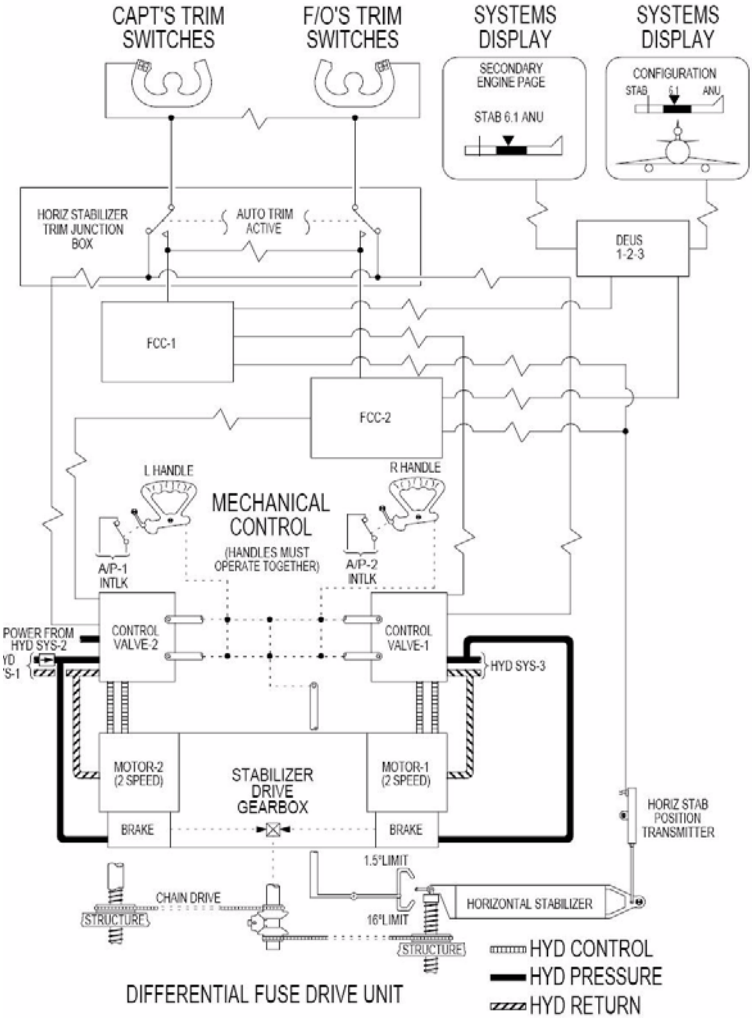
Longitudinal Control System



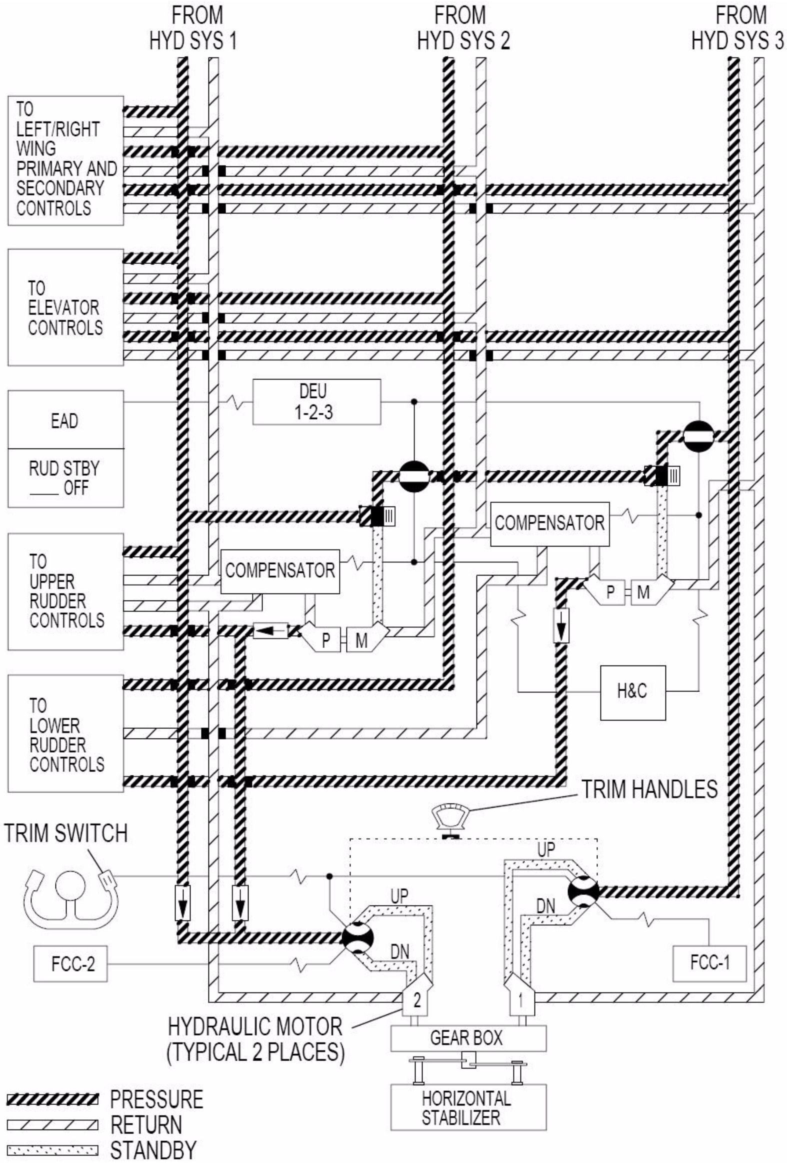
Horizontal Stabilizer System

Trim switches operate as follows:

- If auto trim active, no stabilizer control.
- If in AP cruise, the AP disconnects.
- If in AUTOLAND, there is no effect



Hydraulic Flight Controls



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Description and Operation

General

A Fuel System Controller (FSC) is installed on the aircraft. It is a control device which contains two microprocessors and a control relay system. A second control device, the Ancillary Fuel System Controller (AFSC), is installed for additional control. The FSC and the AFSC together provide complete control of fuel system functions.

FSC and AFSC control of the fuel system components is arranged so that in case of failure of either the FSC or AFSC, the remaining device can control the fuel system.

The FSC is capable of either automatic or manual operation. The crew may choose to operate the system in manual mode, or in certain failure conditions, the system may automatically revert to manual mode.

In manual mode the crew controls all fuel system functions (engine feed, fuel transfer and crossfeed) with controls on the FUEL control panel.

Fuel system indications are displayed on the Engine and Alert Display (EAD), the System Display (SD) and FUEL control panel.

Fuel System Controller (FSC)

FSC automatic functions include the following functions:

- Supplies fuel to the engines and APU.
- Checks and maintains the fuel schedule.
- Performs a preflight test after refueling is completed. On some aircraft, preflight test can be performed if directed by maintenance.
- Maintains a fuel efficient CG by transferring fuel to and from the tail tank.
- Monitors fuel temperature and starts cold fuel recirculation to prevent fuel from freezing.

- Recognizes when ballast fuel is being carried and keeps it in its proper tank.
- Backs up manual/mechanical commands for fuel dump.
- Takes appropriate corrective action for early transfer or no transfer of tip tank fuel.
- Equalizes tank quantities during low fuel flight.
- Maintains wing fuel quantity balance.
- Corrects for tank overfill.
- Reconfigures the fuel system for failure of various elements.
- Reconfigures for a dump valve failed open.
- Employs special management procedures to compensate for various components being inoperative at the beginning of flight.
- Monitors itself and other fuel system components for proper operation and detects and reports faults to the Centralized Fault Display System (CFDS).
- Reverts to manual for certain failure modes.

Fuel Tank Arrangement

Three main fuel tanks are installed in the wings. These main tanks are tank 1, 2, and 3. The numbers correspond to the engine which the tank feeds. Additional fuel is contained in a center wing auxiliary tank consisting of upper and lower sections and a tail tank located in the horizontal stabilizer.

All of the tanks are integral except for the lower auxiliary which contains a bladder cell.

Tanks 1 and 3 in the left and right wings respectively are identical. Each has an outboard compartment and a main compartment. The main compartment is further divided by a check valve bulkhead which allows inboard fuel flow to the boost pump reservoir but prevents outboard fuel flow that could occur under some flight conditions such as a steep climb or uncoordinated maneuvers.

Tank 2 supplies fuel to the APU and the aft engine. It is a split tank with half of the volume in the left wing and half in the right wing. Gravity flow and vent lines connect the two tank sections. This tank has a greater fuel capacity than tank 1 or 3.

Manifold drain/outboard fill valves are located at the outboard ends of the fill/crossfeed manifold in tanks 1 and 3. These valves serve the dual function of controlling manifold venting for drainage and providing an alternate fill path for tanks 1 and 3. A manifold drain float valve is located at the low point of the fill/crossfeed manifold. This valve allows drainage of the manifold into tank 2 when the fuel level in tank 2 is below 1,800 pounds (816 kilograms). In auto mode, the FSC commands the manifold drain/outboard fill valves open at the appropriate time allowing fuel drainage. In manual mode, a crew member operates the MANF DRAIN switch which opens the same valves. The MANF DRAIN switch is a guarded switch.

The center wing auxiliary tanks consist of an upper tank and a lower tank. The upper tank has upper (overwing) and wing box compartments which are interconnected for gravity flow. The lower tank fuel is transferred to the wing box by two transfer pumps through a fill valve. This fill valve controls the transfer flow to maintain a specified fuel level band in the wing box tank. The fill valve also prevents overfilling.

Fuel from the upper tank is transferred to the main tanks through the fill/crossfeed manifold by two transfer pumps. The fuel quantity for the upper and lower tanks is shown on one quantity readout as the total for the auxiliary tank.

The tail tank is located in the horizontal stabilizer and is divided into three compartments by the operating bulkheads. These structural members contain the stabilizer pivots (aft) and are connected to the jack screws which control stabilizer pitch attitude (forward). The operating bulkheads also serve as check valve bulkheads allowing fuel flow into the center (constant) section but inhibiting flow into the outboard compartments.

The tail tank functions as part of the aircraft Center Of Gravity (CG) management system. Fuel is transferred to and from the tail tank as necessary maintain a fuel efficient CG. Fuel is transferred from the tail tank by two transfer pumps.

In case of transfer pump failure, tail tank fuel quantity may be reduced by feeding the tail engine directly from a dedicated alternate pump. During operation in auto mode, the forward boost pump in tank 2 remains on during this procedure to provide uninterrupted fuel flow to the aft engine when tail tank fuel is depleted.

All tail tank pumps and valves are mounted on the front spar of the constant section. The tail tank has four front spar mounted sump drain valves. Two drain the center section and one drains each of the two outboard sections.

Tank Capacity Chart

TANK	GALLONS	POUNDS @ 6.7 LB/GAL	LITERS	KILOGRAMS
Tank 1 (Left Wing)	6,043	40,488	22,873	18,365
Tank 2 (Center)	9,558	64,038	36,177	29,048
Tank 3 (Right Wing)	6,043	40,488	22,873	18,365
Aux Tank Upper Compartment	13,000	87,100	49,205	39,510
Aux Tank Lower Compartment	1,642	11,000	6,215	4,990
Forward Aux Tank 1 (if installed)	1,973	13,222	7,467	6,000
Forward Aux Tank 2 (if installed)	1,973	13,222	7,467	6,000
Horizontal Stabilizer Tank	1,958	13,118	7,411	5,950
Manifold and Engines	91	610	344	277
TOTALS WITH FWD AUX TANKS	42,281	283,286	160,032	128,505
TOTALS WITHOUT FWD AUX TANKS	38,335	256,842	145,098	116,505

Incorporation of SB28-18 adds about 276 gallons (1,850 pounds) as follows:64 gallons (428 pounds) in each tank 1, 2, and 3.

84 gallons (563 pounds) in the upper aux tank.

These approximate usable fuel capacities assume a density of 6.7 pounds per gallon.After engine start, actual fuel onboard (FOB) is used for gross weight calculations. The flight management system (FMS) display changes to show, along with FOB, the sensors used for FOB calculation. The pilot may selector clear the sensor(s) to be used for calculating FOB, or may reinitialize by entering a new value.

Engine Feed System

The engine feed system is controlled and monitored by the FSC. Each engine is normally supplied fuel by an independent system from the respective main tank. Engines are fed by tank boost pumps through fire shutoff valves to the engine pump inlets. The wing engine fire shutoff valves are electric. The tail engine The tail engine has two fire shutoff valves, both mechanical. The boost pumps are driven by AC motors.

Tank 1 and tank 3, which feed the wing mounted engines, have three pumps each. These three pumps are:

- One forward mounted boost pump.
- One aft mounted boost pump.
- One aft mounted transfer pump.

The transfer pump supplies fuel directly to the crossfeed manifold. One of the boost pumps is mounted to the rear spar next to the transfer pump to minimize the unusable fuel during nose up or level flight attitudes. The other boost pump is mounted to the bottom wing skin in the forward part of the tank to minimize unusable fuel during nose down flight attitudes.

The aft engine is fed by tank 2 which contains four fuel pumps. These four pumps are:

- Two aft mounted boost pumps.
- One forward mounted boost pump.
- One forward mounted transfer pump.

The boost pumps feed directly to the aft engine.

A DC powered APU start pump is also located on the right side of tank 2.

In each tank, the pumps are all powered from different electrical buses. In case of electrical failure, the left aft boost pump in tank 2 can be run from the Air Driven Generator (ADG).

The aft feed pump(s) in each tank (one each in tank 1 and 3 and two in tank 2) and the two upper aux transfer pumps have a jet pump installed in the inlet. Each boost pump is capable of supplying fuel at the takeoff fuel flow rate to two engines.

Each tank mounted pump is provided with a pressure sensor which provides information to the FSC.

In auto mode the FSC uses this input combined with fuel quantity information to decide if a tank is empty or a pump is inoperative. If the quantity is above the preset limit when a low pressure situation is sensed, the FSC turns the pump off. The appropriate PUMP OFF alert will be displayed. The forward pumps and tank 2 transfer pump will not be turned off if pump pressure is low due to a high pitch angle with a low fuel level. In manual mode, a pumps LOW light on the FUEL control panel is illuminated if all boost pumps that have been commanded on in a tank have low discharge pressure.

Suction feed is accomplished for the wing engines only through the aft pump inlet. The engine feed pump suction line contains a bypass with a check valve. This allows the inlet to be used for suction feed.

Electrically operated crossfeed valves provide crossfeed capability from any tank to any engine or to any other wing tank. In auto mode, the FSC controls crossfeed and will compensate for failed components.

In either mode of operation, lights on the FUEL control panel illuminate to indicate valve disagreement with switch position. A short time delay is provided in the annunciation logic to allow for normal valve transition. The valve has a manual override for ground use.

Electrically controlled fire shutoff valves are mounted on the front spar for the wing mounted engines. There are two cable controlled fire shutoff valves for the aft engine, one on the rear spar and one in the aft fuselage. The two shutoff valves for the aft engine are operated from the same fire extinguishing handle in the cockpit.

The APU fuel system consists of a dc start pump and two solenoid operated fire shutoff valves. The system is controlled from the APU control panel. The start pump, controlled by the Miscellaneous

System Controller (MSC), is used to supply fuel to the APU for start and ground operation.

When the APU START/STOP switch or the APU PWR ON switch is pushed, the MSC opens both valves. One solenoid valve is located at the rear spar and one is located in the aft fuselage near the inlet to the APU. The solenoid valves are normally closed and require electrical power to open them. A pressure sensor at the APU inlet provides the MSC with APU inlet fuel pressure information.

When the fuel system is in auto mode, the FSC will recognize when the APU is operating and will turn on a tank 2 boost pump. After a 90 second time delay, when the tank 2 boost pump is operating and providing adequate fuel pressure, the FSC will interrupt start pump operation. Fuel then continues to be supplied to the APU through the aft engine feed line.

With the FSC in manual mode, APU start pump operation will not be interrupted, even if tank 2 boost pumps are operated. Fuel feed to the APU, whether from a tank 2 boost pump or the dc start pump, is continued for 90 seconds after a shutdown has been commanded. This prevents possible damage to the APU.

Fuel Transfer and Crossfeed

For fuel transfer from the center wing auxiliary tank (assuming fuel in both upper and lower tanks) the FSC commands both the left and right center aux tank transfer pumps on and energizes the three main tank (tanks 1, 2, and 3) fill valve solenoids.

With the left and right transfer pumps commanded on, the upper and lower pumps are energized along with the upper fill valve solenoid. When the fill valve solenoids are energized, flow through the valve is controlled by the mechanical fill pilot valves. These valves contain floats which sense the level of fuel present in the tank. The three main tank and upper aux tank fill valves cycle open and closed automatically to maintain the tanks full.

If the indicated quantity in the lower aux tank is below 2,000 pounds (907 kilograms) and the pump discharge pressure is low, the FSC starts a time-out procedure. At the end of a clean-up period where the pumps register continuous low pressure for ten minutes, the tank is timed out as empty. The left and right lower pumps are then shut down and the upper aux tank fill valve solenoid is de-energized. Further fuel transfers will rely only on the upper pumps.

The FSC will reinitiate lower aux tank transfer if the fuel quantity should increase to above 300 pounds (136 kilograms).

Transfers continue from the upper aux tank to all main tanks until the aux tanks quantity indicator shows less than 4,000 pounds (1,814 kilograms). If the indicated quantity in the upper aux tank is less than 4000 pounds (1,814 kilograms) and pump discharge pressure is low, the FSC starts time-out procedures. At the end of a ten minute clean-up time where the pumps register continuous low pressure for ten minutes, and the upper aux quantity is less than 500 pounds (227 kilograms), the tank is timed out as empty. The upper pumps are then shut down and the tank 2 fill valve solenoid is de-energized.

The FSC will reinitiate upper aux transfer if the fuel quantity should increase to above 500 pounds (227 kilograms) or after the aircraft is refueled.

In auto mode, the FSC can independently control any pump in the system. In manual mode however, when either the aux tank left or right transfer pumps are selected, both upper and lower pumps are commanded on or off.

In manual mode, after four minutes of continuous low pressure, the lower pumps are automatically turned off by timed relays.

When upper aux transfer is complete, fuel transfer from tank 2 is initiated by the FSC which commands the tank 2 transfer pump on. The fuel quantity gaging system (using a float switch as a backup) signals the FSC when the fuel level in tank 2 drops below 40,000 pounds (18,144 kilograms). The FSC then commands the tank 1 and tank 3 fill valves closed and the tank 2 transfer pump off.

There are three situations where crossfeed is required to maintain proper system operation as follows:

- If a main tank transfer pump fails and fuel must be transferred from that tank, the crossfeed valve is opened and fuel is transferred using the boost pumps.
- If certain boost pump failures occur, the crossfeed valve is opened and the associated engine is fed by the transfer pump.
- Fuel scheduling or balance requirements cause fuel to be moved from tank to tank through the fill system. In the event of a failed closed fill valve, the crossfeed valve associated with that fill valve is opened and the engine is fed by the transfer pump from the heavy tank.

Gravity and Jet Pump Transfer System

To relieve bending stresses caused by the generation of lift by the wings, the tank 1 and 3 outboard compartments are maintained full until the inboard fuel level decreases to about 5,000 pounds (2,268 kilograms).

There are two transfer systems controlled by fuel level in the inboard compartment. These systems will allow fuel to transfer from the outboard compartment to the inboard compartment maintaining the inboard compartment fuel quantity at about 5,000 pounds (2,268 kilograms).

One fuel transfer system utilizes a transfer valve and transfer float valve. The other transfer system, a jet pump system, transfers fuel accumulations in the aft portion of tank 1 and 3 on both sides of the vent box. The jet pump system is the primary system at aircraft attitudes in excess of six degrees nose-up.

The two compartments of tanks 1 and 3 contain float switches which provide the FSC with fuel schedule information. One float switch is located high in the outboard tank and two float switches are located low in the main tank. The FSC compares the condition of the three float switches in each tank with fuel quantity information, checking for possible failures.

If outboard compartment leakage has occurred and the fuel schedule condition is identified with tank total quantity above 11,500 pounds (5,216 kilograms), the FSC will refill the outboard compartment by opening the fill valve and using either the transfer pump or the boost pumps through a crossfeed valve. The manifold drain/outboard fill solenoid valve can also be used to fill the outboard compartment if the FSC senses that the fill valve is failed closed. If fuel schedule condition is identified with total tank quantity below 8,500 pounds (3,850 kilograms), the FSC assumes a failure in fuel transfer from outboard to inboard compartment and an alert will be displayed to warn the crew that the tank fuel quantity is low and that a tip fuel trapped condition exists. In this condition, approximately 5,500 pounds (2,495 kilograms) of fuel will not be available to engines.

Fuel Quantity Gaging System (FQGS)

The FQGS consists of:

- Probes in the fuel tanks
- An electronic module
- A data control unit in the cockpit
- Refueling panel on the right wing

The probes in the fuel tanks send quantity data to the electronic module. The electronic module processes this quantity data and sends it to the data control unit and the refueling panel.

The data control unit sends the fuel quantity data to aircraft components that use the data. These components include:

- FSC
- FUEL control panel in the cockpit
- MCDU through the FMC
- CRTs for display
- Air data computers

The refueling panel sends preselect fuel quantities to the electronic module during refueling.

The FQGS self-tests before each flight and after refueling.

Fuel Dump System

Fuel dumping uses all main tank and upper aux tank pumps to pump the fuel overboard through exits on each wing located at the trailing edge between the outboard aileron and the outboard flap. The dump flow is controlled by two electrically operated shutoff valves, and the low level shutoff float switches in the three main tanks. The dump valves are dc motor operated valves. They are energized by a dedicated dump control network which is activated by a guarded DUMP switch. An alert will be displayed to indicate that the fuel dump system has been activated.

The fuel dump operation is initiated by pushing the guarded DUMP switch on the FUEL control panel. The dedicated dump control network then commands all transfer and boost pumps on, all crossfeed valves open, and the dump valves open in a controlled sequence. The sequence will not overload the electrical system or adversely affect engine feed capability.

The FSC monitors the state of the fuel dump valves. Left or right dump valve disagree alerts are displayed on the SD if one or both of the dump valves are not in the commanded position.

The dump valves are on separate electrical buses. If the FSC is in auto mode, backup commands will be sent to the crossfeed valves and the pumps to ensure that they are properly activated in the event of a malfunction of the dump control network. The FSC performs fault checking of the fuel dump system by monitoring the sequencing of the pumps and valves. Any faults in the operation of the system are isolated and recorded. The FSC has no control over the operation of the dump valves. This feature ensures that fuel cannot be inadvertently dumped due to a malfunction of the FSC.

At any time during the fuel dumping operation a crew member can stop the flow of fuel overboard by pushing the DUMP switch again. This action causes the dump valves to close, all crossfeed valves to close, and the transfer pumps to be commanded off. If fuel dumping is started a second time during a single flight, dump continues to low level dump cutoff or until the DUMP switch is pushed again. If a malfunction of the DUMP switch occurs, the fuel dump sequence can be overridden by pushing the FUEL DUMP EMER STOP switch.

When dumping fuel from the aux tanks, both upper and lower pumps turn on. After the lower aux fuel has been pumped to the upper aux tank, then tail tank fuel is pumped to the upped aux tank and dumping continues using the upper pumps. If the forward aux tank(s) are installed the sequences is lower aux to upper aux, forward aux to upper aux, tail to upper aux.

The aircraft can carry dedicated ballast fuel in either tank 2 or the upper aux tank. Tail ballast fuel will remain on board and will not be moved during fuel dump. Ballast fuel in the upper aux tank will also remain on board, but may be relocated (to tank 2) in the dump process. Total fuel quantity remaining on board following dump will be the low level dump cutoff quantity plus any dedicated ballast.

When dump is discontinued (the dump valves are commanded closed) the FSC will discontinue its dump follow-up procedure in a controlled manner so as not to interfere with the shutdown sequence of the dump system.

The FSC will exit the dump state when any of the following conditions are met:

- 12 seconds have passed since the dump valves were commanded closed.
- A reset interrupt occurs.
- The FUEL DUMP EMER STOP switch is pushed.

The FSC must support engine operation before, during, and after fuel dump. If the FSC is in auto mode when the dump state is exited, it will immediately resume fuel system control. If the FSC is in manual mode at the end of dump, the fuel system will be configured to the last state commanded from the FUEL control panel.

The CG may move slightly out of range (usually forward) during fuel dump. If the FSC is in auto mode, after the completion of the dump process, the fuel remaining on board will be rescheduled. If the FSC is in manual mode, the flight crew must reschedule fuel manually.

During fuel dump operation, the CG OUT OF LIMITS alert may be displayed.

Automatic Operation

Engine and APU Fuel Feed

The FSC supplies fuel to the engine and APU as follows:

- When the aircraft is parked fuel transfer is permitted.
- When APU start is selected, the FSC will check the status of boost pumps in tank 2. If one or more pumps is operating it interrupts the APU start pump. The APU starts and operates using fuel pressure from the operating pump. If no pumps are operating, the APU will turn on its own start pump. When the APU has started and ac power is available, the FSC will turn on a tank 2 pump; 90 seconds later it will turn off the APU start pump.
- During engine start, tanks 1, 2, and 3 aft pumps are turned on as each respective ENG START switch is turned on.
- During taxi, tanks 1, 2, and 3 aft pumps are on. Fuel transfer is permitted. Tail fuel management is allowed, as appropriate.
- During takeoff, tanks 1, 2, and 3 forward and aft pumps are on. Aux manifold fuel transfer and tail fuel management are prohibited.
- During climb tanks 1, 2, and 3 aft pumps are on. Fuel transfer and tail fuel management are permitted.
- During cruise tanks 1, 2, and 3 aft pumps are on. Fuel transfer and tail fuel management are permitted.
- During descent, at 19,750 feet, if any fuel remains in the tail tank, tail fuel is transferred forward.

- During approach, tanks 1, 2, and 3 forward and aft pumps are on. Aux manifold fuel transfer is prohibited.
- After landing, tanks 1, 2, and 3 forward pumps are turned off one minute after landing, unless the fuel level is less than 11,500 pounds (5,216 kilograms) in a tank.
- After engine shutdown, all main tank pumps are turned off unless the APU is operating, in which case the tank 2 left aft pump will remain on.

Fuel Scheduling

The FSC checks and maintains the fuel schedule. Fuel management is required to satisfy aircraft structural load requirements. If fuel is not properly distributed, it will be rescheduled to the correct tanks. Depending on the total fuel quantity and distribution when transfer is permitted, the fuel transfer will continue from that point.

The sequence of fuel management is as follows:

- If tail fuel management is not in use, tail tank to upper auxiliary tank, maintaining the upper auxiliary tank full.
- Lower auxiliary tank to upper auxiliary tank, maintaining the upper auxiliary tank full.
- Simultaneously with the preceding two functions, upper auxiliary tank to tanks 1, 2, and 3, maintaining them full.
- Tank 2 to tanks 1 and 3, maintaining them full.
- When tank 2 quantity equals that in 1 or 3, discontinue transfer from tank 2, allowing tanks 1, 2, and 3 to burn down to equal fuel quantities.
- When tanks 1 and 3 tip fuel equals the fuel in the inboard section of the tank, the tip fuel is mechanically transferred to the inboard section, keeping it at a constant level of about 5,000 pounds (2,268 kilograms) until the tip fuel is depleted (FSC monitors but does not perform this action).

Tail Fuel Management

The FSC manages the tail fuel. Tail fuel management begins when the climb phase of fight begins. The primary purpose of tail fuel management is to improve aircraft cruise performance by maintaining an aft center of gravity (CG). Tail fuel is managed as follows:

- The CG is controlled to a preselected aft limit. This function is allowed only if the total fuel quantity exceeds 60,000 pounds (27,216 kilograms) at termination of refueling. Once the total fuel quantity is below 51,000 pounds (23,134 kilograms), no further fuel will be transferred aft for CG control. If engine 2 is shut down, tail fuel is limited to a maximum of 5,000 pounds (2,268 kilograms). If the CG moves aft of the aft control limit, the fuel system controller will revert to the manual mode and the SEL FUEL SYS MAN alert is displayed.
- CG control maintains a constant moment margin forward of the aft CG limit. The CG control margin tolerance is 0 percent aft and 1.0 percent forward of the selected control point.
- When CG demand requires aft fuel transfer, fuel will be transferred from the lower or upper auxiliary tanks, or main tanks to the tail tank. When the tail tank transfers fuel forward, it goes to the upper auxiliary tank. Once the main tank quantities decrease to 11,500 pounds (5,216 kilograms) each tank (fuel dump cutoff level), tail fuel will be transferred to the main tanks to keep them at that level until tail fuel is exhausted.
- If fuel remains in the tail tank during descent below 19,750 feet (26,750 with FSC-907), it will be transferred forward.
- The FSC will transfer and replace fuel from the tail tank to purge water. Every 30 minutes fuel is transferred forward for two and one-half minutes. When the forward transfer is complete, CG control is again in effect. When the fuel temperature drops to 36°F (2°C) this function is terminated.

- Flow through or pressurization of the tail tank manifold during takeoff and landing is terminated.
- Tail fuel is limited to a maximum of 5,000 pounds (2,268 kilograms) when any of the following conditions occur: tail tank engine 2 alternate pump inoperative, auxiliary fill/isolation valve inoperative closed, or engine 2 shutdown.
- Tail fuel management will be terminated by a number of abnormal conditions. When this occurs, tail fuel will be moved forward and distributed to conform to normal fuel scheduling. These abnormal conditions are:

1. Upper aux fill valve inop closed.
2. Any two of the tail tank pumps inop off.
3. Aux fill isolation valve inop closed and either upper aux tank pump inop off.
4. Both upper aux tank pumps inop off.
5. Tail tank engine 2 alternate pump inop off and aux fill/isolation valve inop closed.
6. Loss of all temperature data.
7. Loss of air data.
8. Loss of all fuel quantity data.
9. Loss of tail tank quantity data.
10. Loss or aircraft CG data.
11. Loss of gross weight data.
12. No tail tank ballast fuel.

- Tail fuel management can be reset by selecting manual mode, then reselecting auto mode. If the conditions that caused termination of tail fuel management no longer exist, management will resume.
- Cold fuel is recirculated (see following).

Cold Fuel Recirculation

Fuel temperature is maintained above freezing. Phase one involves tanks 1 and 3 and applies when fuel quantity in each main tank is greater than 13,500 pounds (6,214 kilograms). When the fuel temperature sensed in the tank 3 tip falls to within 6°C of the fuel freeze point, tanks 1 and 3 transfer pumps will be turned on and their fill valves will open. An alert, COLD FUEL RECIRC will be displayed. The transfer will continue until fuel temperature rises 5°C, or for 15 minutes. Should the fuel temperature/freeze point spread not reach 11°C within 15 minutes, an alert, FUEL TEMP LO will be displayed. Phase two involves the tail tank. When the temperature sensed in the tail tank falls to within 8°C of the fuel freeze point, the fuel within the tail tank is recirculated in order to raise the temperature. If the fuel temperature drops to within 5°C of the fuel freeze point, about one third of the tail fuel is transferred forward. It is then replaced with warmer fuel from another tank. If the fuel temperature drops to within 3°C of the fuel freeze point, tail fuel management is terminated.

Fuel Manifold Draining

When the fuel quantity in tank 2 drops to less than about 1,800 pounds (816 kilograms), the manifold drain float valve in tank 2 will open to drain the fuel manifold into tank 2. The manifold drain float valve is not dependent on system operation, auto or manual. If the fuel system is in auto the FSC will open the manifold drain/outboard fill valves in tanks 1 and 3 when the fuel quantity in tank 2 is less than 1,500 pounds (680 kilograms). This will allow air into the fuel manifold. If the fuel system is in manual the manifold drain/outboard fill valves will open when the MANF DRAIN switch is pushed. The FUEL MANF DRAIN alert will be displayed in auto or manual when the manifold drain/outboard fill valves are open.

Preflight Checks

The FSC will perform preflight checks. The test will be initiated automatically upon completion of the first refueling following a ground to flight transition, if no engines are running and each main tank contains more than 5,000 pounds of fuel. If during the preflight test manual mode is selected, the FSC reverts to manual and the test will stop. The test will not restart until the system is selected back to auto The following functions are performed:

- The standard test will:
- Record fuel float faults from refueling.

1. Verify manifold pressure sensor operation.
2. Verify fuel dump valves closed.
3. Verify all main tank pumps are operational and supplying at least 15 psi fuel pressure.
4. Verify crossfeed valve operation.
5. Verify fill valve operation.
6. Verify fuel temperature probe operation.

- The conditional test will:
  - If more than 1500 pounds (681 kilograms) of fuel is in the lower auxiliary tank, verifies lower auxiliary tank pump operation. In addition, if the auxiliary tank is not full, verifies lower aux fill valve operation.
  - If total usable fuel is more than 60,000 pounds (27,216 kilograms), verifies ability to fill and empty upper auxiliary and tail tanks. If upper auxiliary tank is not full, verifies ability to transfer tail fuel into and out of upper auxiliary tank

Ballast Fuel Control

The FSC will recognize when ballast fuel is being carried and will keep it in its proper tank. Ballast fuel may be carried in tank 2, the upper auxiliary tank, or the tail tank. Tank 2 is allowed to have only up to 25,000 pounds (11,340 kilograms) of ballast fuel. All or part of the fuel in the upper auxiliary tank may be ballast. The tail tank cannot contain both ballast and usable fuel. Only one tank can be assigned for ballast fuel. The fuel must be either all ballast or all usable fuel. The flight crew enters the amount and location of ballast fuel in the FMS, and the FSC then manages it appropriately. In the case of the tail tank, two switches on the aft maintenance panel must also be positioned.

Fuel Dump System Backup

The FSC will back up the manual/mechanical system for fuel dump. The FSC does not have control of the fuel dump valves. The fuel dump valves are always controlled by the flight crew. When the first main tank fuel quantity reaches the undumpable level of about 12,000 pounds (5,443 kilograms), the transfer pump in that tank will be shut off and all crossfeed valves will close.

When fuel dump terminates by the flight crew selecting the FUEL DUMP switch off, the following functions are mechanically performed and backed up by the FSC:

- Crossfeed valves close.
- Transfer pumps turn off.
- Tank pumps are correctly reconfigured for the amount of fuel remaining.
- Fuel is rescheduled as required.

Equalization of Tank Quantities

The FSC will equalize tank quantities during low fuel flight. When tank 2 is below 41,500 pounds (18,824 kilograms), the FSC will correct fuel quantity imbalance between any two main tanks that exceeds 2,400 pounds (1,089 kilograms).

The FSC will maintain wing fuel quantity balance between tanks 1 and 3. Imbalance correction between tanks 1 and 3 stops when wing tip fuel quantity is less than 500 pounds (227 kilograms) or tank 2 quantity is less than 4,000 pounds (1,814 kilograms).

Compensation for Inoperative Components

The FSCs will reconfigure the fuel system for failure of various elements. The FSC can compensate for a number of fuel system component failures by use of alternate pumps and flow paths.

The FSC will turn off all transfer pumps and close the crossfeed valves if a dump valve fails open.

The FSC will employ special management procedures to compensate for various components being inoperative at the beginning of a flight.

The FSC will monitor itself and other components for correct operation. A large number of system components are continually monitored. If any fail to operate properly, the FSC can, in many cases, use alternate means to accomplish the desired action.

The FSC will detect and report faults to the CFDS.

Manual Reversion

The FSC will revert to manual for certain failure modes. The FSC is unable to accommodate certain component failure modes and conditions. When these occur, the FSC will revert to the manual mode and the flight crew will be notified with an alert.

The FSC establishes the following fuel system configuration when it reverts to manual mode:

- Tank 1, 2, and 3 pumps on.
- Fill valves remain in previous state.
- Crossfeed valves commanded off.
- Tank 1 and 3 transfer pumps off.
- Tank 2 transfer pump remains in previous state.
- Aux tank L and R trans pumps on.
- Tail tank trans pump on.

- Tail tank alt pump off.

EIS Test Display

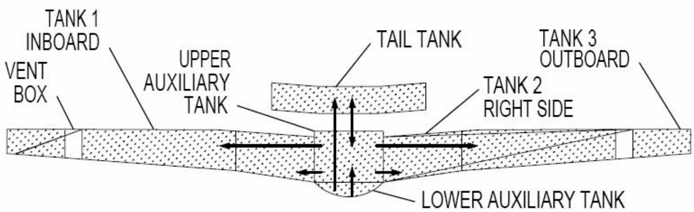
All FUEL synoptic data digits will be crossed out with amber Xs when all of the conditions are met as follows:

- The aircraft is on the ground.
- The aircraft is operational.
- The ANNUN LT TEST button on the forward overhead panel is pushed.
- The FUEL synoptic has been selected to appear on the SD.

Components

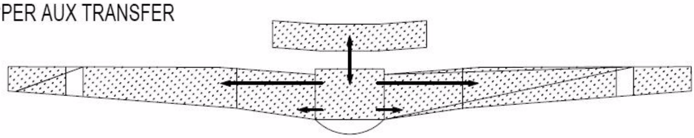
Automatic Fuel Scheduling

LOWER AUX TRANSFER



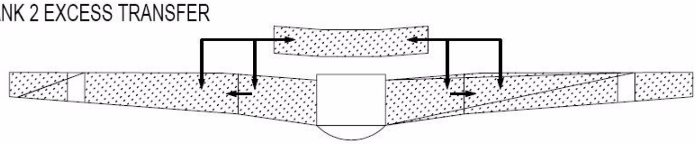
Typical fuel transfer and burn schedule with the fuel system performing tail fuel management, starting with full tanks after T/O. Fuel is transferred from the aux tanks to keep the main tanks full as fuel is burned by the engines.

UPPER AUX TRANSFER



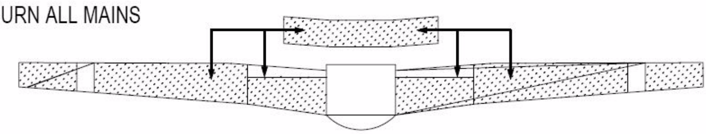
With tail fuel management, the CG is controlled automatically to a preselected aft limit, by allowing fuel to be transferred from any tank to or from the tail tank. The lower aux tank is the first tank to empty. Upper aux tank fuel transfers to main tanks until empty. Optional forward aux tank fuel must be transferred manually, if installed.

TANK 2 EXCESS TRANSFER



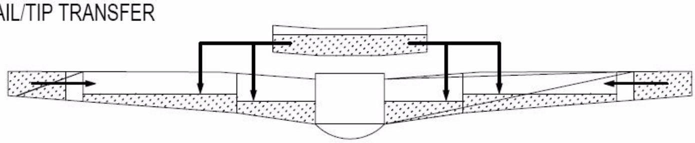
Tank 2 fuel is transferred into tanks 1 & 3 until tanks are equal.

BURN ALL MAINS



Tail tank fuel will transfer forward during descent when descending below 26,750 feet or when any main tank quantity decreases below 11,500 lbs. When tanks 1 or 3 decrease to below 11,500 lbs the associated tip tank will transfer inboard.

TAIL/TIP TRANSFER



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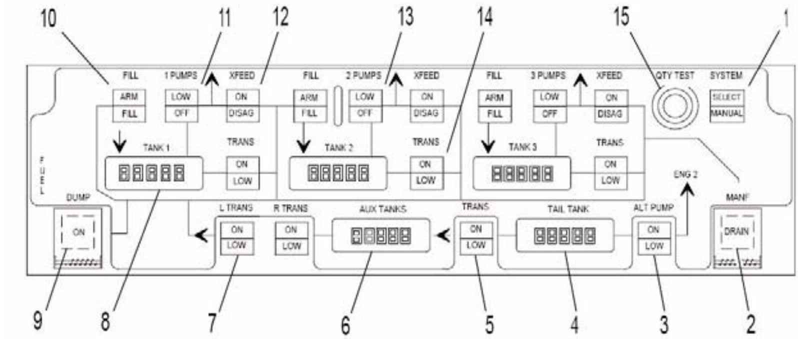
Controls and Displays

FUEL Control Panel



FORWARD OVERHEAD PANEL

1. SYSTEM SELECT/MANUAL Switch - amber

   This is an alternate action switch that allows selection between manual and auto modes.

   There are 2 alternating auto channels. During auto operation, one of the 2 auto channels is not used. Each time auto is selected, the previous unused auto channel is activated.

   SELECT illuminates amber if the fuel system reverts from auto to manual. In this case, the SEL FUEL SYS MAN alert will be on the EAD and the crew should push the FUEL SYSTEM SELECT switch to lock the system in manual.

   MANUAL illuminates amber if the system is in manual.

   MANUAL flashes amber if the system is in auto and a switch on the FUEL control panel has been pushed that has no effect in auto.

   If fuel system is in AUTO, selecting MANUAL configures the fuel system as follows:

   - Tank 1, 2, and 3 pumps on.
   - Aux tank L and R trans pumps on.

- Tail tank trans pumps on.
- Tank 2 transfer pump remains in previous state.
- All fill valves remain in previous state.

2. MANF DRAIN Switch - amber

   The MANF DRAIN switch is a momentary switch that controls the main tank 1 and 3 manifold drain/outboard fill valves. In the manual mode the switch operates both valves together for manual drain function. The switch has no effect in the auto mode. In the auto mode the valves are controlled individually by the fuel system controller as alternate fill valves or together for manifold drain function.

   Illuminates amber in manual mode when valves are commanded open and illuminates in auto mode only when the valves are used to drain the manifold. The FUEL MANIFOLD DRAIN alert is displayed when DRAIN is illuminated. DRAIN will extinguish when the FSC commands the outboard fill valves closed.

   The switch is guarded and safetied.

3. TAIL TANK ALT PUMP Switch - blue/amber

   The TAIL TANK ALT PUMP switch is a momentary switch that turns the tail tank alternate pump on and off when the fuel system is in the manual mode. The switch has no effect in the auto mode.

   ON illuminates blue when the tail tank pump is commanded on.

   In manual mode, LOW illuminates amber when the tail tank pump is commanded on and has low pressure.

   This pump is powered by the right emergency ac bus and supplies engine 2 exclusively.

4. TAIL TANK Quantity Readout

   Total fuel quantity in tail tank.

5. TRANS ON/LOW Switch (Tail Tank) - blue/amber

The tail tank TRANS switch is a momentary switch that turns the tail tank transfer pumps on and off when the fuel system is in the manual mode. When on, the upper aux tank fill valve opens to transfer fuel into the upper aux tank.

The switch has no effect when the system is in the auto mode.

ON illuminates blue when the transfer pump has been commanded on.

In manual mode, LOW illuminates amber when the pump is commanded on and has low pressure.

6. AUX TANKS Quantity Readout

   Total fuel quantity in upper and lower aux tanks. If fwd aux tanks are installed, the quantity includes fwd aux tank fuel.

7. L/R TRANS ON/LOW Switch (Upper and lower aux tanks) blue/amber

   The aux tank TRANS switches are momentary switches that turn the upper and lower pumps on and off when the fuel system is in the manual mode. The switch has no effect in the auto mode.

   ON illuminates blue when the respective transfer pump has been commanded on.

   LOW illuminates amber when the upper aux tank pump is commanded on and has low pressure continuously for several minutes.

8. TANK 1/2/3 Quantity Readouts

   Total fuel quantity in respective main tank.

9. DUMP ON Switch - amber

   The DUMP switch is an alternate action switch that starts and stops the fuel dump sequence. When on:

   - Switch illuminates amber.
   - Fill valves and fill isolation valves close (except upper aux tank).
   - Upper aux fill valve will open.
   - Tank pumps turn on (except tail tank alternate pump).
   - Transfer pumps turn on.
   - Crossfeed valves open.
   - Left and right dump valves open.

   Fuel dump is independent of the auto/manual mode of the FSC. Dump valves are not controlled by the FSC. Pumps are staggered on to avoid excessive electrical power transient loads. Fuel dump rate is initially about 5,800 pounds per minute. As tank fuel levels drop and pumps shut off, the dump rate decreases. An average for the entire fuel dump is about 5,000 pounds per minute.

   Maintaining a high nose-up attitude during dump may cause main tank dump low level shutoff at a higher than normal fuel level.

   The FUEL DUMP LEVEL alert notifies the flight crew that the dump system did not automatically shut off at the low level cutoff and manual stop dump is required.

   This switch is guarded, safetied, and amber stripes will be visible on the side of the switch when not activated.

10. ARM/FILL Valve Switch (Tanks 1, 2, and 3) - blue

    The FILL valve switch is a momentary switch that opens and closes the respective tank fill valves when the system is in the manual mode. Pushing the switch arms the fill valve for as long as the switch is held. Tank 2 fill valve will remain armed following switch release if any upper aux tank pump is on. Tank 1 and 3 fill valves will remain armed following switch release if tank 2 contains more than 40,000 pounds (18,144 kilograms) of fuel. When the fill valve is armed, pushing the switch causes the fill valve to disarm.

ARM illuminates blue when the respective fill valve is armed.

FILL illuminates blue when the respective fill valve is open. In the auto mode, the light is inhibited.

11. 1/3 PUMPS LOW/OFF Switch (Tanks 1 and 3) - amber

    The tank 1/3 PUMPS switch is a momentary switch that turns the respective tank forward and aft pumps on and off when the fuel system is in the manual mode.

    LOW illuminates amber when all pumps that are commanded on have low pressure.

    In manual mode, OFF illuminates amber when neither pump is commanded on. In auto mode, OFF illuminates amber when pumps are off due to suction feed.

12. XFEED ON/DISAG Switch (3) - blue/amber

    The XFEED switch opens and closes the respective crossfeed valves when the fuel system is in the manual mode.

    ON illuminates blue when the respective crossfeed valve is commanded open.

    DISAG illuminates amber when the actual valve position differs from the commanded position. In the auto mode, the light is inhibited for 4 seconds to prevent illumination during valve transition.

13. 2 PUMPS LOW/OFF Switch (Tank 2) - amber

    The tank 2 PUMPS switch is a momentary switch that turns the forward, left aft, and right aft tank 2 pumps on and off when the system is in the manual mode.

    LOW illuminates amber when all pumps are commanded on and have low pressure.

    OFF illuminates amber when none of the three pumps is commanded on.

14. TRANS ON/LOW Switch (Tanks 1, 2, and 3) - blue/amber

    The main tank TRANS switch is a momentary switch that turns the respective tank transfer pumps on and off when the fuel system is in the manual mode.

    ON illuminates blue when the respective transfer pump has been commanded on.

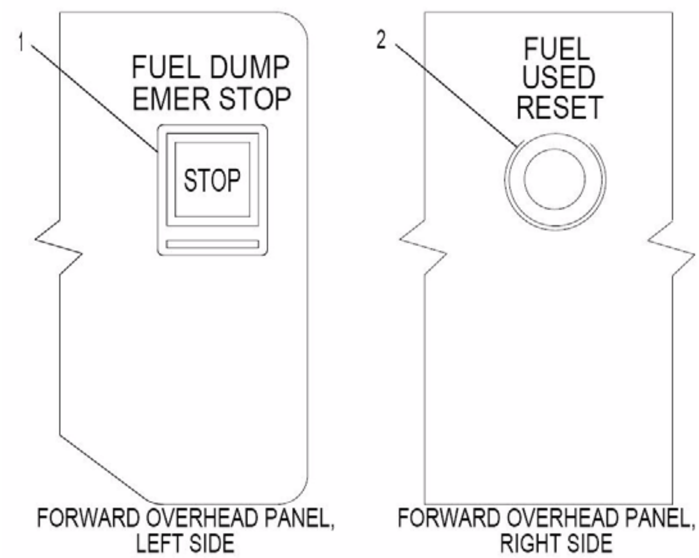
    LOW illuminates amber when the respective pump is commanded on and has low pressure.

15. QTY TEST Button

    The QTY TEST button is a momentary button that initiates a test of both channels of the Fuel Quantity Gaging System (FQGS). When the button is released, the FQGS returns to normal using the alternate channel.

    The FQGS is automatically tested when ac electrical power is applied to the aircraft.

FUEL DUMP EMER STOP and FUEL USED RESET switch



1. FUEL DUMP EMER STOP Switch - amber

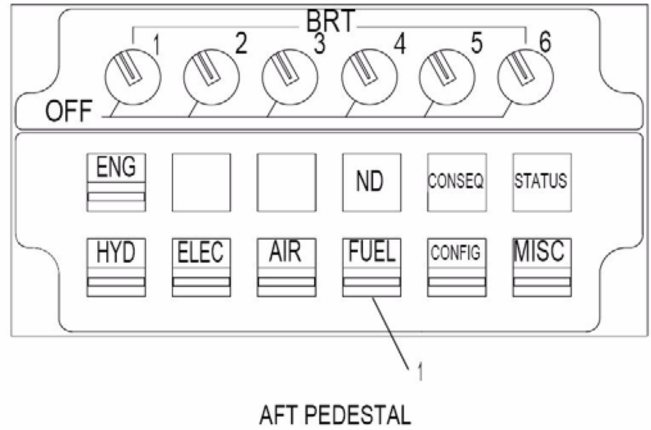
   Alternate action switch that electrically overrides the fuel DUMP switch by reversing the signal and stopping the fuel dump sequence.

   The fuel dump sequence can be restarted by pushing the FUEL DUMP EMER STOP switch a second time.

2. FUEL USED RESET Button

   Push switch to reset fuel used indications to zero on the corresponding synoptic display.

FUEL Cue Switch



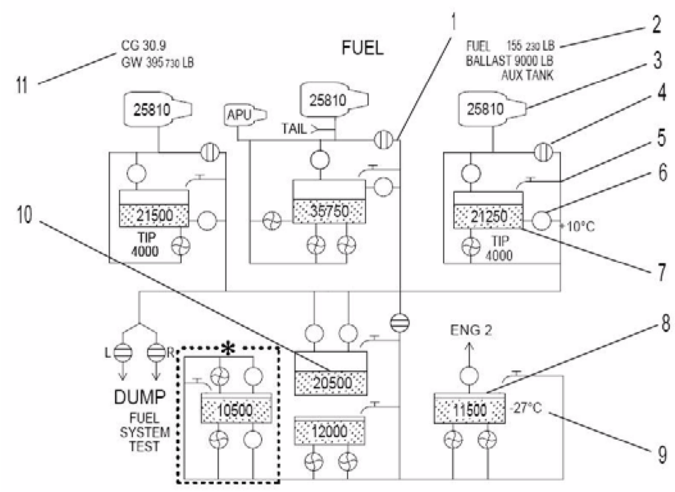
1. FUEL Cue Switch - white

   Illuminates white when a FUEL alert is displayed on EAD. When pushed:

   - MASTER WARNING or MASTER CAUTION lights will extinguish.
   - Reminder message will replace the alert.
   - FUEL synoptic comes into view on the SD.

   Some level 1 alerts are maintenance alerts that appear on the SD . . . . STATUS page only. These maintenance alerts will not illuminate the cue switch or the MASTER CAUTION lights

SD FUEL Synoptic



* Displayed on aircraft with fwd aux tanks only.

1. Schematic Lines

   Pressurized fuel lines are green. Unpressurized fuel lines are white. Flow lines to the APU are only shown when the APU is on. Fuel dump lines are only shown during fuel dump.

2. Total Fuel Quantity

   Fuel quantity digits are white. Ballast fuel digits are cyan. Unit of measurement is pounds. The tank where the ballast fuel is trapped is displayed below the ballast digits. Unavailable total fuel indication is an amber X. Unavailable ballast fuel indicated by a removal of ballast digits.

3. Fuel Used Readout (3)

   The fuel used by each engine is displayed in white within a white outline of the engine. The last digit is fixed as 0. Unit of measurement is pounds. Readouts can be reset by pushing the FUEL USED RESET button on the forward overhead panel. The button must be held in until all readouts return to zero. If no valid fuel used data is available, the digits are replaced with an amber X.

4. Valves

   Closed valves are shown as white circles with lines perpendicular to the fuel line. Open valves are shown as green circles with lines parallel to the fuel line. If a transfer valve does not go to commanded position within 5 seconds, DISAG appears over the valve. The valve will be displayed in the commanded position. There is no fuel dump valve symbology on the FUEL synoptic unless the DUMP switch is on or either dump valve is in disagree.

5. Fill Valve

   Fill valves are shown as spigots. These spigots and associated lines are green when open, white when armed, and not shown when off.

6. Fuel Pump

   Pumps are shown as white circles when off. When on, pumps are shown as green circles with vanes. If pressure is low, the pump is displayed in amber with a small P shown adjacent to the amber pump.

7. Main Tank Quantity Readouts (3)

   The fuel quantity in each main tank is indicated by the level of white shading. Total fuel quantity is also displayed digitally within each tank symbol. Unit of measurement is pounds. If fuel is transferred from tip of tank 1 or 3 too early, TIP LOW will appear adjacent to the appropriate tank. If fuel is trapped in the tank, TIP XXX will appear in amber adjacent to the tank, where XXX is the quantity trapped.

8. Tail Tank Quantity Readout

   The total fuel quantity in the tail tank is indicated by the level of gray shading. Total fuel quantity is also displayed digitally within the tank symbol. Unit of measurement is pounds.

9. Fuel Temperature Readout

   Fuel temperature is displayed for the tail tank and right wing tank. Digits are normally white but become amber and boxed in amber when the fuel temperature drops below the limit temperature.

10. Aux Tanks Quantity Readout

    The upper and lower aux tank quantities are indicated by the level of gray shading. The total quantity of both upper and lower aux tanks is shown digitally in the upper aux tank symbol. Unit of measurement is . . . . pounds.

11. Center of Gravity Readout

    Center of gravity is displayed digitally in top left corner. Digits are normally white but are boxed and turn amber if the CG goes out of limits. If no valid CG data is available the digits are replaced by an amber X.

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Alerts

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

Red Boxed Alerts (Level 3)

- TNK 1/2/3 FUEL QTY LO (FUEL) - 30 seconds have elapsed with a low fuel quantity condition (about 3,500 pounds (1,588 kilograms)) in tank 1, 2, or 3 during fuel dump.

Amber Boxed Alerts (Level 2)

- BALST FUEL DISAG (FUEL) - Amount of fuel in the ballast tank is not compatible with the FMS ballast fuel value or FSC does not acknowledge receipt of ballast fuel data from the FMS.
- CG OUT OF LIMIT (FUEL) - Aircraft CG out of aft limit.
- DUMP VLV L/R DISAG (FUEL) - Left or right fuel dump valve is in disagreement with commanded position.
- FSC AUTO FAIL (FUEL) - FSC cannot control the fuel system in auto mode and has not reverted to manual.
- FUEL DUMP LEVEL (FUEL) - The fuel dump function did not shut off at the low level shutoff.
- FUEL OFF SCHEDULE (FUEL) - Fuel in the tanks is not according to schedule.
- FUEL QTY ALERTS (FUEL) - Data transmission is affected. There is a possible total failure of fuel alerting or a particular bus structure is inoperative.
- FUEL QTY FAULT (FUEL) - Fault in one or more tank quantity indicating systems or total quantity has not changed in the past 12 minutes.
- FUEL QTY/USED CHK (FUEL) - FSC senses a discrepancy between fuel burned and fuel on board.

- FUEL SYS ALERTS (FUEL) - Display electronic units not receiving valid data from fuel system controllers. Fuel system warning and alerting is faulty.
- FWD AUX FILL OPEN (FUEL) - Fwd aux fill valve is open (not shown during refueling). Applies only if fwd aux tanks are installed.
- FWD AUX L/R PUMP LO (FUEL) - The respective fuel pump outlet pressure is low. The pump should be considered inoperative. The rate of fuel transfer from the upper auxiliary fuel tank will be slower. Applies only if the single fwd aux tank is installed.
- FWD AUX OFF SCHED (FUEL) - Fuel remains in the fwd aux tanks when all the fuel should have already been transferred to the upper aux wing tank. Applies only if fwd aux tanks are installed.
- FWD AUX PUMPS LO (FUEL) - Both left and right fwd aux pumps are commanded on and low pressure is sensed in both pumps. Applies only if the fwd aux tanks are installed.
- LAT FUEL UNBAL (FUEL) - The fuel quantities in tanks 1 and 3 differ more than the allowed tolerance.
- TAIL FUEL QTY LO (FUEL) - During operation with alternate tail pump on, tail fuel quantity is becoming low.
- TAIL PUMPS LO (FUEL) - Fuel pressure is low on the tail tank pumps that are commanded on (one or both).
- TANK 1/3 PUMPS LO (FUEL) - Output pressure of both tank 1 or 3 pumps is low. Manual mode.
- TANK 2 PUMPS LO (FUEL) - Output pressure of the three tank 2 pumps is low. Manual mode.
- TNK 1 AFT PMP LO (FUEL) - The fuel pressure output of the aft fuel pump in tank 1 is low. The pump should be considered inoperative.
- TNK 1/2/3 FWD PMP LO (FUEL) - The fuel pressure output of the forward fuel pump in tank 1, 2, or 3 is low and the pump is

commanded on. Manual mode. Inhibited at high pitch angles with low fuel levels.

- TNK 1/3 TIP FUEL LO (FUEL) - The tank 1 or 3 tip quantity is low. Manual mode.
- TNK 1/2/3 XFER PMP LO (FUEL) - The fuel pressure output of the transfer pump in tank 1, 2, or 3 is low and the pump is commanded on. Manual mode.
- TNK 2L AFT PMP LO (FUEL) - The fuel pressure output of the left aft fuel pump in tank 2 is low and the pump is commanded on. Manual mode.
- TNK 2R AFT PMP LO (FUEL) - The fuel pressure output of the right aft fuel pump in tank 2 is low and the pump is commanded on. Manual mode.
- TNK 3 AFT PMP LO (FUEL) - The fuel pressure output of the aft fuel pump in tank 3 is low and the pump is commanded on. Manual mode.

Amber Alerts (Level 1)

- AUX LWR L/R PMP OFF (FUEL) - With the fuel system in the auto mode, the FSC has detected low pressure in the respective pump and turned the pump off. The rate of fuel transfer from the lower aux tank will be slower.
- AUX LWR L/R PMP LO (FUEL) - With the fuel system in manual mode, the respective fuel pump outlet pressure is low and the pump should be considered inoperative. The rate of fuel transfer from the lower aux tank will be slower.
- AUX LWR PUMPS LO (FUEL) - Fuel pressure output is low on the lower auxiliary tank pump(s) that are commanded on (one or both).
- AUX UPR L/R PUMP OFF (FUEL) - With the fuel system in the auto mode, the FSC has detected low pressure in the respective pump and turned the pump off. The rate of fuel transfer from the upper aux tank will be slower.

- AUX UPR L/R PUMP LO (FUEL) - With the fuel system in manual mode, the respective fuel pump outlet pressure is low and the pump should be considered inoperative. The rate of fuel transfer from the upper aux tank will be slower.
- AUX UPR PUMPS LO (FUEL) - Fuel pressure output of the upper auxiliary tank pumps that are commanded on is low.
- CG DISAG (FUEL) - Disagreement between the aircraft CG displayed on the SD and the CG entered in the FMS. Confirm fuel load and entered data.
- COLD FUEL RECIRC (FUEL) - The FSC is automatically circulating fuel in tanks 1 and 3 or the tail tank to increase the fuel temperature. If the fuel temperature continues to drop to within 3°C of the freeze point, the FUEL TEMP LO alert will be displayed.
- ENG 1/3 SUCT FEED (FUEL) - Engine 1 or 3 on suction feed only. Appears only with the FSC in auto, when all boost pumps and crossfeeds for that engine are off.
- FMS DUMP DISABLED (FUEL) - Fuel dump not stopped at FMS dump-to-gross-weight.
- FUEL DUMP ON (FUEL) - DUMP switch is in the ON position.
- FUEL MANF DRAIN (FUEL) - Crew has opened the manifold drain valves with the MANF DRAIN switch.
- FUEL SYS MANUAL (FUEL) - Fuel system is in the manual mode.
- FUEL TEMP LO (FUEL) - The tail and/or wing fuel is within 3°C of the fuel freeze value (or colder).
- FUEL VALVE FAULT (FUEL) - Either the tail fill isolation valve, the aux fill isolation valve, or the left or right outboard fill/manifold drain valve is inoperative. The FSC may be operated in the auto mode, however, tail fuel management may be affected.
- FUEL XFEED1/2/3 DISAG (FUEL) - Tank 1, 2, or 3 fuel crossfeed valve is failed open or closed.

- SEL FUEL SYS MAN (FUEL) - The fuel system has reverted to manual mode but the FUEL SYSTEM SELECT switch is in the auto position.
- TAIL ALT PUMP LO (FUEL) - The tail tank ALT PUMP pressure is low. Additional pumps should be turned on to prevent a possible engine 2 flameout.
- TAIL ALT PUMP OFF (FUEL) - With the fuel system in the auto mode, the FSC has detected low pressure from the tail tank ALT PUMP and turned the pump off. If there is fuel in the tail tank, it may be trapped.
- TAIL FUEL FWD (FUEL) - Control of aircraft CG by tail fuel management has been terminated. The FSC will transfer all fuel out of the tail tank. Recovery of tail fuel management may be possible by selecting the FSC to manual and back to auto.
- TAIL L/R PUMP LO (FUEL) - The respective fuel pump outlet pressure is low. The rate of fuel transfer from the tail tank will be slower.
- TAIL L/R PUMP OFF (FUEL) - With the fuel system in the auto mode, the FSC has detected a fault in the respective tail tank transfer pump and turned the pump off.
- TANK 1/2/3 PUMPS LO (FUEL) - All the boost pumps in the associated tank have low pressure.
- TANK 1/2/3 PUMPS OFF (FUEL) - All the tank pumps in the associated tank have been selected off.
- TNK 1/3 AFT PMP LO (FUEL) - The respective fuel pump pressure is low.
- TNK 1/3 AFT PMP OFF (FUEL) - With the fuel system in the auto mode, the FSC has detected a fault in the respective fuel tank pump and has turned the pump off.
- TNK1/2/3 FUEL QTY LO (FUEL) - Low fuel (about 4,000 pounds (1,814 kilograms)) in tank 1, 2, or 3.
- TNK 1/2/3 FWD PMP LO (FUEL) - The respective fuel pump pressure is low.

- TNK 1/2/3 FWD PMP OFF (FUEL) - With the fuel system in the auto mode, the FSC has detected a fault in the respective fuel tank pump and has turned the pump off.
- TNK 1/2/3 XFER PMP LO (FUEL) - The respective tank transfer pump pressure is low.
- TNK 2L/2R AFT PMP LO (FUEL) - The respective fuel pump pressure is low.
- TNK1/2/3 XFER PMP OFF (FUEL) - With the fuel system in the auto mode, the FSC has detected a fault in the respective transfer pump and has turned the pump off.
- TNK 2L/2R AFT PMP OFF (FUEL) - With the fuel system in the auto mode, the FSC has detected a fault in the respective fuel tank pump and has turned the pump off.

Cyan Alerts (Level 0)

- FUEL XFEED 1/2/3 ON - Fuel system 1, 2, or 3 XFEED switch is on.
- REFUELING - The refueling panel is armed. Aircraft should not be dispatched in the refueling mode.

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Description and Operation

General

Three hydraulic systems provide power to operate nose gear steering, landing gear, wheel brakes, and flight controls.

Hydraulic pressure for each system is provided by two engine-driven pumps. Three separate, parallel hydraulic systems operate continuously at 3000 psi. Each system includes an identical 12-gallon capacity hydraulic reservoir. Each reservoir can be filled from a pressurized ground service unit or from an unpressurized container by use of a hand pump near the fill panel.

Two electrically-driven auxiliary pumps provide an additional source of pressure to hydraulic system 3. If the Air-driven Generator (ADG) is deployed, it powers auxiliary pump 1.

Two hydraulic Reversible Motor Pumps (RMP) provide an alternate source of hydraulic pressure. One RMP is installed between systems 1 and 3, and the other is installed between systems 2 and 3.

Two Non-reversible Motor Pumps (NRMP) provide an alternate source of hydraulic pressure to the rudders and stabilizer trim.

Three bladder-type accumulators in each brake system provide a backup source of hydraulic pressure, and partial antiskid capability if the hydraulic system malfunctions. Pressure gauges are installed on each accumulator.

A BRAKE PRESS indicator, on the cockpit brake control panel, allows verification of brake pressure for aircraft towing.

Heat generated in the engine-driven pumps carries through the case drain lines to the reservoirs and back through the suction lines to the engine-driven pumps. This serves as the main heat radiating system. The entire pressure and return network is a secondary heat radiating system.

Switches on the HYD control panel control hydraulic components and annunciators. Hydraulic system indications are displayed on the System Display (SD) when the hydraulic synoptic is selected with the

HYD cue switch. Hydraulic alerts are displayed on the Engine And Alert Display (EAD) and SD.

Hydraulic System Controller

The Hydraulic System Controller (HSC) has two modes, auto or manual. Only one mode is in control at any time.

If an active HSC channel fails, control is automatically transferred to an alternate HSC channel. Should the second HSC channel fail, the system automatically reverts to the manual mode, and the crew manually operates the hydraulic system for the remainder of the flight.

In the auto mode the HSC performs the following functions:

- Controls the hydraulic system components which supply and route hydraulic pressure.
- Monitors the phase of flight and configures components accordingly.
- Conducts a preflight pressure test of the auxiliary hydraulic pumps and RMPs when initiated by the flight crew.
- Conducts a test of engine-driven hydraulic pumps after engine start.
- Reconfigures the hydraulic systems for various component, system, and aircraft failures.
- Monitors itself and hydraulic components for proper operation and reports faults to the Centralized Fault Display System (CFDS) and EIS.
- Reverts to manual mode if the auto mode is inoperative or if any combination of hydraulic system, and/or aircraft abnormal operation requires more than four engine-driven hydraulic pumps to be commanded off.

Reservoirs and Accumulators

Identical pressurized reservoirs are provided for each system. Mounted on each reservoir is a fluid quantity transmitter, low level switch, fluid temperature sensor, and a pressure relief valve. The 12-gallon reservoir is normally serviced to about 6 gallons. Each hydraulic system has a bladder-type accumulator to store pressurized fluid. After engine shutdown, reservoir pressure is maintained for about 8 hours.

Engine-Driven Pumps

Left and right engine-driven hydraulic pumps are mounted on the accessory drive for each engine. The left pump normally powers its respective system. The right pump is armed to operate if the left pump pressure drops below a predetermined value. The left pump low pressure switch electrically commands the right pump on. When the left pump pressure rises above a predetermined value, the right pump is electrically armed after 20 seconds. The HSC monitors the right pump and commands the right pump on or armed if it does not automatically respond to the electrical commands given by the left pump pressure switch.

The pump FAULT light on the HYD control panel illuminates if pump pressure is low and the pump is on, or if pump temperature is high.

In manual, the pilot commands the left pump on or off, and the right pump armed or off. In auto, the HSC commands the left pump on or off, and the right pump armed, on, or off.

Engine-driven pumps are interchangeable.

Electric Auxiliary Pumps

Two electrically-driven auxiliary pumps, installed in system 3, are used to pressurize system 3 on the ground or in flight. These pumps also pressurize system 1 via the 1-3 RMP, and system 2 via the 2-3 RMP.

In an emergency, auxiliary pump 1 is automatically controlled and powered by a deployed ADG. The ADG remains in the hydraulic mode unless the ADG/ELEC switch on the ELEC control panel is pushed.

The flight crew controls the auxiliary pumps with the HSC in auto or manual mode.

When either auxiliary pump is commanded on, the recirculation fans (if installed) are automatically commanded off. When the auxiliary pumps are commanded off, the recirculating fans are automatically commanded back on.

Reversible Motor Pumps

Two Reversible Motor Pumps (RMP) allow transfer of pressure from an operating hydraulic system to a non-operating hydraulic system. Pressure is transferred in either direction. No fluid transfer takes place. The transfer of energy is mechanical. RMPs are installed between systems 1-3, and between 2-3. The RMPs pressurize a system to 3,000 psi in about 3 seconds when driven by a fully pressurized system. A pressure differential between the connected systems causes pumping direction reversal. If there is no flow demand, the delivery from the pump stops.

The RMPs are commanded off when:

- The reservoir fluid quantity on either side of the RMP is less than 1 gallon.
- The ADG is deployed and ADG/ELEC switch on the ELEC control panel is not illuminated.

Both RMPs are commanded on at automatic slat extend and when any engine N2 rpm is less than 45 percent during taxi or takeoff/land flight phases.

In the manual mode the RMPs are manually commanded on or off. In the auto mode the RMPs are commanded on or off by the HSC.

Rudder Standby Power/Non-Reversible Motor Pumps

Two Non-reversible Motor Pumps (NRMP) provide an alternate source of hydraulic power to the rudder and horizontal stabilizer when the primary hydraulic system cannot provide power. Hydraulic system 2 powers the upper rudder and horizontal stabilizer via the 2-1 NRMP when hydraulic system 1 cannot provide power. Hydraulic system 3 powers the lower rudder via the 3-2 NRMP when hydraulic system 2 cannot provide power.

A compensator is installed for each NRMP. Low NRMP compensator fluid level automatically disarms the affected pump.

NRMPs operate when the primary system pressure falls below 2,000 psi ±200 psi. The NRMPs stop operating when the primary system pressure rises above 2,000 psi ±400 psi.

The NRMPs are always armed in flight. The HSC disarms the NRMPs only during ground maintenance via input through the Multifunction Control Display Unit (MCDU).

Hydraulic System Enhancement

A check valve and motor-operated shutoff valve in hydraulic system 3 enhances system integrity if there is an uncontained failure of engine 2. The installation uses reservoir level sensing to detect leakage, and automatically shuts off system 3 elevators and 3-2 NRMP when the fluid in the reservoir reaches a predetermined level. This action retains enough fluid in hydraulic system 3 for pitch and roll control through use of horizontal stabilizer trim and lateral controls powered by system 3. The HYD 3 ELEV OFF alert is displayed when the shutoff valve closes.

Automatic Operation

The HSC automatically controls the hydraulic system. The HSC calculates aircraft flight phases and configures hydraulic components as necessary.

Normal Configuration

Normal configuration is as follows:

- Engine-driven left pumps on
- Engine-driven right pumps armed
- Reversible motor pumps (RMP) off
- Auxiliary pumps off
- NRMP rudder standby power armed
- Flight control bypass valve open

Normally, only the left engine-driven pump in each system operates. The right pump is controlled by an armed circuit external to the HSC, which turns on the right pump if the left pump pressure falls below 2,400 psi. The HSC also monitors this function and turns on the right pump if the external circuitry fails to do so.

Hydraulic Preflight Pressure Test

The hydraulic preflight pressure test, the first of two preflight tests required to test the hydraulic system, is performed only before engine start, and uses system 3 auxiliary pumps and both RMPs. The following conditions must be satisfied in order to start or continue the test:

- Aircraft is on the ground and all engine FUEL switches are off.
- Hydraulic fluid quantity in each system reservoir is more than a predetermined value, and the quantity transmitters are operative.
- Flight control bypass valve is in the normal position (open).
- System pressure sensors are operative.
- System pressure is less than 1,000 psi when the test is started.
- Auxiliary pumps are off when the test is started.

- Auxiliary pumps are not operated manually by anyone in the cockpit during the test.
- AC ground service bus is energized.

The pressure test can be initiated only by the flight crew. This is necessary to assure proper safety clearance before pressurizing hydraulically powered components. When the HYD PRESS TEST switch is pushed, a series of commands, sent by the HSC, accomplishes the following:

- Performs internal HSC checks for about the first 45 seconds.
- Verifies each auxiliary pump independently produces at least 2,400 psi.
- Verifies RMP 1-3 is able to produce at least 2,400 psi in system 1 and that the associated shutoff valves operate correctly.
- Verifies RMP 2-3 is able to produce at least 2,400 psi in system 2 and that the associated shutoff valves operate correctly.
- Verifies hydraulic fluid quantity in each system reservoir is at least 3.8 gallons (14.38 liters) with the system pressurized.
- Verifies engine pump pressure low switches function correctly while the pumps are depressurized.

Hydraulic Preflight Engine-Driven Pump Test

The hydraulic preflight engine-driven pump test, the second of two preflight tests required to test the hydraulic system, is performed when the ignition is on for engine start.

The following conditions must be satisfied in order to start or continue the test:

- Aircraft is on the ground and the associated engine FUEL switch is on.

- Hydraulic fluid quantity in each system reservoir is more than 2.5 gallons (9.46 liters).
- System pressure sensors are operative.
- Auxiliary pumps remain off.

NOTE: *If the auxiliary pump(s) are on when engine 3 is started, the HSC turns them off in preparation for system 3 pump test.*

When an ENG IGN switch is on, each left engine-driven pump is off and each right pump is armed. After each engine is started and at idle rpm, a test of the engine-driven pumps is automatically conducted.

The pumps are tested to ensure the following:

- The HSC can control the engine-driven pumps.
- The right engine-driven pump produces at least 2,800 psi.
- The right engine-driven pump ARM circuits are operating correctly.

Preflight Fail Alerts Test

If either preflight hydraulic system test fails, a HYD PRES TST FAIL or HYD PUMP TST FAIL alert appears on the EAD. The HSC clears the alert when manual mode is selected. Selecting manual clears the alert only, and does not fix the cause.

Parked Configuration

When the aircraft is on the ground and all engine FUEL switches are OFF, the HSC places the hydraulic system in the normal configuration.

Taxi Configuration

During taxi, the HSC:

- Does not turn the engine-driven pumps off.
- Places the hydraulic system in the normal configuration after each engine-driven pump test is completed. Taxi is

defined as aircraft on the ground, any engine FUEL switch ON, and computed airspeed less than or equal to 80 knots.

Takeoff/Land Configuration

Takeoff configuration is aircraft on the ground, speed more than 80 KTS, and any engine FUEL switch on.

Land configuration is aircraft in the air, altitude equal to or less than 17,750 feet, and slats, flaps, or landing gear extended.

During takeoff/land configurations, the HSC accomplishes the following:

- Allows the engine-driven pumps to remain on.
- Turns off the RMPs when the reservoir fluid quantity is less than 4 quarts, or when certain multiple faults exist.

Cruise Configuration

When in cruise flight, the HSC configures the hydraulic system in the normal configuration. Cruise flight is defined as gear, flaps, and slats retracted, or baro-corrected altitude more than 17,750 feet.

Abnormal Operations

The hydraulic system can be placed into abnormal operations by aircraft failures/faults external to the hydraulic systems, or by component failures within the systems.

The aircraft failures are as follows:

- Engine fire - When an ENG FIRE handle is pulled, a mechanical valve shuts off hydraulic fluid to both engine-driven pumps. The HSC turns off both pumps when this condition is sensed.
- Engine N2 rpm less than 45 percent - Both RMPs are turned on in the taxi or takeoff/land phases of flight.
- Inflight engine start - When the engine FUEL switch is off, and the engine N2 rpm is less than 45 percent, the HSC turns off both engine-driven pumps.

- Electrical power during cruise condition - All left engine-driven pumps are controlled by one electrical circuit and all right pumps by another circuit. Loss of power causes all pumps on a circuit to go on. When the HSC recognizes a failure of one of these circuits, it turns off the opposite pumps. However, if one of the pumps on the failed circuit has low pressure, the HSC turns on the other pump in that system.

The HSC takes corrective action to perform the following functions in response to system faults:

- The HSC pressurizes all three hydraulic systems if the aircraft is in the taxi or takeoff/land phase of flight.
- The HSC pressurizes two systems if the aircraft is in the cruise phase of flight.
- Restores system pressure if the original pressure source fails and there is adequate fluid in the affected system(s).
- Depressurizes a system with high temperature if the aircraft is not in taxi or takeoff/land phase of flight.
- Depressurizes a system when its reservoir quantity drops to 2.5 gallons(9.46 liters) if the aircraft is not in taxi or takeoff/land phase of flight.
- Turns off a source of excessive pressure and substitutes one of correct pressure if the aircraft is in the cruise phase of flight.

When the aircraft enters the land phase, these systems are repressurized, if the reservoir fluid level is greater than 1.0 gallon (3.78 liters).

Fault Priorities

A system of priorities is established for execution of abnormal/emergency procedures by the HSC. For conditions with equal priority, the first condition detected has priority.

The procedure for the highest priority condition is executed when it is detected. Any procedure for a lower priority condition that may be in progress at that time is aborted.

Once the procedure for a higher priority condition is completed, normal monitoring resumes and a lower priority procedure is restarted if still applicable.

The priority sequence is as follows:

1. Loss of fluid (reservoir fluid <2.5 gallons).
2. Engine fire.
3. Inflight engine start.
4. Engine N2 rpm less than 45 percent.
5. System pressure low or high.
6. System temperature or engine-driven pump temperature high.
7. Engine-driven pump pressure low.
8. Engine-driven pump electrical power loss.

Reversion To Manual Mode

Because of the necessity to maintain hydraulic pressure for control of the aircraft, the HSC reverts to manual mode if it receives failure signals that require it to turn off all three systems or more than four engine-driven pumps.

The HSC is not allowed to turn off all three systems or more than four engine-driven pumps, regardless of the failure indications received.

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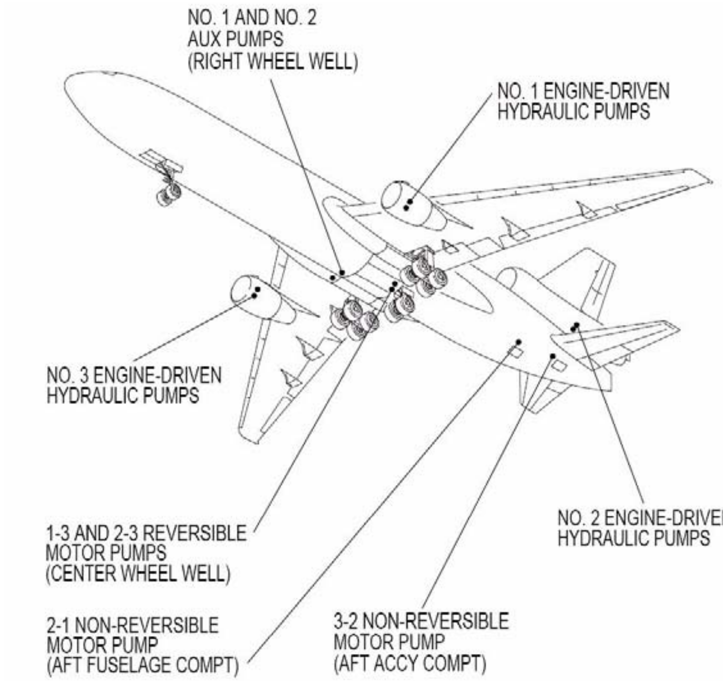
Components


NO. 1 AND NO. 2
AUX PUMPS
(RIGHT WHEEL WELL)
NO. 1 ENGINE-DRIVEN
HYDRAULIC PUMPS
NO. 3 ENGINE-DRIVEN
HYDRAULIC PUMPS
1-3 AND 2-3 REVERSIBLE
MOTOR PUMPS
(CENTER WHEEL WELL)
NO. 2 ENGINE-DRIVEN
HYDRAULIC PUMPS
2-1 NON-REVERSIBLE
MOTOR PUMP
(AFT FUSELAGE COMPT)
3-2 NON-REVERSIBLE
MOTOR PUMP
(AFT ACCY COMPT)

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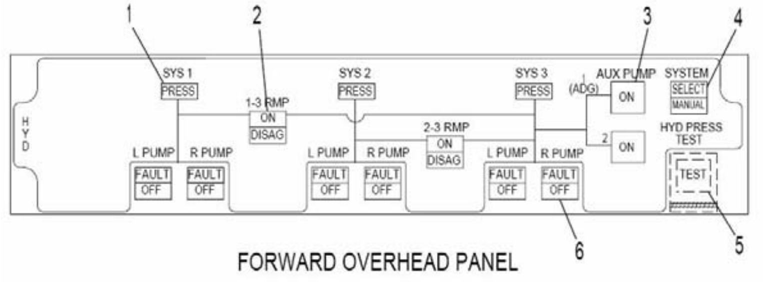
Controls and Displays

Hydraulic Control Panel



1. SYS1/2/3 PRESS Light - amber

   PRESS - Illuminates amber when system pressure is less than 2400 psi or more than 3500 psi. Extinguishes when system pressure is within limits.

2. 1-3/2-3 RMP Switch - blue/amber

   This switch is a momentary switch that controls the RMP shutoff valves when the system is in manual mode. The switch has no effect in the auto mode.

   ON - Illuminates blue when the pump is commanded on (valves commanded open).

   The RMPs are commanded on and provide hydraulic system pressure when:

   - Any engine N2 falls below 45 percent during taxi or takeoff and landing phases of flight.
   - The engine-driven pumps are not able to maintain necessary system pressure during taxi, takeoff and landing phases of flight.
   - The pump receives an auto slat extend signal.

   DISAG - Illuminates amber when one of the valves does not open and the RMP is commanded on. DISAG also illuminates if the RMP is commanded off and the internal pump pressure is more than 600 psi, but is inhibited for 8 seconds when the Hydraulic System Controller (HSC) is in auto

ON and DISAG extinguish when the pump is commanded off. This pump is commanded off when:

- It is not required for the phase of flight.
- The associated hydraulic reservoir has less than 1.0 gallon of fluid (all phases of flight).
- The Air Driven Generator (ADG) is released and the ADG switch is in the hydraulic position.

3. Electric AUX PUMP 1 (ADG)/2 Switch - blue

   The electric AUX PUMP switch is a momentary switch that commands the electric auxiliary hydraulic pump on and off when the system is in manual or auto mode. The aux pumps are under automatic control only during the manually activated preflight hydraulic pressure test.

   ON - Illuminates blue when the AUX PUMP is commanded ON. When on, the applicable pump supplies pressure to hydraulic system 3.

   When either pump is commanded ON, the recirculation fans are automatically commanded off. When the pumps are commanded off, the recirculation fans are automatically commanded on.

   AUX PUMP 1 is powered by the ADG when the ADG is deployed in the hydraulic mode.

4. HYD SYSTEM SELECT/MANUAL Switch - amber

   This is an alternate action switch that allows selection between manual and auto modes.

   There are 2 alternating auto channels. During auto operation, one of the 2 auto channels is not used. Each time auto is selected, the previous unused auto channel is activated.

   SELECT - Illuminates amber when the system reverts to manual with auto selected. The SEL HYD SYS MAN alert is displayed on the EAD. Pushing the HYD SYSTEM SELECT/MANUAL switch locks the system in manual.

MANUAL - Illuminates amber when the system is in manual.

MANUAL - Flashes amber when auto is selected and a switch on the HYD control panel has been pushed that has no effect in auto.

5. HYD PRESS TEST Switch - blue

   The HYD PRESS TEST switch is a guarded momentary switch that initiates the hydraulic pressure test in the HSC. The switch has no effect when the system is in manual.

   TEST - Illuminates blue when testing is in progress.

   The switch, when pushed, tests the electric aux pumps and RMPs. If the test is stopped before completion, the RMPs and aux pumps turn off. If the electric AUX PUMP switches are pushed during the test, the test stops.

6. SYS 1/2/3 L/R PUMP Switches - amber

   These system (SYS 1/2/3) switches command the left (L) engine-driven hydraulic pump on or off, and the right (R) engine-driven pump armed or off, when the respective system is in manual mode. The respective switches have no effect when the system is in auto.

   The right pump is armed when the L PUMP switch is commanded on. If the left pump pressure is less than 2400 psi, the right pump is commanded on.

   FAULT - Illuminates amber on the respective system PUMP switch when pump pressure is less than 2400 psi and the pump is on, or the pump case drain temperature is more than 245°F.

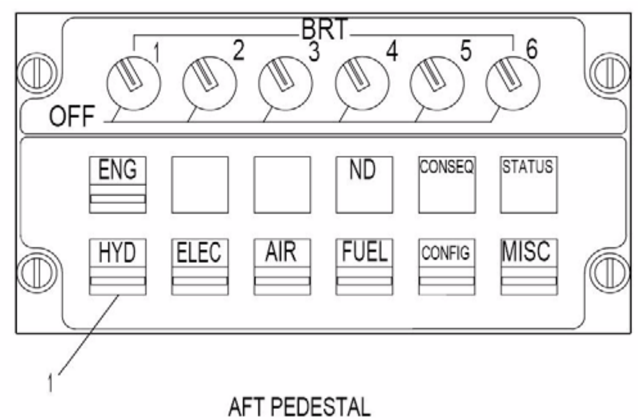
   Both FAULT and OFF on the L PUMP switch are extinguished when the left pump is pressurizing its respective hydraulic system (SYS 1/2/3).

Both FAULT and OFF on the R PUMP switch are extinguished when the right pump is armed or is pressurizing its respective hydraulic system (SYS 1/2/3).

The pumps are commanded off when:

- Pump pressure is low.
- Pump temperature is high.
- Fluid quantity is low.
- System temperature is high.
- System pressure is low.
- System pressure is high.
- The engine is started.
- The engine FIRE handle is pulled.

HYD Cue Switch



1. HYD CUE Switch - white

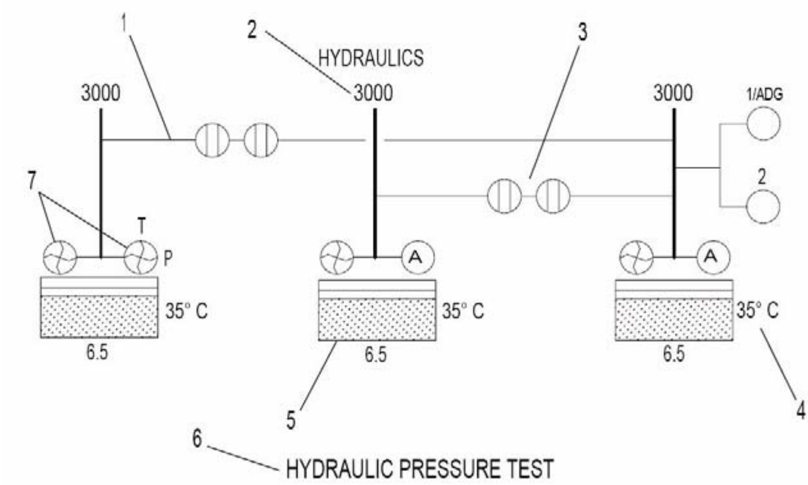
HYD - Illuminates white when a HYD alert is displayed on the EAD. When pushed:

- MASTER CAUTION or MASTER WARNING lights extinguish.

- Reminder message replaces EAD alert.
- Synoptic and consequences are displayed on the SD.

Some amber alerts are maintenance alerts that appear on the SD STATUS page only. The HYD cue switch and the MASTER CAUTION lights do not illuminate for these maintenance alerts.

SD Synoptic



1. Schematic Lines - green/white

   Schematic lines representing hydraulic systems and pressure transfer lines are green when pressurized and white when unpressurized.

2. System Pressure Readout (3) - white/amber

   Hydraulic system pressure (psi) is shown digitally at the head of each system. White digits turn amber and are boxed when the pressure is out of limits (high or low). When no valid pressure data is available, the digits are replaced by an amber "X".

3. Reversible Motor Pumps (2) - white/green/amber

RMPs are displayed as double valve symbols. When closed, the valves are white with valve lines perpendicular to the schematic line. When open, these valves are green and the valve lines are parallel to the schematic line. If the valves do not go to the commanded position within 8 seconds, the commanded valve position is displayed with DISAG in amber above the valves.

4. Reservoir Temperature Readout (3) - white/amber

   Reservoir temperature in degrees C is shown in white digits to the right of each reservoir. If the temperature exceeds 100 degrees C, the digits are displayed in amber and are boxed. The digits are replaced by an amber "X" when no valid temperature is available.

5. System Reservoir (3) - grey/white/cyan/amber

   Hydraulic fluid quantity is shown as a grey shaded area, proportional to reservoir quantity. Quantity in gallons is displayed in white digits below each reservoir.

   During minimum idle speed each tank is marked with a cyan line to represent the preflight quantity. This line is used as a reference to monitor for fluid leakage. Minimum dispatch quantity for system 3 is 6 gallons.

   If the system is below 3.8 gallons during preflight, an alert is displayed to have the reservoir filled. If the quantity drops below 2.5 gallons, the shaded area, the reservoir outline, and the quantity digits are displayed in amber. The digits are boxed.

   If no valid quantity data is available, the digital quantity display and grey shading are removed, and the digital quantity is replaced by an amber "X".

6. HYDRAULIC PRESSURE TEST Display

   This text appears during the hydraulic pressure test.

7. Engine and Auxiliary Pumps - white/green/amber

Engine pumps are shown as white circles when the pump is off or armed (containing the letter "A" when armed). When commanded on, the pumps are green circles with vanes.

Low pump pressure is shown as an amber pump symbol with the letter "P" displayed next to it.

High case drain temperature is shown as an amber pump symbol with the letter "T" above it.

Auxiliary pumps are shown as white circles when commanded off, and green circles with vanes when the pump is on.

EIS Test Display

All hydraulic synoptic data digits are crossed with amber X's when all of the following conditions are met:

- The aircraft is on the ground and operational.
- The ANNUN LT TEST button on the overhead panel is pushed.
- The HYDRAULIC synoptic is selected on the SD.

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Alerts

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

Red Boxed Alerts (Level 3)

- HYD 1 & 2/1 & 3/2 & 3 FAIL (HYD) - Fluid quantity in respective systems (1 and 2/1 and 3/2 and 3) is less than 1 gallon.

Amber Boxed Alerts (Level 2)

- HYD 1/2/3 FAIL (HYD) - Fluid quantity in respective system is less than 1 gallon.
- HYD 1/2/3 PRES HI (HYD) - Respective system pressure is more than 3500 psi.
- HYD 1/2/3 PRES LO (HYD) - Respective system pressure is less than 2400 psi. Manual mode.
- HYD 1/2/3 QTY LO (HYD) - Respective system fluid less than 2.5 gallons| (manual mode only).
- HYD 1/2/3 TEMP HI (HYD) - Respective system has exceeded 100 degrees C (manual mode).

Amber Alerts (Level 1)

- HYD 1/2/3 OFF (HYD) - Respective system engine driven pumps 1/2 and the respective reversible motor pumps 1-3/2-3 are off.
- HYD 1/2/3 PRES LO (HYD) - Respective system pressure is less than 2400 psi. Auto mode.
- HYD 1/2/3 QTY LO (HYD) - Respective hydraulic system fluid quantity low. This alert is displayed if there is less than 4.75 gallons on the ground prior to engine start, or less than 2.5 gallons after engine start.
- HYD 1/2/3 TEMP HI (HYD) - The temperature in the respective hydraulic system reservoir has exceeded normal limits.

- HYD 3 ELEV OFF (HYD) - The elevator shutoff valve in hydraulic system 3 is closed. Hydraulic system 3 is not powering the elevators.
- HYD PRES TST FAIL (HYD) - The flight crew initiated hydraulic pressure test has failed. A second test may be performed. If alert is displayed again, call maintenance.
- HYD PUMP 1L/1R/2L/2R/3L/3R <2800 (HYD) - Respective pump pressure is less than 2800 psi during engine pump preflight test. This test is accomplished by the HSC during each engine start. This alert will be displayed in conjunction with a HYD PUMP TST FAIL alert
- HYD PUMP 1L/1R/2L/2R/3L/3R FAULT (HYD) - The respective engine-driven hydraulic pump pressure or temperature is out of limits. The HSC will turn off the affected pump when the aircraft is in cruise.
- HYD PUMP 1L/1R/2L/2R/3L/3R OFF (HYD) - The respective engine-driven hydraulic pump is off.
- HYD PUMP TST FAIL (HYD) - The engine-driven hydraulic pump preflight pressure test has failed.
- HYD SYS MANUAL (HYD) - The HSC is in the manual mode.
- RUD STBY LWR OFF (HYD) - The 3-2 non-reversible motor pump is inoperative. Standby hydraulic power to the lower rudder is not available.
- RUD STBY UPR OFF (HYD) - The 2-1 non-reversible motor pump is inoperative. Standby hydraulic power to the upper rudder and stabilizer trim motor is not available.
- RUDDER BOTH INOP (HYD) - No primary or non-reversible motor pump power to the upper or lower rudder actuator.
- RUDDER LWR INOP (HYD) - No primary or non-reversible motor pump power to the lower rudder.
- RUDDER UPR INOP (HYD) - No primary or non-reversible motor pump power to the upper rudder.

- SEL HYD SYS MAN (HYD) - The hydraulic system has reverted to manual mode but the HYD SYSTEM SELECT switch is in the auto position.

Cyan Alerts (Level 0)

- HYD 1-3/2-3 RMP ON - Respective reversible motor pump 1-3/2-3 is on.
- HYD AUX PUMP ON - One or both of the hydraulic system aux pumps are on.
- HYD PRES TEST - The automatic hydraulic pressure test is in progress.

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Description and Operation

General

Ice and rain protection consists of:

- Airfoil (wing and tail) anti-ice systems
- Engine cowl anti-ice system
- Air data heater system (pitot, static, TAT)
- Windshield/window anti-ice and defog systems
- Windshield/window wiper system
- Rain repellent system, if installed
- Ice detection system, if installed

The Environmental Systems Controller (ESC) monitors engine cowl anti-ice system operation.

The Pneumatic Systems Controller (P SC) monitors wing and horizontal stabilizer anti-ice system operation.

The Miscellaneous Systems Controller (MSC) automatically controls and monitors pitot tube, static port, and AOA heater operation.

Ice and rain protection controls are located on the forward overhead panel. Alerts are displayed on the Engine and Alert Display (EAD) and System Display (SD) to provide system status information to the crew.

The AIR cue switch illuminates when alerts related to wing, tail, engine anti-ice, and ice detection system (if installed) are displayed.

The MISC cue switch illuminates when alerts related to air data heaters, windshield heat, or defog are displayed.

As an optional installation, an automatic anti-ice system for airfoil and engine cowl ice protection is available.

Airfoil Anti-Ice System

The airfoil anti-ice systems consist of the wing anti-ice system and the tail (horizontal stabilizer) anti-ice system. Pushing the WING and TAIL ANTI-ICE switches ON prior to takeoff arms the airfoil anti-ice systems to function automatically when left and/or right ground sense mechanisms sense flight.

Wing Anti-Ice System

The wing anti-ice system provides ice protection for the outboard wing slats. Ice protection is not provided for the inboard slats.

Each wing has 8 leading-edge slats. The outermost slats (4 through 8) are anti-iced with hot engine bleed air. The bleed air source is either low stage air, high stage air, or low stage air augmented with high stage air, depending on the engine power setting.

The bleed air, drawn from the main pneumatic manifold, flows through a stainless steel duct to the piccolo duct. The piccolo duct, installed in the slats, controls the anti-ice airflow rate. The anti-ice air is discharged from the piccolo duct and through double skin passages. After leaving the double skin passages, the air is discharged overboard at the slat lower trailing edge.

Pushing the WING ANTI-ICE switch to ON before takeoff arms the airfoil anti-ice system to automatically function when the left and/or right ground sense mechanism senses flight. The system automatically turns off when the aircraft lands. An alert warns the flight crew if the system fails to shut off when on the ground. The slats may be damaged if the anti-ice system is on longer than 30 seconds while on the ground.

Normally the flight crew operates the wing anti-ice system manually, except during a Center Accessory Compartment (CAC) manifold fail condition. In this case, during the failure, wing anti-ice is turned off automatically in order to facilitate the manifold decay check (manually performed by flight crew).

The wing anti-ice valves are armed on the ground or open during flight if selected on. The two wing anti-ice shutoff valves are normally opened and closed with the WING ANTI-ICE switch on the ANTI-ICE/WINDSHIELD control panel. The valves open only inflight, when pneumatic pressure is available. Pushing the WING ANTI-ICE switch opens the wing anti-ice valve. ON illuminates. DISAG illuminates when the open limit switch is tripped and the switch is off, or the closed limit switch is tripped and the switch is ON. A WNG A-ICE (L or R) DISAG alert is displayed.

On the ground, the WNG A-ICE DISAG alert is displayed, and the DISAG light illuminates, when an anti-ice valve is open, regardless of the switch position.

If wing anti-ice valve power fails, the valves fail in the closed position.

Tail Anti-Ice System

The tail (horizontal stabilizer) anti-ice system functions in the same manner as the wing anti-ice system.

Hot engine bleed air from pneumatic system 2 manifold is routed over the horizontal stabilizer box, diverging to right and left leading edges. Piccolo tubes, positioned along the leading edges, supply the hot engine bleed air.

Pushing the TAIL ANTI-ICE switch opens the horizontal stabilizer anti-ice valve. The two PSCs provide the following functions:

- Controls pneumatic system temperature and pressure requirements for ice protection
- Monitors horizontal stabilizer anti-ice valve position
- Monitors system ducts for leaks

ON illuminates on the TAIL ANTI-ICE switch when the horizontal stabilizer is commanded open.

DISAG illuminates on the TAIL ANTI-ICE switch when the switch is OFF and flow is sensed, or when the switch is ON and flow is not sensed. The TAIL A-ICE DISAG alert is displayed.

On the ground, the TAIL A-ICE DISAG alert is displayed, and the DISAG light illuminates, when an anti-ice valve is open, regardless of the switch position.

The ESC depressurizes pneumatic system 2 after 25 seconds if the anti-ice valve disagree condition continues to exist, and anti-ice air flow exceeds normal flow tolerances after duct pressurization. A tail manifold fail signal is transmitted to the PSC, which sends a signal to the ESC for annunciation and shutdown of pneumatic system 2.

The tail anti-ice shutoff valve fails closed if valve power fails.

Engine Cowl Anti-Ice System

The engine cowl anti-ice system uses hot engine bleed air (11th stage for GE engines, 8th or 15th stage for P&W engines) incorporating a swirl system for cowl ice protection. Hot bleed air is ducted to the nose lip, where it is discharged by a nozzle, producing a swirling flow into the circumferential chamber (D-duct).

For the aft engine cowl anti-ice system, hot bleed air is ducted from the engine and discharged into the D-duct. The hot air then enters into a double skin passage through openings located in the inner skin. The anti-ice air is exhausted from the double skin passage into the aft compartment and vented overboard.

Engine cowl anti-ice valves are open when the flight crew selects the respective anti-ice system on. The engine cowl anti-ice valves are opened by pushing the appropriate ENG 1/2/3 ANTI-ICE switch. The anti-ice valve ON light illuminates on the switch when the valve is commanded open.

DISAG illuminates on the respective ENG 1/2/3 ANTI-ICE switch when the valve position (open or closed) does not agree with the commanded position. Momentary illumination of the DISAG light occurs while the valve is in transit.

The ESC inhibits an engine anti-ice DISAG annunciation while the FUEL switch is selected OFF. The DISAG annunciation is also inhibited for up to 45 seconds after the FUEL switch is selected ON, (all GE engines, and those P&W engines with the automatic anti-ice system installed). With the engine 2 anti-ice switch selected ON, if a leak is detected adjacent to anti-ice ducting for engine 2, causing the valve to automatically close (DAC fuselage 575 and subsequent), the alert SEL ENG2 AICE OFF is displayed.

With the engine 2 anti-ice on or commanded OFF and not verified off, if a leak exists in the anti-ice ducting for engine 2, the alert ENG 2 A-ICE DUCT (DAC fuselage 574 and previous) is displayed.

If electrical power to the valve fails, the valve fails open.

Air Data Heater System

A Miscellaneous Systems Controller (MSC) automatically controls and monitors operation of the air data heaters (pitot tube, static port, angle-of-attack, and TAT probe heaters.)

The MD-11 is equipped with 3 pitot tubes, static pressure ports (2 sets), 2 angle of attack sensors, and a TAT probe.

The three pitot heat systems are Captain's, First Officer's, and auxiliary. All three systems have different power sources.

The pitot tubes are installed on the underside of the fuselage. Each pitot tube is electrically anti-iced with two self-regulating heaters.

A set of primary and alternate static pressure ports are installed on each side of the fuselage. Both primary and alternate static pressure ports are protected from ice formation by an electrical heating system.

One angle-of-attack sensor is installed on each side of the fuselage. The angle-of-attack sensors are electrically heated.

A TAT probe is installed on the underside of the fuselage. The TAT probe is electrically heated.

The MSC turns on all air data heat (except TAT) when any engine FUEL switch is moved to ON. The MSC turns these heating systems (except TAT) off when all three engine FUEL switches are moved to OFF.

The MSC allows the TAT heat to be on only when the ground sense mechanism senses flight. However, maintenance personnel can override the MSC, as necessary, with switches on the maintenance panel.

Windshield/Window Anti-Ice and Defog Systems

The clearview windows and aft windows are equipped with a defog system only. The windshields are equipped with both defog and anti-ice systems.

All cockpit windshields/windows can withstand full airplane pressurization with one glass pane cracked.

The windshield anti-ice system (which may also be used for backup windshield defogging) consists of separate, independent, electrically-heated left and right windshields, selector switches, temperature controllers and temperature sensors.

A controller and sensor maintains the windshield at the correct temperature. The controller automatically provides ramp warm-up (gradually increasing) power to the windshield for three to four minutes during initial turn-on to minimize thermal shock. The controller automatically removes power from the windshield if an overheat condition occurs.

Windshield anti-ice can be selected on at NORM anti-ice heat or HIGH anti-ice heat without thermal shock to the windshield. Appropriate alerts are displayed for windshield heat on and for failure conditions.

The windshields are constructed of a glass-vinyl-glass-vinyl-glass, layered configuration. A thin anti-ice heating film (stannous oxide) is on the inboard surface of the outer glass pane, next to the vinyl layer. Heating is accomplished by electrical potential across the resistive oxide film.

Defogging is accomplished by applying power to a similar conductive film on the outboard surface of the inner glass pane. The defogging system consists of elements and sensors in each windshield, clearview, and aft window and a controller for each window. A single DEFOG switch controls defogging. DEFOG should be on for all flight conditions.

Two switches (L/R WINDSHLD ANTI-ICE) on the lower maintenance panel allow maintenance personnel to switch between primary and spare (L and R) anti-ice heat sensors on each windshield. Six switches on the lower maintenance panel (L/R WINDSHLD, L/R CLEARVIEW, and L/R AFT WINDOW) allow maintenance personnel to switch between primary and spare (L and R) defogging heat sensors on each window.

Windshield/Window Wiper System

A separate wiper system is installed for left and right windshields. Each wiper system is independently controlled by a WIND SHLD WIPE selector on the forward overhead panel. The wipers may be selected to OFF/SLOW/FAST (some airplanes), or OFF/INT/SLOW/FAST.

With wipers selected to OFF, the wiper and arm assembly move to the vertical, parked position.

Wing/Tail and Engine Cowl Anti-Ice Control System

The wing and tail anti-ice valves are armed on the ground or open in flight, and the engine cowl anti-ice valves are open for the following:

- When in manual and the flight crew selects the respective anti-ice system on.

The ESC turns off the wing, tail, and associated engine cowl anti-ice system when the system is in auto and all three engines are not running.

Wing or Tail Anti-Ice Manifold Failure

The ESC turns the associated anti-ice system off during a wing or tail anti-ice failure if the system is active. The associated pneumatic system is turned off if the failure continues, or, for a nonactive system.

ESC - CAC Manifold Failure Test Procedure

The ESC commands wing and tail anti-ice valves closed during a CAC manifold failure test procedure.

The wing and tail anti-ice system must be selected off if the air system is in manual mode.

ESC - 1-2 Manifold Failure Test Procedure

For the duration of the test, during a 1-2 manifold failure test, the ESC commands the wing anti-ice system off when pneumatic system 1 is depressurized. The tail anti-ice system is commanded off when pneumatic system 2 is depressurized.

ESC - Single Manifold Failures

The wing anti-ice system is commanded off when the ESC senses a pneumatic system 1 or 3 manifold failure, or a left/right wing manifold failure.

The tail anti-ice system is commanded off when the ESC senses a pneumatic system 2 manifold failure, or a tail manifold failure.

SMOKE ELEC/AIR Selector Operation

Moving the SMOKE ELEC/AIR selector on the ELEC control panel from NORM turns off wing anti-ice. Returning the selector to NORM turns wing anti-ice back on.

Tail anti-ice is not available when 3/1 OFF or 1/2 OFF are selected. Tail anti-ice operates normally when 2/3 OFF is selected.

DITCHING Switch

The ESC commands the associated wing and tail anti-ice systems off as pneumatic systems are shut down following selection of DITCHING ON.

Bleed Air Temperature High Operation

The ESC reverts the ice protection system and the air system to manual when a single bleed air source is feeding 2 or 3 pneumatic manifolds and a high temperature condition exists in an airfoil (wing or tail) anti-ice system bleed air source.

DEU Alerting

The ICE DETECTED alert is displayed when, in automatic mode, any anti-ice system is not commanded on while in icing conditions.

AIRFOIL A-ICE ON indicates wing and/or tail anti-ice valves are open

ENG 1/2/3 A-ICE ON indicates respective engine cowl anti-ice valve is open.

ENGINE A-ICE ON indicates all three engine cowl anti-ice valves are open.

A-ICE ALL ON indicates wing, tail, and engine cowl anti-ice valves are open.

Annunciator Controls

Status of the respective anti-ice valves is indicated on the ANTI-ICE control panel. WING and TAIL ANTI-ICE switches illuminate ON when commanded open/armed. ENG 1/2/3 ANTI-ICE switches illuminate ON when the associated engine cowl anti-ice valves are commanded open.

The PSCs provide wing and tail anti-ice disagree indication.

The ESC inhibits an anti-ice disagree annunciation when the FUEL switch is OFF, and up to 45 seconds after the FUEL switch is turned ON.

Airfoil Anti-Ice System Preflight Test (Optional)

On airplanes without the automatic anti-ice system installed, an optional anti-ice system preflight test is initiated when the WING or TAIL anti-ice switches (alternate action) are pushed to ON. During the test, ground sensing is bypassed and the respective airfoil anti-ice valve opens. If the test is successful, DISAG is displayed above the respective anti-ice valve on the AIR synoptic. The respective anti-ice valve then closes.

The A-ICE SYS TEST alert is displayed during the airfoil anti-ice test. If the left or right wing or tail anti-ice systems are detected as failed, the A-ICE TEST FAIL alert is displayed.

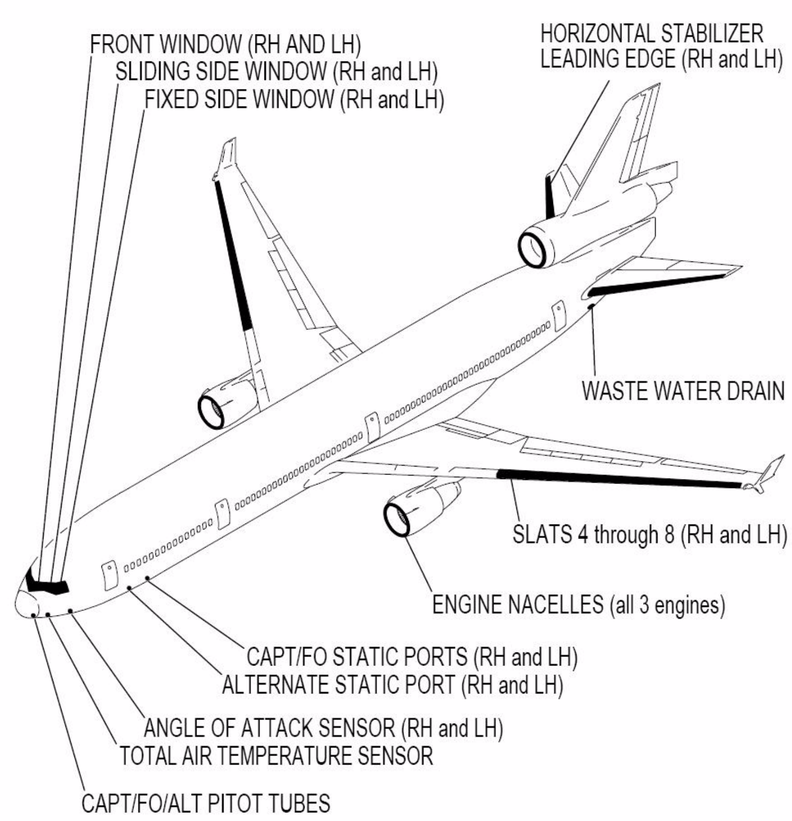
The A-ICE TEST FAIL alert is not displayed for the following:

- System passes after retest
- Airplane becomes airborne

These tests are not associated with the ANNUN LT test.

Components

Ice and Rain Protection Locations



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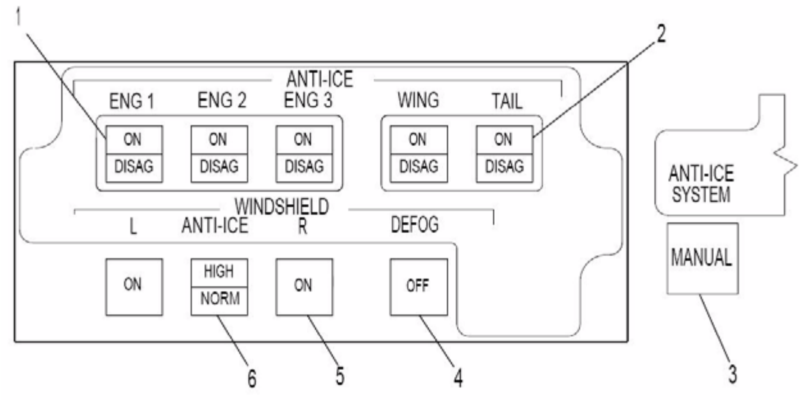
Controls and Displays



FORWARD OVERHEAD PANEL, RIGHT SIDE

1. ENG ANTI-ICE Switch (3) - blue/amber

   The ENG ANTI-ICE switches are alternate action switches that open and close the respective cowl anti-ice shutoff valves.

   ON illuminates blue when engine anti-ice is on.

   DISAG illuminates amber when the anti-ice shutoff valve is in transit and remains illuminated if the valve position disagrees with the switch position.

2. WING and TAIL ANTI-ICE Switches - blue/amber

   The WING and TAIL ANTI-ICE switches are alternate action switches that open and close the wing and tail anti-ice shutoff valves.

   ON illuminates blue when the respective switch is on.

   Inflight, DISAG illuminates amber when the anti-ice shutoff valves are in transit, and when valve position disagrees with the commanded anti-ice flow.

   On the ground, DISAG illuminates amber when the valve is open, regardless of switch position.

The associated pneumatic system turns off when the respective anti-ice manifold fails.

On the ground, the SR preflight test operates by pushing the WING or TAIL ANTI-ICE switch. The following occurs:

- Ground sensing is bypassed.
- The respective (WING or TAIL) anti-ice valve opens.
- Disagree (DISAG) appears above the respective (WING or TAIL) anti-ice valve on the AIR synoptic to indicate proper system function.
- The respective (WING or TAIL) anti-ice valve closes.

3. ANTI-ICE SYSTEM MANUAL Switch (Not Installed)
4. WINDSHIELD DEFOG Switch - amber

   The WINDSHIELD DEFOG switch, an alternate action switch, turns defog power to the windshield on and off. WINDSHIELD DEFOG OFF illuminates amber when windshield defog is commanded off.

   With electrical power applied to the airplane, the defog controllers are energized. Windshield defog automatically turns on and the WINDSHIELD DEFOG OFF light extinguishes. The inner panes of the windshields and window are heated.

5. (L/R) WINDSHIELD ANTI-ICE Switches - blue

   The WINDSHIELD ANTI-ICE switch, an alternate action switch, turns power to the windshield anti-ice controller on and off. The switch illuminates blue when anti-ice is on normal or high (NORM or HIGH).

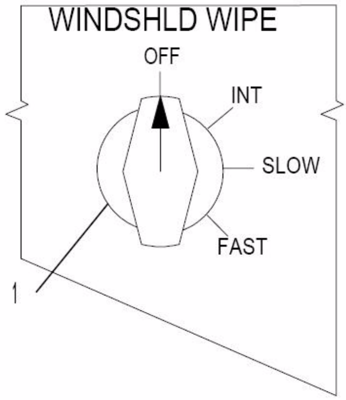
6. WINDSHIELD ANTI-ICE HIGH/NORM Switch - blue

   The WINDSHIELD ANTI-ICE HIGH/NORM switch, an alternate action switch, provides high or normal anti-ice heat to the windshield. HIGH illuminates blue when the WINDSHIELD ANTI-ICE switch is on and high heat is selected. NORM illuminates blue when the WINDSHIELD ANTI-ICE switch is on and normal heat is selected.

HIGH position may be used to remove ice if NORM is inadequate.

Use of windshield heat prevents window fogging during a descent into high humidity conditions.

WINDSHIELD WIPER Selector (Captain and First Officer)



FORWARD OVERHEAD PANEL, LEFT AND RIGHT SIDES

1. WINDSHLD WIPE Selector - (Captain and First Officer)

   Each wiper has an OFF, SLOW, FAST and optional INT speed. When selected OFF, the wiper moves to a parked position below the windshield and out of the airstream.

   Operation on a dry surface is not recommended.

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Alerts

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

Red Boxed Alerts (Level 3)

- ENG 2 A-ICE DUCT (AIR) - (Effective for aircraft fuselage 575 and subs) Leak in the engine 2 anti-ice duct. Engine 2 anti-ice valve is still open.

Amber Boxed Alerts (Level 2)

- TAIL A-ICE DISAG (AIR) - Flow/no flow not in agreement with switch position.
- WNG A-ICE L/R DISAG (AIR) - Flow/no flow not in agreement with respective switch position.

Amber Alerts (Level 1)

- A-ICE TEST FAIL (AIR) - Indicates crew-activated airfoil anti-ice test failure, if installed. Wing or tail surface anti-ice may be inoperative.
- AOA HEAT L/R FAIL (MISC) - Left/right angle-of-attack probe heater has failed.
- ENG 1/2/3 A-ICE DISAG (AIR) - Respective engine (1/2/3) anti-ice valve in disagreement with commanded position.
- ICE DETECTED (AIR) - Icing conditions exist with an airfoil or engine anti-ice system not on. On airplanes with auto anti-ice system installed, and auto or manual anti-ice selected, ice is detected and one of the ice protection systems is not commanded on.
- NO ICE DETECTED (AIR) - Ice detection system, if installed, indicates icing conditions do not exist and one of the ice protection systems is commanded on. May turn anti-ice systems off.

- WSHLD DEFOG OFF (MISC) - WINDSHIELD DEFOG switch is in OFF.

Cyan Alerts (Level 0)

- A-ICE ALL ON - All engine and airfoil ANTI-ICE switches are on.
- A-ICE SYS TEST - Displayed on the ground when the flight crew selects airfoil anti-ice on. Initiates a 15-second automatic test of the airfoil anti-ice system, if installed.
- AIRFOIL A-ICE ON - Wing anti-ice has been commanded on.
- ENG 1/2/3 A-ICE ON - Respective engine (1/2/3) ANTI-ICE switch is ON. ENGINE A-ICE ON - All 3 ENG ANTI-ICE switches are ON.
- WSHLD HEAT HI - L and/or R windshield heat is on and in the HIGH mode.
- WSHLD HEAT ON - L and/or R windshield heat is on and in the NORM.

Description and Operation

General

The instrumentation and navigation systems include both ground dependent and independent systems. The systems provide displays and annunciations for aircraft attitude, airspeed, altitude, vertical speed, heading, direction, course, and time.

EIS Control Panel (ECP)

An ECP is installed on both outboard ends of the glareshield. The ECPs control the operation of the Captain's and First Officer's ND and PFD.

For a description of the ECP controls relating to the PFD refer to the Automatic Flight chapter.

Multifunction Control Display Unit (MCDU)

Two MCDUs are installed in the forward pedestal. These are the primary interfaces for the Flight Management System (FMS). A third MCDU is installed in the aft pedestal for interface with the centralized fault display and ACARS systems.

Each MCDU continuously stores current flight plan waypoints. The MCDUs are coupled to the Inertial Reference System (IRS). This provides navigation flight planning and lateral guidance to all waypoints previously stored in the FMS flight plan (or added to the flight plan in the standby mode) in case of dual flight management computer (FMC) failure.

The MCDUs also provide flight plan data for the Navigation Display (ND) and standby tuning for the navigation radios.

The VOR, ADF, and ILS equipment are automatically tuned from the FMS in accordance with the selected SID, STAR, or enroute navigational aid requirements. The FMS also tunes the scanning DME to the associated VOR and ILS station and scans three other DME frequencies to obtain position updating data.

Manual tuning of the VOR/DME, ADF, ILS, or MLS is available through the MCDU.

If either the Captain's or First Officer's MCDU fails, operation is normal through the remaining MCDU. If a single FMC fails, normal operation continues through the remaining FMC. If both FMCs fail, each radio may be manually tuned by entering the required frequencies in the associated MCDU.

For a complete description of the MCDU refer to the FMS chapter.

Primary Flight Display (PFD)

The PFD (one for each pilot) will display aircraft:

- Airspeed
- Altitude
- Vertical speed
- Attitude
- Heading
- Position

The PFD symbology maintains the basic T configuration with attitude in the center, airspeed on the left, altitude and vertical speed on the right, and direction of flight on the bottom.

In addition to the basic T, the PFD will also show:

- Glideslope and localizer deviation
- Marker beacon annunciation
- Flight modes
- Radio altitude
- Pitch and roll limits
- Limit speeds
- Slip and skid indication

- Pilot or FMS selected speeds, altitudes, and headings

In addition, the PFD displays computed pitch and roll attitude commands.

For a complete description of the PFD, refer to the Automatic Flight chapter.

Navigation Display (ND)

The ND (one for each pilot) will display:

- Aircraft position
- Waypoints
- Navaids
- Airports
- Weather
- Groundspeed
- True airspeed
- Wind speed/direction
- Distance/time to waypoint
- Chronograph

Four ND modes (MAP, PLAN, VOR, and APPR) can be selected from the ECPs.

Bearing pointer and weather radar displays are available in MAP, VOR, and APPR modes only.

Selected sources are not annunciated for the normal on-side sources (Captain on 1 First Officer on 2). When alternate sources have been selected the source is annunciated in the upper right of the display.

The selected IRS heading/track source is not annunciated if the source is the normal on-side source for that display. If a different source is selected, it will be annunciated in white to the left of the digital heading/track display area. When the Captain's and First

Officer's IRS source are the same, they are annunciated in amber on both NDs.

When an alternate FMS source has been selected (Captain on 2 or First Officer on 1) and the ND is in MAP or PLAN modes, the source is annunciated in amber below the distance to go display in the top right corner of the display.

When an alternate Course Deviation Indicator (CDI) source (VOR, ILS, or MLS) has been selected (Captain on 2 or First Officer on 1) and the ND is in VOR or APPR modes, the source is annunciated in amber below the distance to go display in the top right corner of the display.

If data is marked as no computed data by its source, all symbology dependent on that data will be removed from the ND. No failure flags will appear.

VHF Omnidirectional Range/Marker Beacon (VOR/MB)

The VOR/MB radio system is an aircraft navigation aid in the frequency range of 108 to 118 MHz (VOR) and 75 MHz (MB).

Two VOR/MB receivers are installed but marker beacon signals are received and processed by VOR/MB receiver 1 only.

The VOR ground station transmits an RF signal with two 30-Hz modulated signals. The relative phase of the 30-Hz signals defines radial lines in space with respect to the ground station. The VOR ground station antenna is aligned with the zero degree radial aligned with magnetic north. Each VOR transmitter also transmits an identifier so it can be positively identified.

The VOR airborne equipment receives and presents this information in such a way that the relative bearing with respect to the ground transmitter can be determined. Any bearing with respect to the ground station can be selected and flown.

The VOR unit supplies bearing data to interface with the ND and the FMS.

The marker beacons provide enroute flight reference points and landing guidance. Marker beacon annunciations are displayed above the minimums (DH or BARO) display on the PFD. Passing over an outer marker generates a sequence of two aural dashes and a flashing blue light. The middle marker generates an aural dot dash sequence and a flashing amber light. The inner marker generates an aural string of dots and a flashing white light.

Distance Measuring Equipment (DME)

The DME radio system functions as an aircraft navigation aid in the frequency range of 960 to 1,215 MHz. Two DME interrogators are installed.

The DME transmits coded interrogation signals (pulsed pairs) to the ground station. The ground station receives the interrogation signal and returns a coded reply signal (pulse pair) for each interrogation. One antenna is used for both transmission and reception.

The DME measures the slant range distance between the aircraft and ground stations. The DME can provide multiple station distance data to the FMS for high accuracy position fixing.

The DME can use up to five ground stations at once. The DME provides for 200 channels. Distance is sent to the NDs.

The DME is tuned automatically by the FMS. In case of FMC failure, the MCDUs may be used to provide backup inertial navigation, flight planning, coupled lateral guidance, and MAP display capability. To support these functions, each MCDU can generate its own limited page displays.

Automatic Direction Finding (ADF)

The ADF radio functions as an aircraft navigation aid in the frequency range of 190 to 1,750 KHz.

The ADF receiver provides relative bearing information for display on the NDs. Relative bearing is sensed and computed electronically. The single pointer represents ADF1 and the double pointer represents ADF2.

The ADF selects signals from a sense antenna (omnidirectional) and two directional loop antennas. Audio volume and tone filter controls are on the audio control panels.

Instrument Landing System (ILS)

The ILS components consist of:

- Two ILS receivers installed in the main avionics rack
- Two glideslope (G/S) antennas installed in the radome
- Two G/S antennas installed in the nose landing gear (NLG)
- Two VOR/LOC antennas installed on the tail

The ILS receiver provides localizer and G/S course information to the AFS and GPWS.

ILS frequencies are from 108.10 to 111.95 MHz.

The localizer and G/S deviation data are shown on the PFDs and NDs.

The NLG G/S antennas are automatically selected when the nose gear is down. Both G/S antennas must be in the NLG configuration for dual land operation. Single land configuration is allowed for a single NLG G/S antenna configuration.

NAV Radio Tuning

Navigation radio stations are stored in the Nav Data Base (NDB). VOR/DME and ILS (or MLS) radios are normally tuned and updated automatically by the on-side FMC. On-side means that the Captain's radios are tuned by FMC-1, and the First Officer's radios are tuned by FMC-2. Any radio can be manually tuned from either MCDU.

ADF stations are tuned in the following order of priority:

1. Pilot manually tunes a station.

2. FMC tunes a station required for current leg.
3. FMC tunes a station required for an upcoming F-PLN waypoint.
4. FMC tunes a station required for a preceding F-PLN waypoint.

ADF stations are never used for radio position computations.

Radio Altimeter System

The radio altimeter system provides terrain clearance (altitude) data during approach, landing, or climb out. The altitude range of the system is from 2,500 feet to touchdown.

The altitude indications are displayed on the PFDs. The decision height minimum can be set by turning the inner knob of the MINIMUMS control knob on the ECPs.

The radio altimeter uses an FM radio wave to measure the distance between the aircraft and the terrain. The radio altimeter uses two microprocessors, one for altitude calculation and one for monitoring.

Three radio altimeter transceivers are located in the center accessory compartment. The transmitter and receiver antennas are installed on the bottom of the fuselage.

Inertial Reference System (IRS)

The IRS continuously computes:

- Latitude and longitude
- Track
- Attitude
- Heading (magnetic and true)
- Vertical speed
- Ground speed

The IRS interfaces with several aircraft systems including the FMS and the Automatic Flight System (AFS).

The IRS is powered by 115-volt ac power. About 15 minutes of backup DC power is available from a dedicated battery.

EAD alerts provide the flight crew with IRS status information. IRS faults are stored in the Centralized Fault Display System (CFDS) for review by maintenance personnel.

The IRS control panel provides mode selecting and annunciation for the three IRUs. Each IRU (1, 2, and AUX) has a mode selector and a NAV OFF light. When the selector is set to NAV, the respective IRU powers-up and enters the align mode for about 10 minutes. During this time NO TAXI will appear on the PFD airspeed tape. The pilot can enter position into the MCDU during this time.

After 10 minutes in the align mode, the IRU automatically enters the nav mode. During nav mode, navigation and steering are done by the FMC. No pilot inputs to the IRUs are accepted during operation in the nav mode. In-flight realignment of the IRS is not possible.

Aircraft Clock

An electronic clock/chronograph/elapsed timer is controlled and located on the maintenance panel. The clock provides the Universal Time Coordinated (UTC) and date reference for the FMC and DEUs.

The ND provides UTC, elapsed flight time, and an individual count up/down counter. The elapsed flight time starts when the aircraft transitions from

ground-to-air and stops 30 seconds after the air-to-ground transition. The elapsed flight time is held as long as aircraft electrical power is available. The elapsed flight time is reset when V2 is computed on the FMS TAKEOFF page for the next flight. The elapsed time display is the default display.

The count up/down counter is started, stopped, and reset from the controls on the lighting control panel. The countdown timer value is entered on the FMS APPROACH page. A tone will sound when counter passes through zero. The counter display will override the elapsed counter display.

Air Data System

The air data system consists of pitot and static air lines, one Total Air Temperature (TAT) sensor, two AOA sensors, two CADCs, and one standby altimeter/airspeed indicator.

Baroset data is received from the glareshield control panel. Wing tip fuel quantity data is received from the Fuel Quantity Gauging System (FQGS) for VMO computation.

Three pitot tubes (Captain's, First Officer's and auxiliary) sense aircraft pitot (impact) pressure and send it to the two CADCs and the standby altimeter/airspeed indicator.

The four static ports sense the static (outside air) pressure and send it to the two CADCs, standby altimeter/airspeed indicator and the avionics fan control pressure switch.

The TAT sensor (one for both CADCs) send outside air temperature to the CADCs.

The AOA sensors send angle-of-attack data to the CADCs.

Wing tip fuel quantity from the FQGS is used to compute VMO/MMO. VMO/MMO will decrease linearly as wing tip fuel quantity decreases. Wing tip fuel quantity does not affect VMO/MMO when tip quantity is below 60% full.

The CADCs compute and output airspeed, Mach number, altitude, maximum airspeed, vertical speed, TAT, static air temperature, AOA, True Airspeed (TAS), and pressures (pitot, impact, and static).

Static source (position) errors and AOA effects are corrected in each CADC. TAT is corrected for anti-ice heater effect.

Pitot/Static System

The Captain's pitot tube is connected to CADC1 and the First Officer's pitot tube is connected to CADC2. The auxiliary pitot tube is connected to the standby altimeter/airspeed indicator.

Four static ports are installed on each side of the aircraft. A port from each side is provided for the Captain's static pressure system and the First Officer's static pressure system. The other ports are spares.

Each pilot port is cross connected to minimize errors caused by aircraft yaw. The Captain's ports are connected through the Captain's STATIC AIR selector to CADC1. The First Officer's ports are connected through the First Officer's STATIC AIR selector to CADC2.

The alternate static system has two flush ports symmetrically located on each side of the aircraft at some distance from the static plates. The ports are cross connected to minimize errors and are connected to the standby altitude/airspeed indicator and both STATIC AIR selectors.

The STATIC AIR selectors allow the pilots to switch the source of static pressure for their respective CADCs from their normal ports to the alternate port.

Air Data Sensor Heater System

The air data sensor heater system consists of integral heating elements within the pitot tubes, AOA sensors, and the TAT probe. Heaters are also mounted to the static pressure ports.

All of the heating elements are controlled by the Miscellaneous Systems Controller (MS C). In addition the TAT probe heater is wired to a ground/air sense relay which turns off the TAT probe heater when the aircraft is on the ground.

Each pitot tube heater contains two elements which may be powered individually or in series. When on the ground, the elements operate in series to prolong their life.

The TAT probe and AOA sensors each contain a single heating element. On the ground, the TAT probe heater is not powered and the AOA heaters operate from 28-volt ac. In the air, the AOA heaters operate from 115-volt ac.

All static pressure port heaters contain dual heater elements.

The MSC controls the operation of the heaters, monitors heater currents, and provides alerts to the flight crew.

Air Data Parameters

The following parameters are output by the CADCs:

- Standard altitude
- Captain's baro-corrected altitude
- First Officer's baro-corrected altitude
- Computed airspeed
- Mach number
- Altitude rate
- Maximum operating speed
- True airspeed
- Total air temperature
- Static air temperature
- Overspeed signal
- Total pressure
- Static pressure
- Impact pressure
- Indicated angle-of-attack

The following aircraft systems use the CADC outputs:

- Flight control system
- Flight Management System (FMS)
- Electronic Instrument System (EIS)
- IRUs
- FADEC
- ATC transponders
- CAWS
- GPWS

- Cabin Pressure Controllers (CPC)

Standby Attitude Indicator

A standby attitude indicator is installed on the standby instrument panel below the GEAR lever. It is a self-contained, electrically-operated gyroscope that turns around a vertical axis. It operates on DC power from the battery bus. An OFF flag comes into view when there is a power failure.

Standby Compass

A direct reading standby magnetic compass is installed in the cockpit. It is magnetically compensated to read within plus or minus 10 degrees error on all aircraft headings.

ATC Transponder

The system consists of two mode S transponders in the main radio rack, four antennas installed on the top and bottom fuselage, and a single control panel on the aft pedestal.

The transponders respond to Air Traffic Control Radar Beacon System (ATCRBS) mode A, C, and S interrogations.

Aircraft with mode S transponders have the capability of air-to-air data exchange with other aircraft with mode S transponders.

Traffic Alert and Collision Avoidance System (TCAS)

The TCAS is an airborne system that interrogates ATC transponders in nearby airplanes to identify and display potential collision threats. Visual and aural warnings are provided when a penetration of the TCAS protected airspace is predicted.

Threat airplanes are displayed with data tags on the ND with different symbols and color codes to indicate threat level of each airplane. The data tag shows relative altitude and climb/descent in excess of 500 fpm of the intruders. TCAS cannot detect traffic unless the traffic has an operating transponder turned on. TCAS controls are on the transponder control panel and the EIS mode select panel.

A Resolution Advisory (RA) appears on the PFD and ND when a threat airplane is about 25 seconds from the Closest Point Of Approach (CPA). There are two types of RAs. Corrective RAs recommend changing vertical speed with a green fly-to zone on the PFD vertical speed display. Preventive RAs recommend not changing vertical speed with red forbidden zones on the PFD vertical speed display. On the ND, the RAs are red squares.

Voice warnings associated with RAs for basic TCAS and Change 7 (if installed) are as follows:

BASIC ANNUNCIATION	CHANGE 7 ANNUNCIATION
Traffic, Traffic	Traffic, Traffic
Climb, Climb, Climb	Climb, Climb
Descend, Descend, Descend	Descend, Descend
Climb, Crossing Climb. Climb Crossing Climb	Climb, Crossing Climb. Climb Crossing Climb
Descend, Crossing Descend. Descend, Crossing Descend	Descend, Crossing Descend. Descend, Crossing Descend
Reduce Climb. Reduce Climb	Adjust Vertical Speed, Adjust
Reduce Descent. Reduce Decent.	Adjust Vertical Speed, Adjust
Climb, Climb Now. Climb, Climb Now.	Climb, Climb Now. Climb, Climb Now.
Descend, Descend Now. Descend, Descend Now.	Descend, Descend Now. Descend, Descend Now.
Increase Climb. Increase Climb.	Increase Climb. Increase Climb.
Increase Descent. Increase Descent.	Increase Descent. Increase Descent.

BASIC ANNUNCIATION	CHANGE 7 ANNUNCIATION
Monitor Vertical Speed. Monitor Vertical Speed (Initial Preventive RAs)	Monitor Vertical Speed. Monitor Vertical Speed
Monitor Vertical Speed. Monitor Vertical Speed (Non-crossing, maintain rate RAs)	Maintain Vertical Speed, Maintain
Monitor Vertical Speed. Monitor Vertical Speed (Altitude crossing, maintain rate RAs)	Maintain Vertical Speed, Crossing Maintain
Monitor Vertical Speed (Corrective VSL)	Adjust Vertical Speed, Adjust
Monitor Vertical Speed (Preventive VSL)	Monitor Vertical Speed
Clear of Conflict	Clear of Conflict

Traffic Advisories (TA) are amber circles on the ND representing airplanes that are 40 seconds from the CPA. There is no requirement to change or monitor vertical speed but visual acquisition of the threat airplane is required. The voice warning associated with TAs is TRAFFIC, TRAFFIC. All TCAS voice warnings are inhibited below 1,000 feet AGL (+/-100 feet) for basic version or 500 feet AGL (+/-100 feet) for Change 7 version, and during windshear guidance or GPWS warning.

Proximate traffic are cyan diamonds on the ND that represent airplanes that are not threat traffic but are within 6 NM and 1200 feet vertically.

Other traffic are outline cyan diamonds on the ND representing nonthreat traffic that are outside the range of TA, RA, or proximate traffic.

Off scale RAs and TAs are shown by one half of the symbol at the edge of the display area. Data tags and vertical trend arrows are shown.

A two-mile range ring with an asterisk (*) at each of the twelve clock positions will appear when TCAS mode is selected on the ECP and the range goes to 10 NM.

TCAS Display Modes

Pushing the TRFC switch on the ECP displays proximate or other TCAS targets either full time or part time.

Full-Time Mode (TRFC selected). Pushing the TRFC switch displays proximate and other traffic regardless of the occurrence of a TA or RA. In this case, TRFC will appear in the lower left box on the ND.

Part-Time Mode (TRFC not selected). TAs and RAs cause TCAS targets to automatically appear on all ND modes except PLAN mode. During a TA or RA, any proximate or other traffic will also be displayed.

TCAS mode - This ND mode is selected by pushing the TCAS switch on ECP. The ND will:

- Declutter (remove FMS course line, radar returns, bearing pointers, and waypoint symbols).
- Go to a 10-mile range.
- Display a 5-mile range ring and a 2-mile range ring (made of asterisks).

TCAS mode range can be changed by using the INCR/DECR switches on the ECP.

The 10-mile range is automatically selected only when selecting the TCAS display from MAP, PLAN, VOR or APPROACH. If the NAV display is already in TCAS mode at another range, pushing the TCAS switch again does not automatically select the ND back to the 10-mile range.

TCAS Operating Modes

TA/RA mode - This mode is selected from the transponder control panel. In this mode, TAs and RAs are generated on the basis of the calculated time for a threat airplane to reach the

CPA. The CPA will vary with altitude. An RA is generated when an intruder is either 20, 25, or 30 seconds from the CPA, depending on altitude. A TA is generated at 35, 40, or 45 seconds from the CPA.

TA mode - In this mode TCAS generates only TAs, proximate, and other traffic. RAs are not generated. When in this mode, a white TA ONLY message appears in the lower left of the ND and changes to flashing amber when a TA occurs. This mode can be selected from the transponder control panel or occurs automatically when:

- In flight below 1000 feet AGL (+/-100 feet).
- On ground and transponder control panel is set to TA or TA/RA.
- In flight when uplink from the ground commands a sensitivity level 2 (TA ONLY).
- Whenever there is a GPWS warning or windshear guidance.

Autopilot Disconnect Switch - Pushing the AP disconnect switch during an RA will always remove the FD bars from view. This occurs with the AP on or off. The TCAS CLEAR OF CONFLICT voice message will automatically return the FD bars into view.

Operating Constraints

TCAS operating constraints are as follows:

- Descend RAs are inhibited below 1,200 feet AGL in takeoff and 1,000 feet AGL in approach.
- Increase descent RAs are inhibited below 1,450 feet AGL.
- Climb RAs are inhibited above 44,000 feet MSL.
- RAs are inhibited below 1,100 feet in takeoff and 900 feet in approach.

There are no TCAS voice warnings below 500 feet (+/-100 feet) for Change 7 version or 1,000 feet (+/-1 00 feet) for basic version.

There are no TCAS voice warnings or RAs during windshear guidance.

There are no TCAS voice warnings or RAs during GPWS warnings.

RAs are based on pilots starting the maneuver within 5 seconds (for a corrective RA).

Navigation Display Failure Flags And Annunciations

Comparison Monitor Annunciation

Captain and First Officer heading and position data are cross compared in the DEUs. FMS position is also compared with averaged IRS position. If the difference between the parameters exceeds a predetermined value, a miscompare message annunciation is displayed on the NDs. The following miscompare messages can be displayed on the ND:

- HDG - IRS Heading miscompare
- LOC - ILS Localizer/MLS azimuth miscompare
- CHK POS - IRS/FMS position miscompare

Inertial Reference System Failures

Failure of IRS heading information is shown by removing the displayed digital heading value, compass scale, map data (if any), VOR bearings (ADF bearings remain), wind vectors and selected or preselected heading or track bugs, and displaying in red the label HDG FAIL at the top center of the ND compass arc or rose.

FMC Map Data Failure (Map Mode)

Loss of map data allows crew selection of the associated MCDU for flight plan data. When an MCDU is used for flight plan data, MAP STDBY is annunciated in white on the ND in the MAP mode annunciation area (lower left corner). Loss of FMC and MCDU map data results in the removal of all flight plan data and the display of MAP FAIL in amber above the aircraft symbol.

FMC Map Data Failure (Plan Mode)

Loss of map data results in the loss of PLAN Mode. Selection of PLAN mode results in the display of NO PLAN MODE in amber in the center of the display.

Bearing Pointer Data Failure

Failure of bearing pointer data results in the removal of the associated bearing pointer and replacement of the digital value at the bottom of the display with an amber X.

DME Failure

Failure of DME data will cause the associated digital value at the bottom of the display to be replaced by an amber X. The DME data associated with the CDI distance is removed and flagged with an amber X.

CDI Source Failure

Failure of the CDI source results in removal of the course deviation indicator (pointer and scale), with the display of an annunciation (VOR, ILS/MLS) FAIL in red within the compass rose.

No Computed Data Indications

When data is marked as No Computed Data (NCD) by its source, all symbology dependent on that data will be removed from the display. No failure flags will be displayed for NCD data.

Source Test Indications

Source test mode data is displayed as follows:

- If the aircraft is on the ground the associated symbology will be displayed but flagged as not valid.
- If the aircraft is not on the ground, the data is considered not valid and the symbology will be removed and flagged.

IRS Source Annunciation

The selected heading/track source is not annunciated if the current source is the normal on-side source for the display. If the auxiliary source is selected, it is annunciated in white to the left of the heading/track display area. When the Captain and First Officer source is the same, the annunciation is amber on both NDs.

Possible IRS source annunciations on the ND are as follows:

- IRS AUX on Capt ND (white)
- IRS AUX on F/O ND (white)
- IRS AUX on F/O, Capt, or both NDs (amber)

FMS Source Annunciation

When an alternate FMS source has been selected (Capt on 2 or F/O on 1), and the ND is in MAP or PLAN mode, the source is annunciated in amber in the top right corner of the ND.

Possible FMS source annunciations on the ND are as follows:

- FMS1 on F/O ND
- FMS2 on Capt ND

CDI Source Annunciation

When an alternate CDI source (VOR, ILS, or MLS) has been selected (Capt on 2 or F/O on 1) and the ND is in VOR or APPR modes, the source is annunciated in amber in the top right corner of the ND.

Possible CDI source annunciations on the ND are as follows:

- ILS1 (MLS1) on F/O ND
- ILS2 (MLS2) on Capt ND
- VOR1 on F/O ND
- VOR2 on Capt ND

FMS Range Disagree

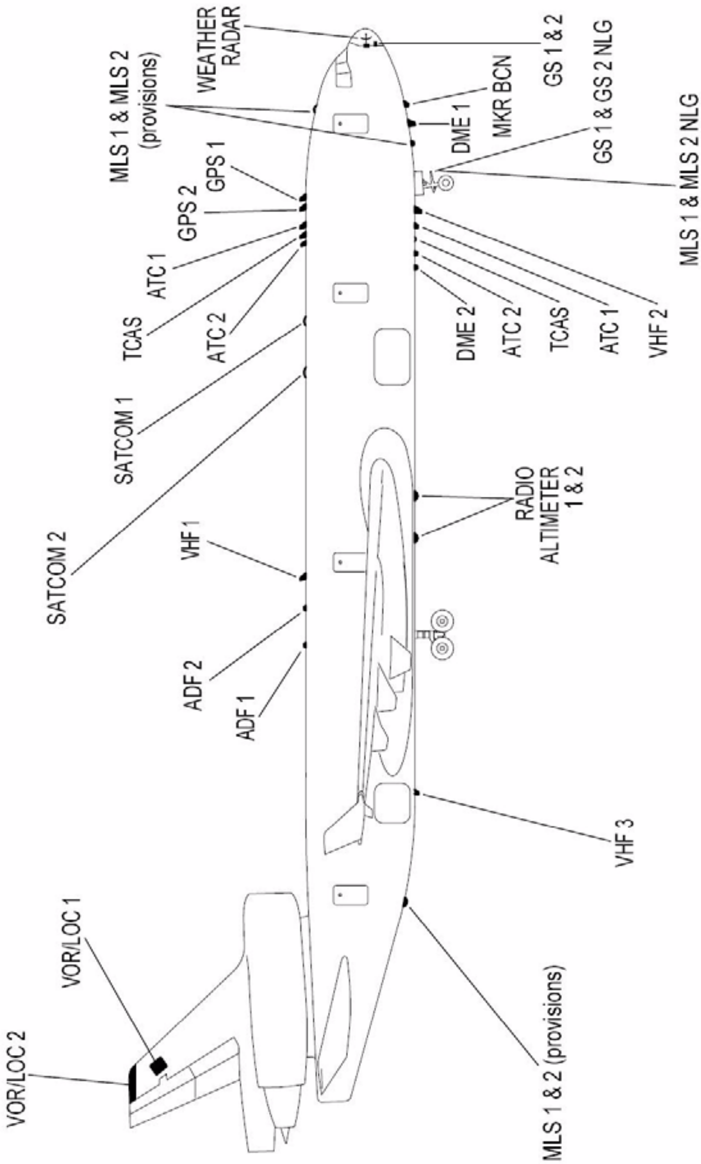
If the FMS map range disagrees with the pilot selected ECP map range, FMS RANGE DISAGREE is shown in amber (MAP and PLAN modes only).

Map Full

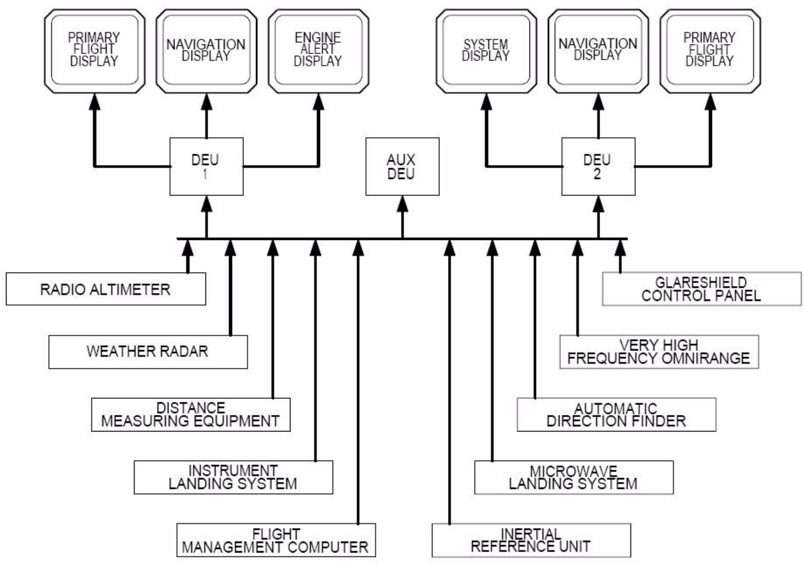
If the crew selects a range for which there are a greater number of map symbols to be displayed than can be displayed, DECLUTTER or REDUCE RANGE is shown in amber (MAP and PLAN modes only).

Components

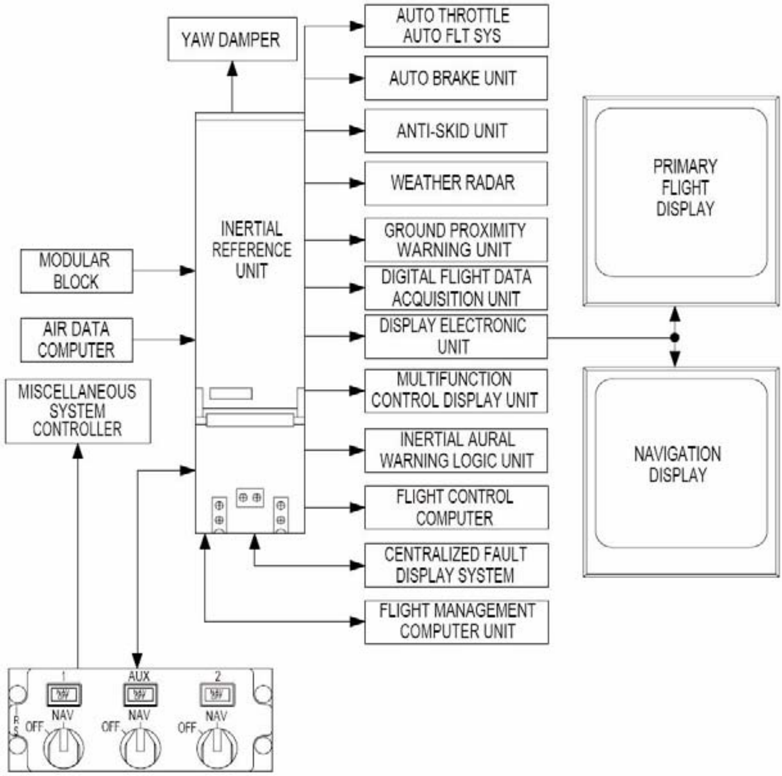
Antenna Locations



Navigation System



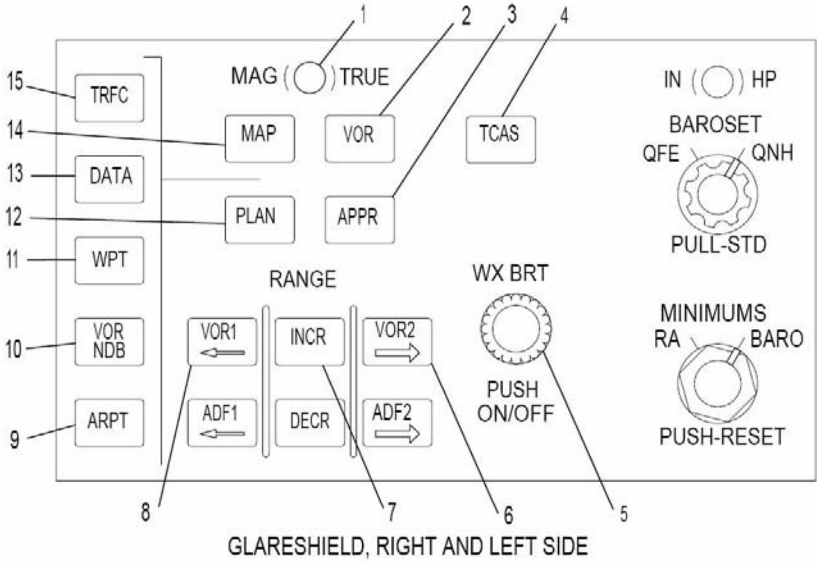
IRS System


YAW DAMPER
AUTO THROTTLE
AUTO FLT SYS
AUTO BRAKE UNIT
ANTI-SKID UNIT
WEATHER RADAR
GROUND PROXIMITY
WARNING UNIT
DIGITAL FLIGHT DATA
ACQUISITION UNIT
DISPLAY ELECTRONIC
UNIT
MULTIFUNCTION
CONTROL DISPLAY UNIT
INERTIAL AURAL
WARNING LOGIC UNIT
FLIGHT CONTROL
COMPUTER
CENTRALIZED FAULT
DISPLAY SYSTEM
FLIGHT MANAGEMENT
COMPUTER UNIT
INERTIAL
REFERENCE
UNIT
MODULAR
BLOCK
AIR DATA
COMPUTER
MISCELLANEOUS
SYSTEM
CONTROLLER
PRIMARY
FLIGHT
DISPLAY
NAVIGATION
DISPLAY
1
AUX
2
NAV
OFF
NAV
OFF
NAV
OFF

Intentionally Left Blank

Controls and Displays

EIS Control Panel



1. MAG/TRUE Changeover Button

   Controls the reference for the heading/track indicator on the ND. If MAG is selected the reference will be magnetic north. If TRUE is selected the reference will be true north.

2. VOR Mode Switch

   Push to select VOR mode on the ND. VOR mode allows the display of full compass rose and a course deviation indicator. VOR display is compatible with MAP and APPR mode display. Weather data may be displayed in the VOR mode.

3. APPR Mode Switch

   Push to select APPR mode on the ND. APPR mode is identical to the VOR mode except that the CDI data source is either an ILS or MLS receiver. No TO/FROM display is shown in the APPR mode.

4. TCAS Mode Switch

   Push to select TCAS display on the ND with 2 nm range ring and auto range to 10 nm.

5. WX BRT Knob

   Not Modeled

6. VOR/ ADF Switch

   Controls the bearing pointer display on the ND. Pushing selects or deselects the corresponding source.

7. Range INCR/ DECR Switch

   Controls the function of the map range on the ND. Push INCR to increase the map range from 10/20/40/80/160/320, up to a maximum of 640 nautical miles. Push DECR to decrease map range to a minimum of 10 nautical miles. Map range is displayed on the ND.

8. VOR/ADF Switch

   Controls the bearing pointer display on the ND. Pushing selects or deselects the corresponding source.

9. ARPT Switch

   Push to select display of non-flight plan airports normally not displayed on the ND. Runways displayed have at least 5,000 feet of available stopping distance. Origin and destination airports are normally displayed on the ND.

10. VOR/NDB Switch

    Push to select display (cyan) of non-tuned VORs, DMEs, VOR/ DMEs, or non directional beacons (NDBs) on the ND. Tuned stations are displayed in white and are not deselectable through this switch.

11. WPT Switch

    Push to select display (cyan) of non-flight plan waypoints on the ND.

12. PLAN Switch

    Push to select PLAN mode on the ND. PLAN mode displays the north-up flight plan with a reference aircraft moving along it. All map data may be displayed in the PLAN mode.

13. DATA Switch

    Push to select display of waypoint data on the ND. Waypoint data consists of an identifier, crosstrack deviation, and waypoint constraint data.

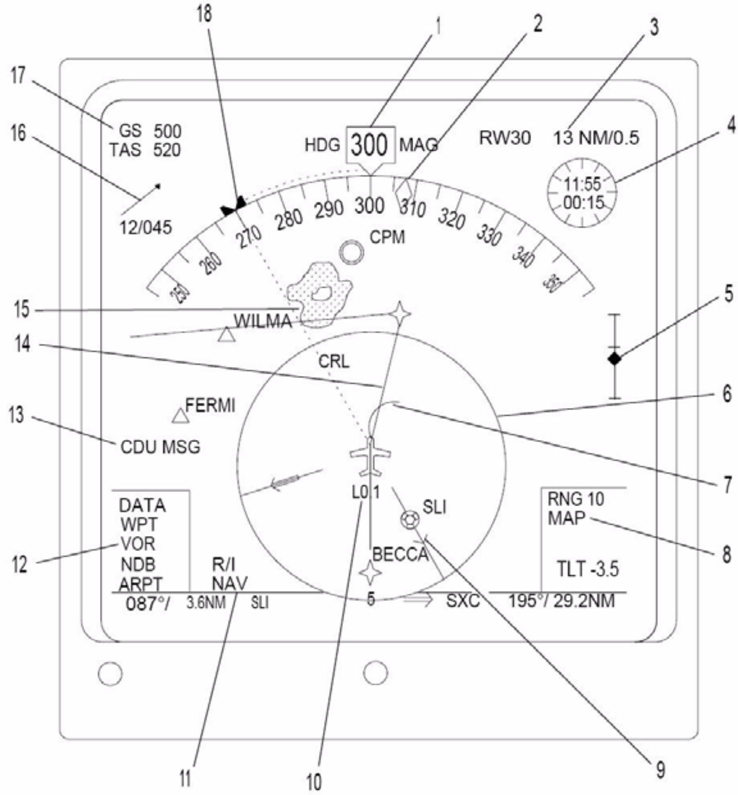
14. MAP Switch

    Push to select MAP mode on the ND. MAP mode allows the display of non-flight plan waypoint, airports, navaids, weather radar data, and bearing pointers.

15. TRFC Switch

    Push to select full-time TCAS traffic display on the ND in MAP, VOR, APPR and TCAS modes. If a full-time display is not selected with this switch, traffic display is inhibited until TA or RA occurs.

Navigation Display - Map Mode



The MAP mode is selected by pushing the MAP mode switch on the ECP. The MAP mode has the following characteristics:

- The map is referenced to the aircraft position and heading (or track).
- It allows display of non-flight plan waypoints, airports, navaids, weather radar data, and bearing pointers.

1. Heading/Track Display

   Heading or track can be selected with the HDG/TRK button on the FCP. Reference (magnetic or true) can be selected with the MAG/TRU switch on each pilot's ECP. Default is magnetic except at latitudes more than 73 degrees when the default is true. When in the polar region (more than 85 degrees) map orientation is FMS true track.

Selected heading or track is a filled white bug. A white dotted arc is turn direction. A white dotted line goes from the aircraft to the bug and is removed when a selected heading has been captured or the aircraft is in FMS NAV with no preselected heading or track. Preselected bugs are the same as selected except that they are outline only.

2. Drift Angle Pointer

   Drift angle is a green diamond that points to track when in heading mode and is removed when in track mode.

3. Distance/Time To Go

   Distance (NM) and time (MIN) to the active FMS waypoint is displayed in magenta.

4. Clock/Chronograph Display

   Current time (UTC) is on top and elapsed time/timer is on bottom. The bottom display defaults to elapsed flight time in cyan, unless timer is in operation. Timer is displayed in white and is controlled by the TIMER knob on the light control panel. Elapsed flight time is started at ground-to-air transition and stops 30 seconds after air-to-ground transition. Elapsed flight time is held until reset when a new V2 speed is entered on the FMS takeoff page.

5. FMS Vertical Deviation

   FMS vertical deviation is indicated by a magenta diamond, moving against a scale on the right side of the map display. Full scale deviations is 1,000 ft. For deviations more than 1,000 ft., half the pointer is visible in the direction of deviation.

6. Half Range Ring

   The half range ring is a white circle 2.0 inches in radius centered on the nose of the reference aircraft. The bottom of the circle displays half of the full range selected through the ECP.

7. Curved Trend Vector

   The curved trend vector consists of three green arcs starting at the nose of the reference aircraft. The end points of these segments correspond to the predicted position of the aircraft in 30, 60, and 90 seconds at the current groundspeed and rate of turn. The 30 second arc is shown for all ranges. The 60 second arc is shown for ranges equal to or more than 20 miles. The 90 second arc is shown for ranges equal to or greater than 40 miles. These arcs are filtered to reduce activity due to gusts.

8. Weather Radar Annunciator Display

   Weather radar data consisting of range, tilt angle, and fault or warning messages are displayed in this area. Maximum range of weather radar display is 320 NM. Tilt angle is controlled from the weather radar control panel located on the pedestal. When weather radar display is disabled, WX OFF is displayed in this area.

9. Bearing Pointers

   Bearing pointers are controlled from the ECP. Each pointer may show VOR or ADF data or may be turned off. Pointer 1 (cyan single arrow) always shows data from the left radios and pointer 2 (green double arrow) always shows data from the right radios. Bearing pointer data is at the bottom of the ND. Outboard of the ident or frequency is the bearing and distance to the station. Pointer 1 data is in cyan and pointer 2 data is in green.

10. Crosstrack Deviation

    Crosstrack deviation is activated when the DATA switch on the ECP is pushed.

11. Navigation Modes

    Navigation modes are displayed as follows:

    - R NAV indicates radio navigation only
    - IRS NAV indicates inertial navigation only
    - R/I NAV indicates radio and inertial navigation

- NO NAV indicates no navigation mode is active
- Any invalid mode is flagged with an amber X

12. Active Map Modes

    Additional map data is controlled with the DATA, WPT, VOR, NDB, and ARP modes switches on the ECP. Active modes are shown in the lower left of the ND. Modes are displayed as follows:

    - TRFC indicates full time traffic display is on.
    - The DATA mode displays FMS constraint data (time and/or altitude) next to the waypoints.
    - The WPT mode displays ground reference points (non-flight waypoints).
    - The VOR/NDB mode displays non-tuned VORs/DMEs and NDBs.
    - The ARPT mode displays non-origin/destination airports.

13. Messages

    During descents ADD DRAG or RMV DRAG (magenta) will flash five times and remain steady when applicable. CDU MSG will be displayed (white) when there is a message on the MCDU.

14. Flight Plan Course

    Flight plans are shown according to selected range and are displayed from the last waypoint passed through all succeeding waypoints. Flight plans are displayed as follows:

    - Active (First Choice) - A series of magenta lines and arcs.
    - Secondary (Second Choice) - Cyan dotted lines.
    - Provisional (Has Alternate Destination) - Magenta dotted lines and arcs.
    - Offset (Parallel to Active Flight Plan) - Long magenta dashed lines and arcs.

- Temporary - Short magenta dashed lines and arcs.

15. Weather Radar Display

    Not Modeled

16. Wind

    Wind is shown with a vector display or optional component display. If the vector display is selected, a white vector points along the direction of the wind with direction and speed in digits below. If the component display is selected, two white components are labeled with corresponding wind speed. Wind is not displayed until wind speed is more than 5 knots and is removed when wind speed falls to less than 3 knots.

17. Speed

    Aircraft ground speed and true airspeed are in white.

18. Selected Heading/Track Display

    Selected heading or track is displayed as a solid white bowtie shaped bug. This bug is connected to the heading/track index with a dotted white arc indicating direction of turn, and with a dotted line to the nose of the reference aircraft. This line is removed when the aircraft has captured a selected heading, or is in the FMS NAV mode with no preselected heading or track. For selected headings or tracks that are off scale (more than 55 degrees from the index) the bug is parked and the selected heading or track is digitally displayed at the edge of the screen corresponding to the direction of the turn. If this heading/track is removed far enough the display will appear on the opposite side of the screen and the parked bug will disappear.

    Preselected heading/track bugs are displayed only as an outline.

Navigation Display - VOR/APPR Mode

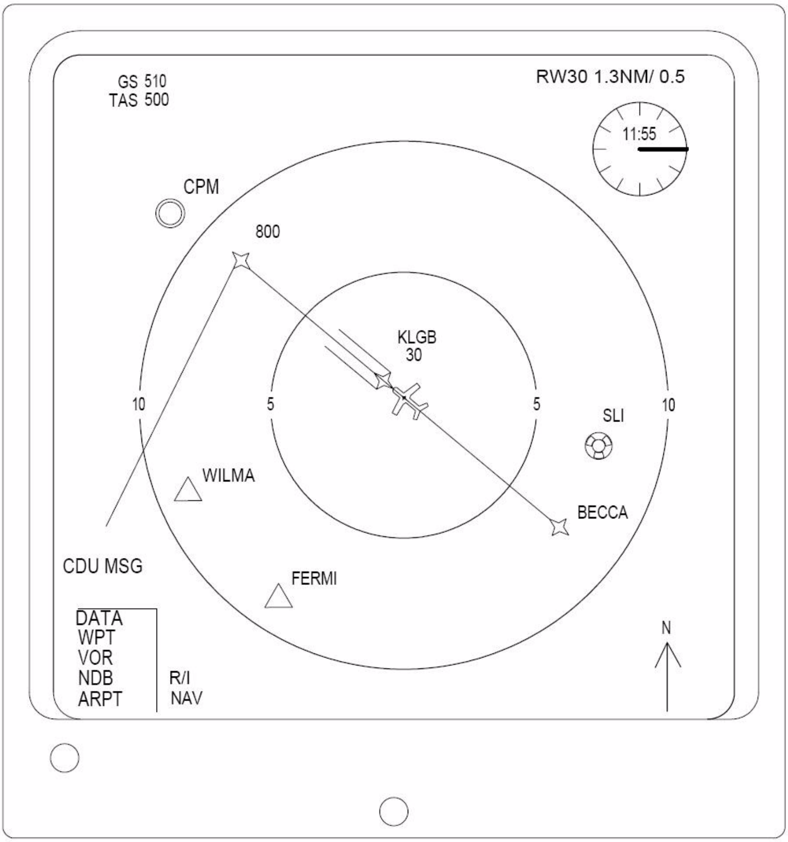
The VOR mode is selected by pushing the VOR mode switch on the ECP.
The VOR mode has the following characteristics:

- Weather radar data may be displayed
- A compass rose is centered around the reference aircraft and represents half the selected weather radar range. Current aircraft heading is at the top.
- Selected heading is shown with a solid white bug on the compass. Preselected heading is shown with an outline bug on the compass.
- The CDI is a magenta arrow and bar showing deviation from selected VOR course. Four circles make up the CDI scale.
- To/from is shown by an arrow on the end of the CDI bar.
- CDI source and DME distance is shown in the lower left.

The APPR mode is selected by pushing the APPR mode switch on the ECP.

- The APPR mode is identical to the VOR mode except the source for the CDI data is ILS and the to/from arrow on the CDI bar is not shown.

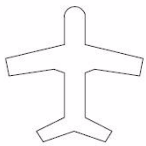
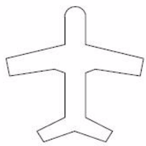
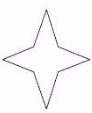
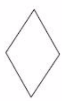
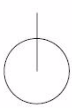
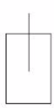
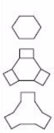
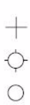
Navigation Display - Plan Mode



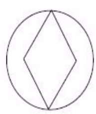
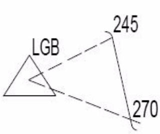
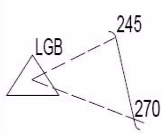
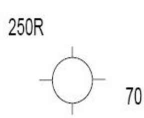
The PLAN mode is selected by pushing the PLAN mode switch on the ECP.
The PLAN mode has the following characteristics:

- It displays a north up flight plan.
- All map data may be displayed.
- Two range rings are centered in the display. The center of the rings corresponds with the reference waypoint selected through the MCDU. The half range ring is half the selected range.
- A north pointer is displayed in the lower right hand corner except when in the polar region (more than 85°) where the pole symbol is displayed.
- The aircraft symbol is relative to true north when the present position is in the flight plan segment and range. When in the polar region (more than 85°), the aircraft is relative to FMS true track.

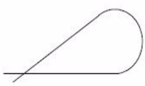
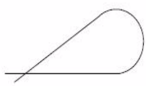
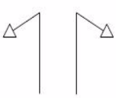
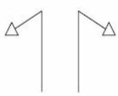
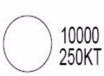
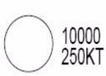
ND Flight Plan Symbology (Sheet 1)

U.S. SELECTED	EUROPEAN SELECTED	EXPLANATION
		Airplane Symbol The aircraft symbol is visible in all modes. In the PLAN mode the symbol will be displayed only if the present position of the airplane is within the flight plan segment and range. Symbol will point to true north, except in polar ranges above the 85° latitude when symbol will be referenced relative computed FMS track. In the MAP mode symbol will be oriented relative to aircraft heading.
 PERSAN 12:00 FL230	 PERSAN 12:00 FL230	Waypoint and Waypoint Data The active (next) waypoint and its identifier are displayed in magenta; all other flight plan waypoints are displayed in white. Waypoint data consists of any constraint data from the FMS at the waypoint. Waypoint data is displayed in the same color (magenta or white) as the associated waypoint. Display of waypoint data is selected/deselected by pushing the DATA switch on the ECP.
		Airports Destination and departure airports are white and are displayed with runway lines (when available), or as parallel lines indicating runway orientation (scale 40 nautical miles or less). Display of Non-Origin/Destination airports (displayed as cyan circles) may be selected or deselected with the ARPT mode switch on the ECP.
 VOR VORTAC DME/TACAN	 VOR VORTAC DME/TACAN	VOR Non-tuned VOR, DME, or VOR/DME stations are displayed in cyan and can be selected or deselected by pushing the VOR switch on the MSP. Tuned stations (through MCDU) are displayed in white and are not deselectable through the ECP.

ND Flight Plan Symbology (Sheet 2)

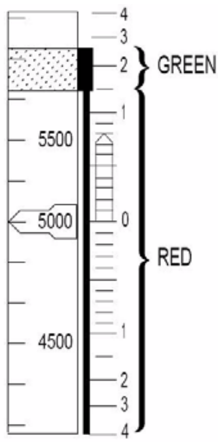
U.S. SELECTED	EUROPEAN SELECTED	EXPLANATION
		NDB Non-tuned or Non-Directional Beacons (NDB) are displayed in cyan and are selected/de-selected by pushing the NDB switch on the ECP. Tuned stations are displayed in cyan within a magenta circle and are not deselect-able through the ECP.
		Ground Reference Points Ground reference points (non-flight waypoints) are displayed in cyan, and can be selected or deselected by pushing the WPT switch on the ECP.
		Selected Reference Points Up to two ground reference points or navaids may be selected through the MCDU. The appropriate symbol will be displayed in white circle. Points will be displayed even if sym-bology of the same class has been deselected through the ECP.
		Selected Reference Points Radials Up to four (three selectable plus a beam) radials from selected reference points may be displayed as a white dashed line labeled with its bearing from the navaid. The display and selection of these radials is through the FMS MCDU.
		Tuned Navaids Tuned navaids are displayed in magenta within a circle (indicating FMS selection).

ND Flight Plan Symbology (Sheet 3)

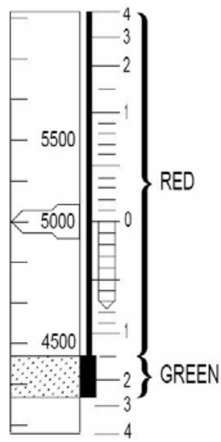
U.S. SELECTED	EUROPEAN SELECTED	EXPLANATION
		Holding Pattern Holding patterns are displayed using a race-track shaped symbol. For smaller ranges (80 n mi or less), the racetrack symbol is replaced with arcs and lines representing the actual flight path along the holding pattern. Holding patterns are generated by the FMS via the HOLD page. The pilot may select a holding pattern at present position (PPOS) or at a defined waypoint.
		Procedure Turns Procedure turns are displayed as a standard tear drop pattern. For smaller ranges (40 n mi or less) the procedure turn is replaced with arcs and lines representing the actual flight path in the procedure turn. Procedure turns are generated by the FMS through the PROC TURN page.
		Turn Direction Turn direction symbols are displayed in amber to indicate which direction to make a course change when it is not obvious such as a leg sequence discontinuity or a large course change.
		Speed Limit/Constraint (Climb or Descent) Altitude, speed limit, and a circle symbol represent the lateral path point the FMS predicts the climb or descent speed limit will be reached. Data is displayed in magenta. A speed limit may be entered or altered via the LEGS page on the MCDU. An altitude speed limit is defaulted into the flight plan as 250 knots at or below 10000 feet. Altitude speed limits may be altered or cleared.

ND Flight Plan Symbology (Sheet4)

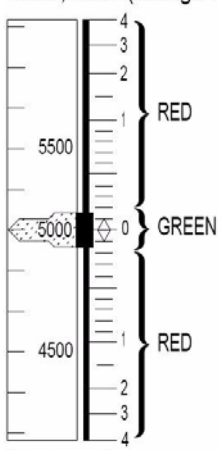
U.S. SELECTED	EUROPEAN SELECTED	EXPLANATION
		Step Climb The symbol is displayed in magenta and represents the lateral path point where the FMS predicts a step climb will begin.
 FL320	 FL320	Top of Climb Flight level and a circle symbol represent the lateral path point along the flight path plan the FMS predicts the airplane will level off at the requested cruise level.



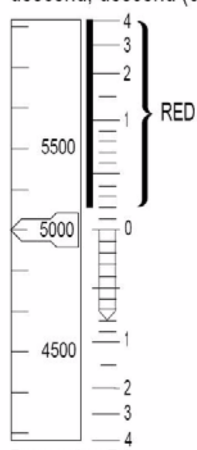
Corrective RA
Up Advisory
Climb >1500 fpm
Voice warning:
climb, climb, climb (basic).
climb, climb (change 7)



Corrective RA
Down Advisory
Descend >1500 fpm
Voice warning:
descend, descend, descend (basic).
descend, descend (change 7).

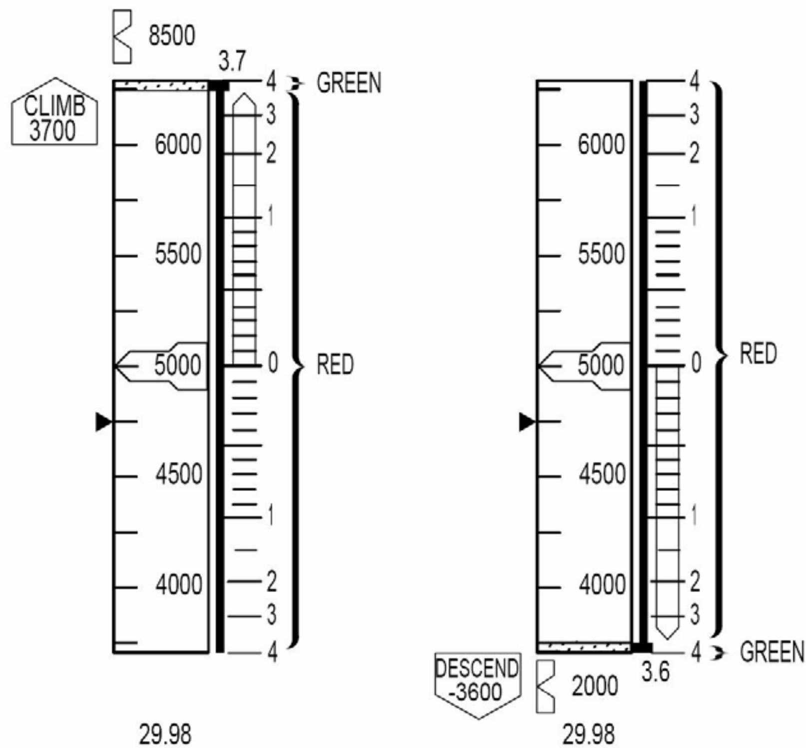


Preventive RA
Don't Climb
Don't Descend
Voice warning: monitor vertical speed, monitor vertical speed (basic & change 7).
No action required.



Preventive RA
Don't Climb
Voice warning: monitor vertical speed, monitor vertical speed (basic & change 7).
No action required.

TCAS - Offscale RA on PFD

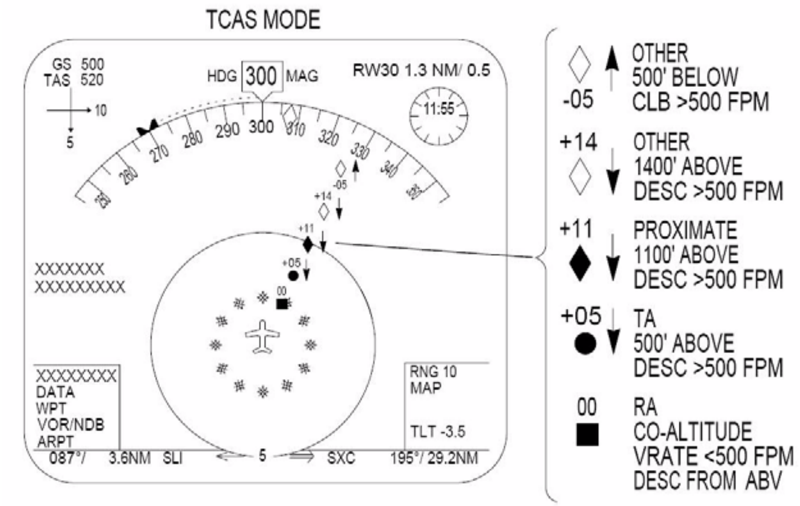


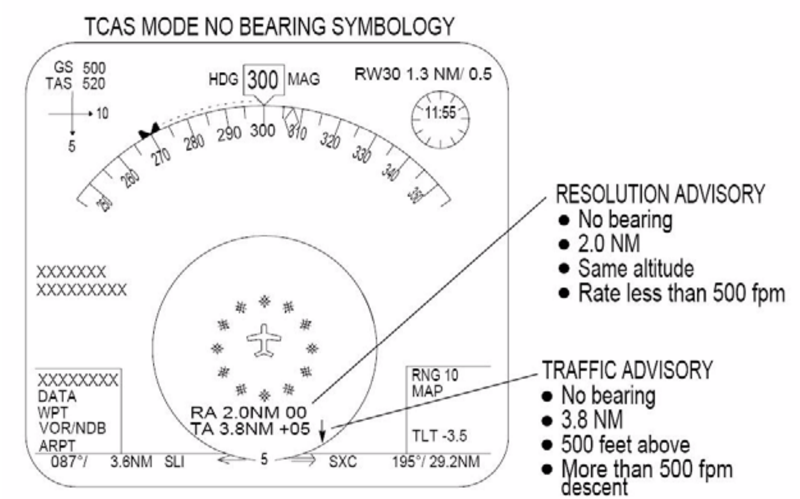
- Corrective RA
- Up advisory
- Climb 3700 fpm
- Voice warning:
- monitor vertical speed, monitor vertical speed (basic)
- maintain vertical speed, maintain (change 7).

- Corrective RA
- Down advisory
- Descend 3600 fpm
- Voice warning:
- monitor vertical speed, monitor vertical speed (basic)
- maintain vertical speed, maintain (change 7).

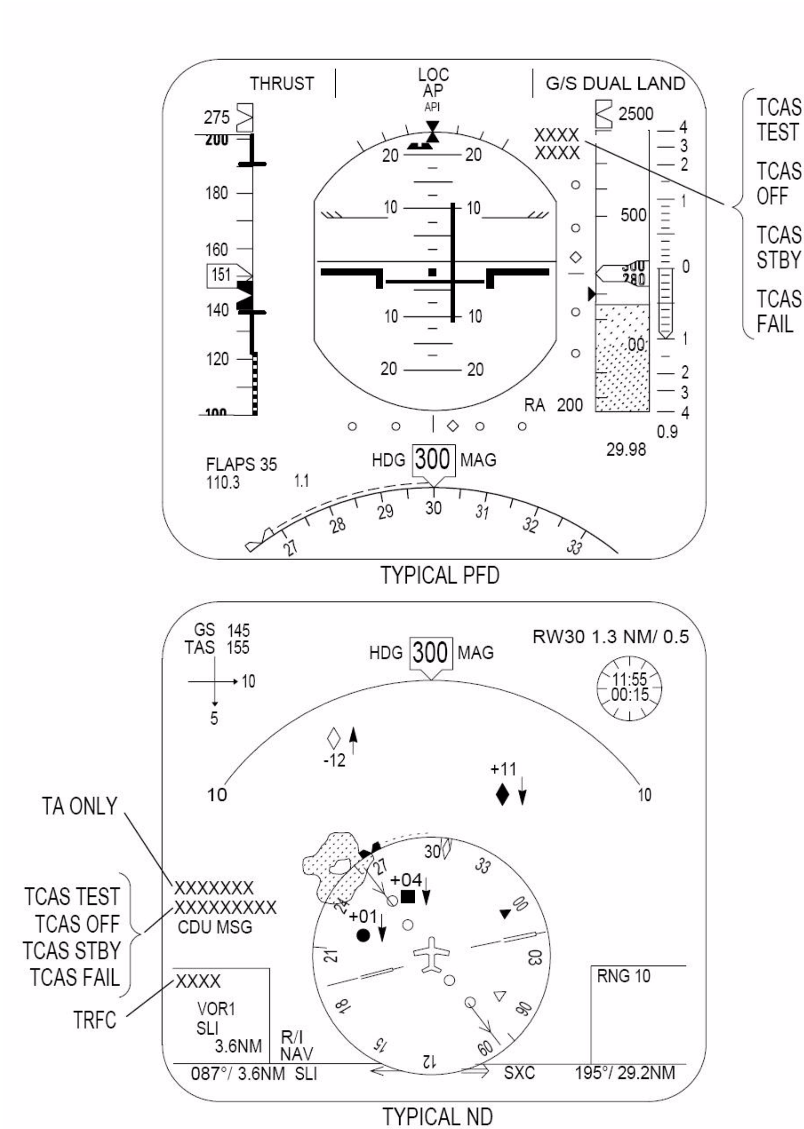
The limits of the PFD vertical speed tape are 4000 fpm climb and 4000 fpm descent. If an RA is more than 3000 fpm up/down, an appropriate climb or descend doghouse box appears. The required V/S appears in the box with the word CLIMB or DESCEND. The box and text are initially green, however, if desired V/S is not met the two lines forming the tip of the arrow are red and turn green when the required V/S is achieved.

TCAS Displays on ND

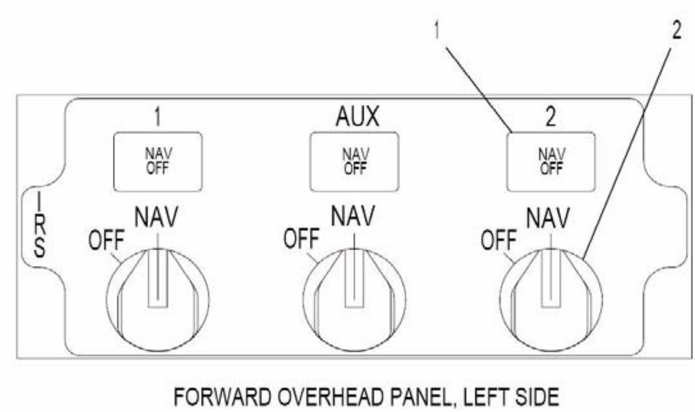




TCAS Displays on PFD and ND



IRS Control Panel



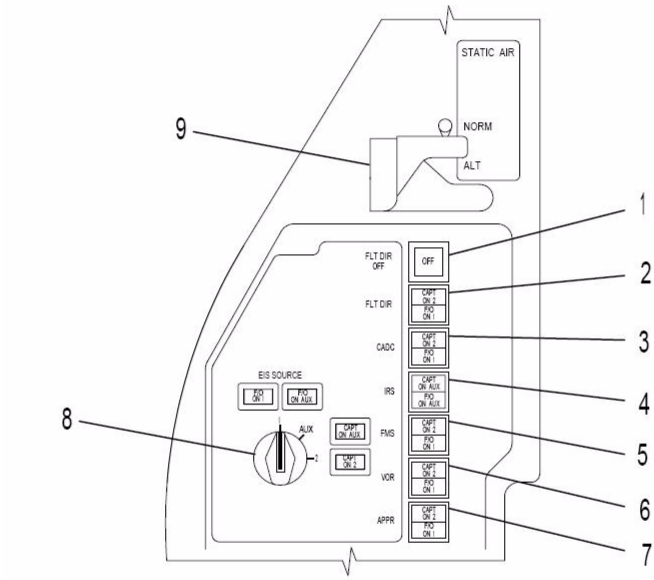
1. NAY OFF Light (3) - amber Illuminates amber if:
    - System is off
    - System is in align submode
    - Primary IRU failure (attitude, heading, angular rate, or acceleration) has been detected by the built-in-test functions

    Flashes amber if:
    - During alignment the IRS does not receive present position initialization within 10 minutes of turn on
    - Present position entry fails the comparison test with either the stored present position or calculated position. The comparison test must be about 1 degree latitude and/or 1 degree longitude
    - Excessive aircraft motion is sensed during align submode
2. Mode Selector (3)

    OFF - Turns off power to system.

    NAV - Normal position. The cargo fire test is performed automatically when the first IRU is turned on after landing.

Source Input Select Panel



CAPTAIN'S AUXILIARY PANEL
(First Officer's opposite)

1. FLT DIR OFF Switch - amber

   Illuminates amber when flight director is selected off. Pushing switch while illuminated will reengage the flight director. See Automatic Flight chapter for a complete description.

2. FLT DIR Switch - amber

   Allows selection of flight director source displayed on PFD.

3. CADC Switch - amber

   Allows selection of respective CADC output to the Captain's or First Officer's DUs. Under normal operation, the Captain's DUs use CADC 1 as a source, and the F/O's DUs use CADC 2 as source. No light will illuminate if conditions are normal. CAPT ON 2 or F/O ON 1 will illuminate amber to indicate respective condition. Pushing switch while illuminated will return DUs source to normal CADC output.

4. IRS Switch - amber

   Allows selection between normal operation of the IRS or using the auxiliary IRU as a display source. Under normal conditions, the Captain's DUs use IRU-1 and the F/O's DUs use IRU-2 as a display source. CAPT ON AUX or F/O ON AUX will illuminate amber to indicate respective condition. Pushing switch while illuminated will return system to normal operation.

5. FMS Switch - amber

   Allows selection between normal in line operation of the FMS or a transfer to a secondary FMS. Captain may select F/O's FMS (FMS-2) or F/O may select Captain's FMS (FMS-1), but Captain and F/O may not select each other's FMS simultaneously.

6. VOR Switch - amber

   Allows selection of VOR display source to be transferred from an alternate source. Normally the Captain's VOR display is controlled by the left radio systems, and the F/O's VOR display is controlled from the right radio systems. CAPT ON 2 or F/O ON 1 will illuminate amber to indicate respective condition. Pushing switch while illuminated will return VOR source to normal.

7. APPR Switch - amber

   Allows selection of approach data (ILS or MLS) to be transferred from an alternate source. Normally the Captain's APPR display is controlled by the left radio systems, and the F/O's APPR display controlled by the right radio systems. CAPT ON 2 or F/O ON 1 will illuminate amber to indicate respective condition. Pushing switch while illuminated will return APPR source to normal.

8. EIS SOURCE Selector and Annunciator Lights

   Normally DEU 1 drives the Captain's DUs (DU1, DU2, and DU3) and DEU 2 drives the F/O DUs (DU4, DU5, and DU6). Normal selector position is Captain on 1 and F/O on 2. If the selector is out of the normal position, the appropriate annunciator light will illuminate amber.

9. STATIC AIR Selector

   When Captain's and F/O's selector is in NORM, CADC 1 receives static pressure from Captain's static system and CADC 2 receives static pressure from F/O's static system. When Captain's or F/O selector is in ALT, respective CADC receives static pressure from alternate system.

Alerts

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

Amber Boxed Alerts (Level 2)

- IRU AUX FAIL (MISC) - Auxiliary IRU failed. May also appear during transponder and TCAS test.
- IRU 1/2 FAIL (MISC) - Respective IRU failed.

Amber Alerts (Level 1)

- DFDR OFF (MISC) - DFDR is not operating. On the ground, the DFDR requires engines operating and parking brakes released to operate.
- IRU BAT LO (MISC) - One or more of the IRU backup batteries is not fully charged.
- IRU OFF (MISC) - One or more IRU mode selectors is in OFF during flight.
- IRU 1/2/AUX NAV FAIL (MISC) - Respective IRU navigation function failed. Attitude data remains usable.
- IRU 1/2/AUX NO ALIGN (MISC) - Respective IRU did not align. Pilot should confirm position coordinates are entered.
- IRU 1/2/AUX ON BAT (MISC) - Respective IRU is operating on backup battery power. The battery will provide about 15 minutes of power.

Cyan Alerts (Level 0)

- IRU IN ALIGN - One or more IRU in alignment mode. Aircraft should not be moved during alignment.

Intentionally Left Blank

Intentionally Left Blank

Description and Operation

General

The aircraft has a tricycle landing gear consisting of four-wheel trucks on each main gear, dual wheels on the nose gear, and a dual wheel center gear. Maximum tire speed is 204 KTS.

All landing gear as well as the main gear wheelwell doors are hydraulically actuated. The main and nose gear can be extended without extending the center gear. A free fall capability is designed into the system for use in case of hydraulic failure.

An electrically monitored, visual/aural indicating and warning system provides gear status indications during the various flight phases.

Dual, hydraulic powered, multi-disk wheel brakes with anti-skid control systems are installed on the main and center gear.

Hydraulic accumulators provide reserve brake pressure in case of normal hydraulic pressure loss.

Tire pressure and brake temperature are monitored continuously and displayed on the CONFIGURATION page of the System Display (SD).

Alerts on the Engine and Alert Display (EAD) and SD will warn the flight crew of anti-skid, brake, and tire malfunctions.

Gear Retraction and Extension

The landing gear and main doors are retracted and extended by hydraulic system 3. If system 3 has a pressure loss, but fluid is available, hydraulic power to retract the gear can be supplied if either the (1-3) or (2-3) Reversible Motor Pumps (RMP) are operating.

HYD SYS 3 hydraulic quantity indication will show a slight increase when the gear is retracted.

If no hydraulic pressure is available due to loss of fluid or complete system failure, or if the GEAR handle is jammed in the up position, the main and nose gear can be mechanically unlatched by an alternate gear extension lever in the floor at the right side of the pedestal. The center gear can be unlatched by a center gear

alternate extension handle on the cockpit floor. All landing gear will then free fall and mechanically latch in the down position. The main landing gear is normally held in the up position by hydraulic pressure. In case of pressure loss, the main gear will rest on the main wheelwell doors. The nose gear and center gear are held up by overcenter linkage.

Trim cylinders maintain the truck beams perpendicular to the main gear struts. A trim cylinder interlock mechanism prevents moving the GEAR handle up in the event of hydraulic failure in the trim system.

Nose Gear Steering

Nose gear steering is powered by hydraulic systems 1 and 3. The nose gear steering wheel and rudder pedals provide steering control. The nose gear steering wheel has override authority over the rudder pedal steering.

Maximum steering angle using the nose gear steering wheel is 70 degrees either side of center. Full rudder pedal travel provides steering to a maximum of 10 degrees either side of neutral.

If hydraulic system 1 or 3 fails completely, nosewheel steering is limited to 25 degrees in the direction of the inoperative system. Rudder pedal steering is not affected noticeably by loss of one hydraulic system.

Rudder pedal steering is rendered inoperative by the mechanical ground sensing mechanism during nose gear strut extension at takeoff.

Nose gear steering using the nose gear steering wheel while the gear is retracted is not possible as the steering bypass valve is mechanically placed in a bypass mode upon nose gear retraction. This prevents inadvertent steering and possible jamming of the nose wheels in the nose wheelwell.

Ground Sensing System

A mechanically operated ground sensing mechanism is installed. It is operated by extension and compression of the nose gear strut.

The system does the following:

- Mechanically disables rudder pedal nose gear steering.
- Releases the GEAR handle anti-retract lock.
- Activates flight or ground mode for various systems.

When the ground sensing mechanism does not shift to flight mode, the following systems are affected:

- Takeoff warning system will remain active.
- Pressurization will not function in automatic.
- Airborne engine thrust reverse possible.
- Stall warning, stickshakers, and auto slats will not function.
- Pitot and angle-of-attack heat stays low.
- Airfoil anti-ice inoperative.
- Spoilers have unrestricted operation.
- Autoflight system limited to TO function.

Gear Indicating and Warning

The landing gear position indicating system consists of lights, aural warning, mechanical indicating, and indications shown on the SD.

Two separate systems provide gear position and warning indications. Indication and warning lights for one system are installed adjacent to GEAR handle. Inputs from the second system are shown on the SD. Either system can be connected to the display adjacent to GEAR handle. This is done by reversing the output signal connectors in the avionics compartment.

Both indication displays will show a separate green indication for each landing gear when gear is down and locked. It will also show a separate red indication for each gear when a gear is not in a position that corresponds with the GEAR handle.

With the GEAR handle in the DOWN position, both indication systems will display an unsafe condition if the down-lock links are not over center.

With the GEAR handle in UP position, both indication systems will display an unsafe condition if either main gear door is not closed and latched or the nose and centerline gear are not in the retracted position with lock links over center.

The gear warning horn will sound when any throttle is retarded to idle with the landing gear up, the airspeed below 210 knots, and radio altitude 1200 feet or less. The warning horn can be silenced with the GEAR HORN OFF button on the forward pedestal.

The primary system is responsible for the gear warning horn. The secondary system is responsible for green box indication on the secondary display.

The nose gear primary system is responsible for the TOO LOW GEAR aural warning.

The gear warning horn will also sound any time any gear is not down and locked and the flaps are extended 30 degrees or more. In this case, the horn cannot be silenced with the GEAR HORN OFF button.

When the CTR GEAR NORM/UP switch is in UP and the center gear is up and locked, the CTR gear light will remain off during any subsequent gear warning. The center gear position will not input to the aural warning.

With the CTR GEAR NORM/UP switch in UP and the center gear in the down and locked position, the green and red indicator lights will illuminate based on the agreement/disagreement status with the GEAR handle position.

Both indication systems function in the normal manner when the alternate control system is used for gear extension.

An interlock prevents nuisance aural warnings during normal low thrust descents.

Brake System

There are two independent brake systems for each of the eight main wheels and two center wheels. Each brake system uses a separate hydraulic system.

Brake system 1 is powered by hydraulic system 1. Brake system 2 is powered by hydraulic system 3.

Both systems actuate brakes on all main and center gear wheels independently. One brake system can provide braking for all landing conditions. Electric aux hydraulic pump 1 can provide reserve pressure to hydraulic system 3 to power the brakes. The pump switch is located on the AUTO BRAKE control panel and the HYD control panel.

The hydraulic pressure available for each brake system is displayed on the AUTO BRAKE control panel.

Brakes are available when the brake system pressure is above the red band on the respective BRAKE PRESS indicator.

Three accumulators in each brake system will supply reserve braking pressure in case of hydraulic system failure. Fully charged accumulators allow about 10 manual brake applications and will permit anti-skid operation.

Excessive brake temperature will melt a wheel fuse-plug, releasing tire pressure at that wheel to protect against wheel failure.

Parking brakes are set by applying full braking pressure with the toe-operated rudder pedal brakes, positioning the PARK BRAKE handle full aft, and then releasing the rudder pedals. This traps braking pressure in the system.

Adequate parking brake pressure is available if the brake system BRAKE PRESS indicators indicate pressure in the green band or higher.

With the parking brake set for several hours, hydraulic system pressure bleed off can occur. Normal hydraulic pressure to the brakes is backed up by three accumulators in each brake system. As long as the BRAKE PRESS indicators show pressure, there will be hydraulic pressure at the brakes.

When the brake system is in park, an amber PARK brake light on the forward pedestal and a PARK BRAKE ON alert will illuminate.

The parking brakes can be released by fully depressing and then releasing the toe pedals. Depressurization of the hydraulic system(s) will not affect parking brake capability. Subsequent pressurizing of the hydraulic system(s) will automatically reset full parking brake capability regardless of initial parking brake pressure.

If throttles 1 and 2 are advanced for takeoff, the ground mechanism is in ground mode, and parking brake is on, a tone and BRAKE voice warning will sound.

Anti-Skid System

The anti-skid system is an automatic, pressure modulating system controlled by an anti-skid control box, with individual wheel speed transducers, and anti-skid control valves for each main and center wheel brake. The system prevents tire skid by reducing individual brake pressure (manual or automatic braking) as required. Touchdown protection prevents inadvertent brake application on landing. Automatic brake release of a locked wheel is provided down to speeds of 25 knots.

A continuous anti-skid self test is performed whenever power is supplied to the anti-skid control unit. A more extensive powerup test is performed whenever the gear extends down or the ANTI-SKID switch is cycled from off to on.

A failure in the anti-skid system which may affect anti-skid function will cause an ANTI-SKID L FAIL, ANTI-SKID R FAIL, or ANTI-SKID FAIL alert to be displayed.

The anti-skid system can be manually disarmed with the ANTI-SKID switch on the forward pedestal (switch will illuminate OFF).

Automatic Brake System (ABS)

The ABS automatically applies the brakes during landing and rejected takeoff. The system consists of an AUTO BRAKE control panel on the forward pedestal, an amber ABS DISARM light on each side of the glareshield, two Integrated Brake Control Valves (IBCV), and an autobrake control unit.

Hydraulic systems 1 and 3 are required for normal auto brakes.

In the landing mode, the ABS operates from both brake system 1 (hyd sys 1) and brake system 2 (hyd sys 3) and provides selection of one of three modes: MIN, MED, or MAX. ABS is available in STANDARD or HIGH deceleration rates. With the AUTO BRAKE selector in the MIN and MED position, the system compares actual aircraft deceleration data obtained from the Inertial Reference Units (IRU) with the selector position. The system then maintains a constant level of deceleration.

In the MAX position, maximum pressure from brake system 1 and 2 is applied to the brakes by both of the IBCVs. The maximum individual brake pressure is reduced only by anti-skid operation. Maximum deceleration is achieved.

The ABS landing mode is armed after the gear is down prior to landing by selecting the deceleration level desired. Arming of the ABS requires:

- ABS operative (no system failure).
- Deceleration level selected prior to landing.
- Anti-skid armed and operational.
- IRU1 and IRU2 operational.
- Flaps more than 28 degrees.

The ABS landing mode is activated when the spoilers are deployed automatically or manually with throttles retarded to the idle position and brake pedals released. Automatic braking is delayed after spoiler deployment for about 1 second in MAX position and 3 seconds in MIN and MED positions. This allows for a normal nosewheel touchdown.

Pilot takeover can be initiated at any time and ABS will disarm if:

- Brake pedal is depressed beyond about 40 percent travel (ABS DISARM lights illuminate).
- Throttle 1 or 3 is advanced beyond 5 degrees (ABS DISARM lights illuminate).
- AUTO BRAKE selector is placed in OFF position (ABS DISARM lights do not illuminate).

The ABS will also disarm and ABS DISARM lights will illuminate if flaps are less than or equal to 28 degrees when spoilers are deployed.

After the ABS initiates braking, normal landing mode braking will continue regardless of flap setting. Stowing the ground spoilers will release the brake pressure without disarming the ABS landing mode. ABS DISARM lights will remain off and automatic braking will again be available if spoilers are deployed.

The ABS takeoff mode is armed by selecting T.O. with the AUTO BRAKE selector. It is desirable that auto ground spoilers be armed and flaps must be in the takeoff range.

In the Rejected Takeoff (RTO) mode above 100 knots the ABS provides maximum brake pressure from both brake system 1 (hyd sys 1) and brake system 2 (hyd sys 3). Maximum individual brake pressure is reduced only by anti-skid operation. Maximum deceleration is achieved.

RTO initiation must occur at speeds greater than 100 knots for maximum dual system braking. If RTO is initiated below 100 knots, the ABS reverts to landing mode operation and MIN braking is applied. The ABS takeoff mode is activated during a rejected takeoff when automatic or manual ground spoilers are deployed. If spoilers fail to deploy automatically, manual deployment will activate the ABS.

Once automatic brakes are applied for an RTO, pilot takeover can be initiated by either advancing throttles 1 or 3 beyond 5 degrees of travel or by depressing the brake pedals beyond 90 percent of travel for MAX RTO and 40 percent of travel for MIN RTO. Automatic disarming will cause the ABS DISARM lights on the glareshield to illuminate. Automatic disarming will cause the ABS DISARM lights on the glareshield to illuminate.

An ABS malfunction will cause the system to automatically disarm. The ABS DISARM lights will illuminate and the AUTO BRAKE FAIL alert will be displayed.

To rearm the ABS system after it has automatically disarmed, the AUTO BRAKE selector must be moved to the OFF position and then back to a deceleration setting. If the fault has cleared, the system will rearm. In flight, when the GEAR handle is up, power to the ABS is removed.

ABS Deceleration Rates

An operator can select either HIGH or STANDARD ABS. The CFDS can display the ABS configuration (HIGH or STANDARD). Approved Flight Manual (AFM) stopping performance with ABS is available for both configurations and data used should match the CFDS display. Both configurations are described below.

ABS HIGH DECELERATION RATES		
MODE	**DECEL RATE**	**REMARKS**
MIN	6.5 ft per sec²	Normal braking for most day to dat operations. Comfortable ride for passengers.
MED	9.0 ft per sec²	This braking should be used on short runways, contaminated runways, or any time greater than normal braking is required.
MAX	N/A	This braking allows maximum antiskid braking for the shortest stopping distance.
Effective for AA, AY, AZ, DA, DL, FM, GA, JL, JU, KE, KL, LH, QZ, RF, RG, SR, TG, X2, YM, YS, Z5, Z8, ZG.		

ABS STANDARD DECELERATION RATES		
MODE	**DECEL RATE**	**REMARKS**
MIN	4.0 ft per sec²	This braking is a slow maximum comfort deceleration similar to stopping with reverse thrust only.
MED	6.5 ft per sec²	Normal braking for most day to day operations. Comfortable ride for passengers.
MAX	N/A	This braking allows maximum antiskid braking for the shortest stopping distance.
Effective for AE, CI, LT, QC, VA, X6, XK, Y4, Y9, Z4, Z9.		

Brake Temperature Monitoring/Tire Pressure Indicating (BTM/TPI)

General

The BTM/TPI system consists of a BTM/TPI computer in the Center Accessory Compartment (CAC) and pressure and temperature sensors on the landing gear. The system monitors tire pressures and individual brake temperatures. These temperatures and pressures are displayed on the SD when the CONFIGURATION page is selected with the CONFIG cue switch.

Abnormal tire pressures and temperatures are annunciated by EIS alerts.

The BTM/TPI computer interfaces with both Flight Management Computers (FMC) and all 3 display electronic units (DEU). BTM/TPI faults are stored in the CFDS.

Tire Pressures

Normal tire pressures are as follows:

- Main gear - 210 psi.

- Center gear - 176 psi.
- Nose gear - 180 psi.

An overpressure fuse will release if any main or center gear tire pressure exceeds 375 psi. On the nose gear, the fuse will release if tire pressure exceeds 330 psi.

Brake Temperatures

If any brake temperature exceeds 5 50°C, the BRAKE OVERHEAT alert is displayed. The alert goes off when the overheated brake(s) cool to 450°C. Each wheel has a thermal fuse plug that may release if the temperature exceeds 550°C.

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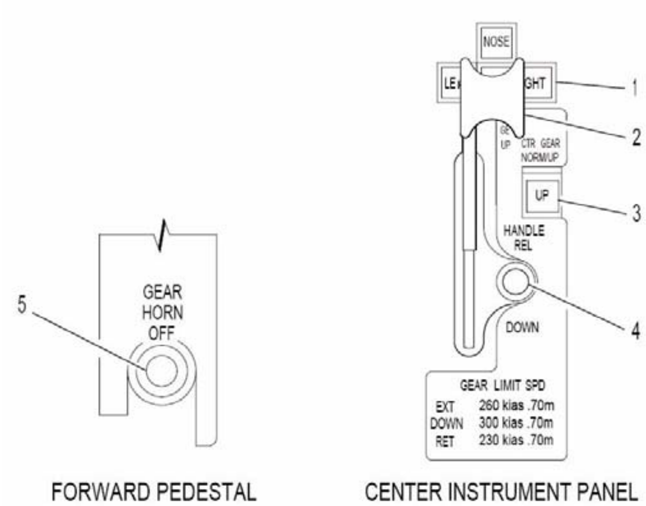
Controls and Displays

Landing Gear Control Panel



1. GEAR Lights - green/red

   Green illuminates when:

   - GEAR handle is down and landing gear is down and locked.
   - GEAR handle is up and landing gear is down and locked via the alternate gear extension lever.

   Red illuminates when:

   - Landing gear is not down and locked and GEAR handle is down.
   - Landing gear is in transit or not in agreement with GEAR handle.
   - Any unsafe gear condition exists.

   All lights are extinguished when the GEAR handle is up and the landing gear is up and locked.

An unsafe condition on one of the two gear indicating systems does not require a mandatory visual inspection. Any green indication indicates a safe gear.

2. GEAR Handle

   Mechanically positions landing gear hydraulic control valve for retraction or extension of landing gear. To move handle from UP or DOWN it must be pulled aft. An interlock prevents moving GEAR handle to UP if hydraulic pressure to landing gear trim system fails. A force of 160 pounds may be applied to GEAR handle without causing damage to system.

   Failure of the landing gear trim system prevents moving the GEAR handle to UP.

3. CTR GEAR NORM/UP Isolation Switch - blue Permits main gear to be extended without extending center gear.

   UP prevents center gear from extending when main gear is extended. Center gear warning circuits are inhibited.

   If switch is not illuminated, center gear will extend and retract when main gear extends and retracts by means of gear handle. If switch is illuminated, the centerline gear remains retracted regardless of GEAR handle position.

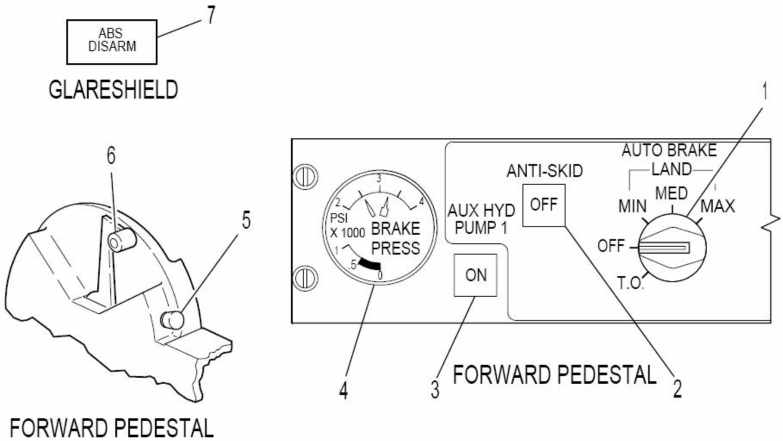
4. HANDLE REL Button

   Releases anti-retraction mechanism and permits gear handle to be placed in UP in event of ground sensing release mechanism malfunction.

5. GEAR HORN OFF Button

   When pushed, will silence gear warning horn when flaps are not in landing range and landing gear is up.

Brake Controls



1. AUTO BRAKE Selector

   OFF - ABS is not armed but manual braking is available.

   T.O. - Provides maximum braking from brake system 1 and 2 when spoilers deploy during RTO with ABS armed above 100 knots. Below 100 knots MIN braking is provided.

   MIN, MED, MAX - Selected braking level engages when spoilers are deployed automatically or manually during landing with ABS armed.

   If any AFS land mode is selected with aircraft on ground, the ABS disarms and the ABS DISARM light illuminates.

2. ANTI-SKID OFF Switch

   Push to select anti-skid off. Illuminates amber when anti-skid is selected off.

3. AUX HYD PUMP 1 Switch - blue

   Turns on electric aux pump 1 to pressurize hydraulic system 3 if pressure is lost. Hydraulic system 3 powers brake system 2. Pump can also be turned on from the HYD control panel.

4. BRAKE SYS HYD PRESS Gage (1 and 2)

   Pointer 1 shows hydraulic pressure in brake system 1. Pressure shown is highest of hydraulic system 1 or brake system 1 accumulator. Pointer 2 shows hydraulic pressure in brake system 2. Pressure shown is highest of hydraulic system 3 or brake system 2 accumulator.

5. PARK Light - amber

   Illuminates amber when PARK BRAKE handle is set to park position. Will extinguish when parking brake is released.

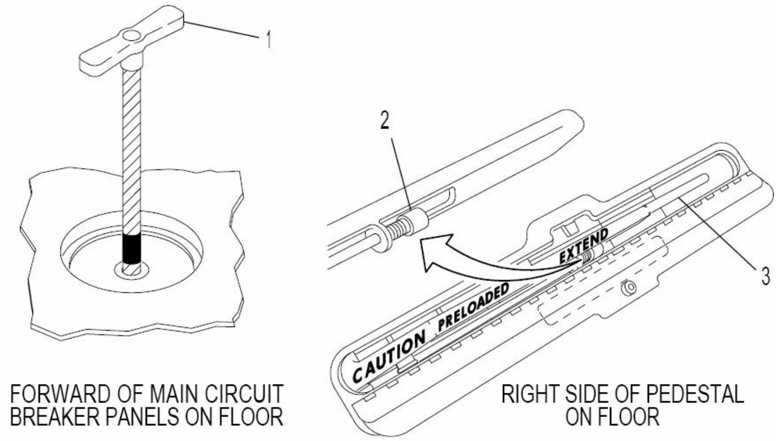
6. PARK BRAKE Handle

   Brakes are fully applied for parking by positioning the handle aft. Pressure from brake system 1 and 2 is maintained with trapped fluid.

7. ABS DISARM Light (2) - amber

   Illuminates amber when ABS is disarmed by malfunction or flight crew. Pilot can disarm ABS during rejected takeoff by depressing brake pedal 90 percent full travel. Pilot can disarm ABS during landing by depressing brake pedal 40 percent full travel.

Alternate Gear Extension



1. Center Gear Alternate Extension Handle

   Pulling handle up will mechanically unlatch center gear and allow it to free fall and lock in the down position. Before this can occur, the alternate gear extension lever must be raised to position the landing gear control valve to a bypass position.

   To determine the position of the center gear, gently pull the center gear alternate extension handle until a pronounced increase in resistance is felt (a force of 10-15 pounds may extend the gear if a loss of hydraulic system 3 pressure has occurred). As long as the red band on the cable is not visible or the bottom of the red band is at or below the floor level, the gear is up and locked. If the bottom of the red band is above the floor level, the center gear is unlocked.

2. Alternate Gear Extension Lever Lifting lever will:

   - Mechanically release all uplatches except center gear.
   - Mechanically position landing gear control valve to bypass and shut off hydraulic system 3 pressure to nose gear steering.

- Limit nose gear steering to 25 degrees to right (pressure from hydraulic system 1) when using nose gear steering wheel.

Stowing lever if hydraulic system 3 is operative will:

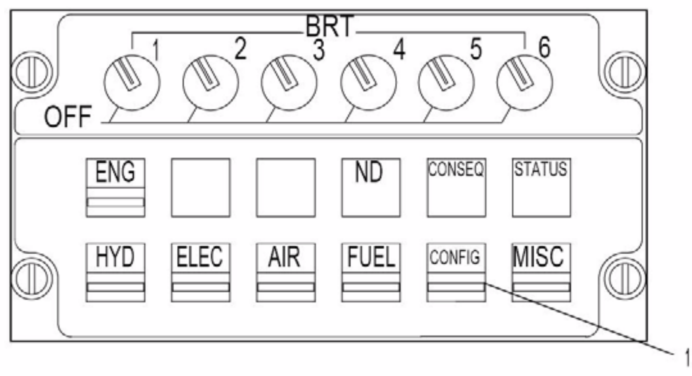
- Retract gear if gear handle is in GEAR UP position.
- Return nose gear steering to normal (hydraulic system 3 restored).

A force of 160 pounds may be applied to the alternate gear extension lever without causing damage to the system.

3. Lever Release Pushrod Knob

To unlock alternate gear extension lever and return to stowed position, lift the lever to relieve tension on link in detent, then press down on pushrod knob on outboard side of lever and allow lever to return to stowed position.

Config Cue Switch



AFT PEDESTAL

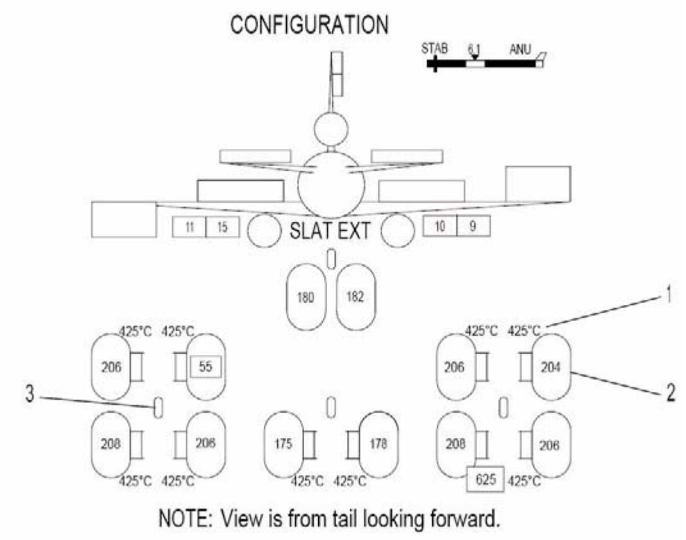
1. CONFIG Cue Switch - white

Illuminates white when CONFIG alert is displayed on EAD. When pushed:

- MASTER WARNING or MASTER CAUTION lights will extinguish.
- Reminder message will replace alert.
- Configuration synoptic comes into view on the SD.

Some level 1 alerts are maintenance alerts that appear on the SD STATUS page only. These maintenance alerts will not illuminate the cue switch or the MASTER CAUTION lights.

SD Synoptic Configuration



1. Brake Temperature Readout (Typical)

   Brake temperature is shown digitally (°C) adjacent to the brake outline at the side of the respective wheel. The white digits turn amber and are boxed in amber when brake temperature is out of limits. If brake temperature is not available, no data is shown. Temperatures above 936°C cannot be measured. The display will go blank for the affected brake(s). As the temperature falls back below 936°C, the temperature(s) will appear again if sensors are not damaged.

2. Tire Pressure Readout (Typical)

   Actual tire pressure is shown digitally (psi) within gray outline of tire. The white digits turn amber and are boxed in amber if tire pressure is low or substantially different from adjacent tire. If tire pressure data is not available, no data is shown.

3. Secondary Gear Lights (Typical)

   Green - Landing gear is down and locked.

   Red - Indicates one of the following:

   - Landing gear is not down and locked and gear handle is down.
   - Landing gear is in transit or not in agreement with gear handle.
   - Any unsafe gear condition exists.

   All lights are extinguished when the gear handle is up and the landing gear is up and locked.

Alerts

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

Amber Boxed Alerts (Level 2)

- ANTI-SKID FAIL (CONFIG) - Anti-skid system is inoperative.
- AUTO BRAKE FAIL (CONFIG) - Auto brake system is inoperative.
- BRAKE OVERHEAT (CONFIG) - Brake temperature exceeds limits.
- TIRE FAIL (CONFIG) - Pressure in one or more tire(s) drops below 50 psi.

Amber Alerts (Level 1)

- ANTI-SKID OFF (CONFIG) - ANTI-SKID switch selected OFF.
- AUTO BRAKE OFF (CONFIG) - AUTO BRAKE selector is in OFF and the GEAR handle is down.

Cyan Alerts (Level 0)

- AUTO BRAKE MAX - AUTO BRAKE selector set to maximum braking.
- AUTO BRAKE MED - AUTO BRAKE selector set to medium braking.
- AUTO BRAKE MIN - AUTO BRAKE selector set to minimum braking.
- AUTO BRAKE T.O. - Auto brake system selected to takeoff.
- PARK BRAKE ON - PARK BRAKE lever is set and the parking brake is engaged.

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Description and Operation

Lighting

Aircraft lighting systems are installed in the cockpit, exterior, and cabin area. Aircraft lighting is controlled from the cockpit except for certain functions of the cabin area lighting.

Cockpit Lighting

Cockpit dome lights provide area lighting. They can be turned on or off with a switch on the forward overhead panel. They also illuminate when the THNDRSTRM switch is on.

Floodlights illuminate the Captain's, First Officer's, and center instrument panels, overhead panel, glareshield, and pedestal. The controls are rotary knobs that vary light intensity with rotation. When the THNDRSTRM switch is on, all floodlights illuminate full bright.

Panel lights illuminate integrally lighted instruments and lightplates. The controls are rotary knobs that vary light intensity with rotation.

Six individual controls are installed to vary brightness of the six cockpit CRTs. Selected brightness is automatically maintained throughout a wide range of light conditions.

Exterior Lights

Retractable landing lights are located on the forward section of the fuselage. Fixed landing and taxi lights are located on the nose gear support assembly.

Runway turnoff lights provide additional side and forward lighting during taxiing and runway turnoff.

Navigation lights consist of a red light on the left wing tip, a green light on the right wing tip, and a white light on the trailing edge of each wing tip.

Beacon lights consist of two red flashing lights on the fuselage. One is located on top and the other is on bottom of the fuselage.

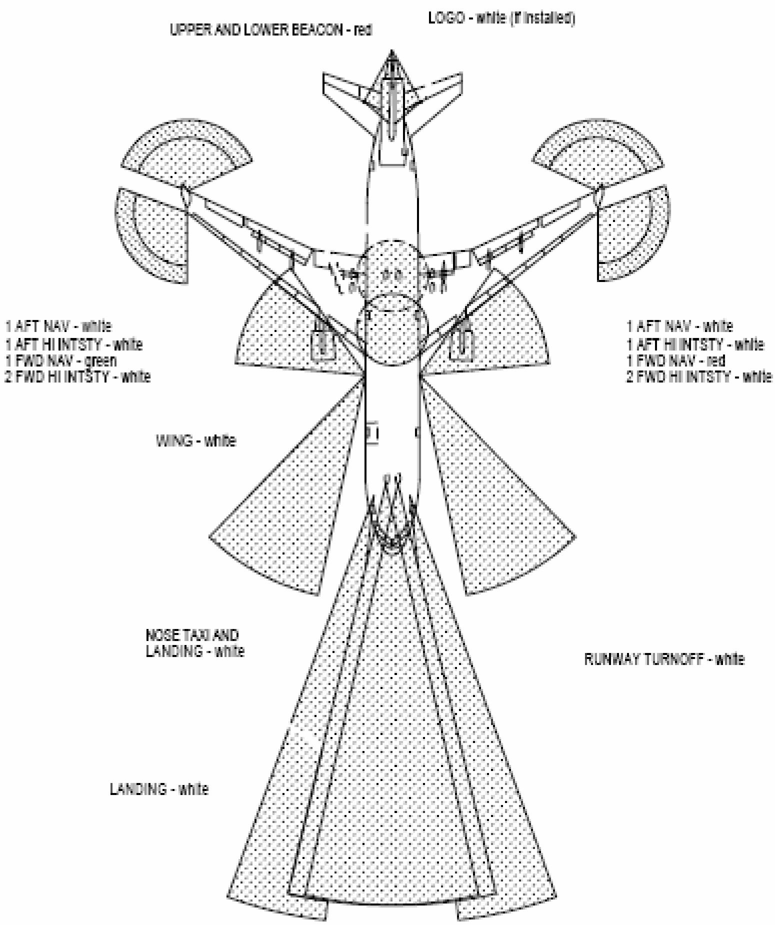
Wing and engine scan lights illuminate engine 1 and 3, wing leading edge, and wing surfaces to aid the flight crew in visually checking for icing.

High intensity supplemental lights consist of forward and aft facing strobe lights on each wing tip.

Logo lights are located in the horizontal stabilizers to illuminate the airline logo on the vertical stabilizer.

Components

Exterior Lighting Illumination Zones



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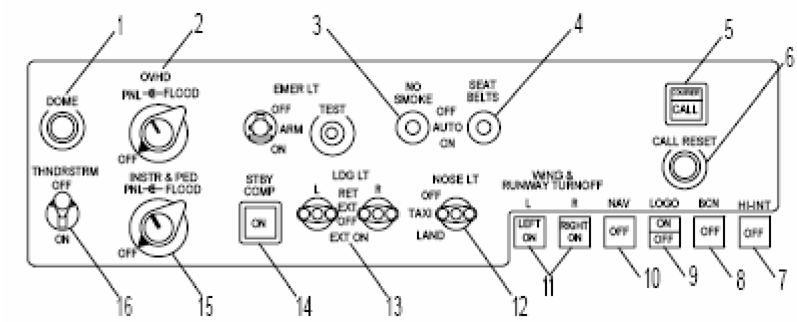
Controls and Displays

Lighting - Forward Overhead Controls



FORWARD OVERHEAD PANEL

1. DOME Switch

   Turns dome lights on and off.

2. OVHD PNL FLOOD Rheostats

   Outer rheostat regulates intensity of overhead panel lighting.

   Inner rheostat regulates intensity of overhead panel floodlights.

   All lights are off when rheostats are turned completely counterclockwise. Light intensity increases by turning rheostat in a clockwise direction.

3. NO SMOKE Sign Switch

   ON - Illuminates NO SMOKING signs and sounds a chime in cabin.

   AUTO or OFF - NO SMOKING signs will illuminate and a chime will sound in cabin if a cabin decompression occurs (cabin altitude exceeds 10,000 feet).

   AUTO - NO SMOKING sign will illuminate and a chime will sound in cabin when landing gear handle is in DOWN position.

4. SEAT BELTS Sign Switch

   ON - Illuminates FASTEN SEAT BELT and RETURN TO CABIN signs and sounds a chime in cabin.

   AUTO or OFF - FASTEN SEAT BELT signs will illuminate and a chime will sound in cabin if a cabin decompression occurs (cabin altitude exceeds 10,000 feet). RETURN TO CABIN signs will not illuminate.

   AUTO - FASTEN SEAT BELT and RETURN TO CABIN signs will illuminate and a chime will sound in cabin when FLAP handle is out of the UP position and/or landing GEAR handle is in DOWN position.

5. COURIER CALL Switch

   When the cockpit is called from the courier interphone station, a chime will sound and the CALL light (lower half) will illuminate.

6. CALL RESET Button

   Pushing the button will turn off the blue CALL light.

7. HI-INT Switch - blue

   Turns on supplemental high intensity recognition lights on each wingtip. Each wing tip has three lights (two forward and one aft). Lights flash in sequence with anticollision lights. Illuminates blue when high intensity lights are off.

8. BCN Switch - amber

   Turns on beacon lights on top and bottom of aircraft. OFF illuminates amber when anti-collision lights are off.

9. LOGO Switch - blue

   Turns on Logo Light on horizontal stab to illuminate vertical stab

   ON illuminates blue when switch is selected on.

   OFF illuminates blue when switch is selected off.

10. NAV Switch - amber

    Turns on position lights in each wing tip. The two left forward lights emit red lighting. The two right forward lights emit green lighting. The two aft lights in each wing tip emit white lighting.

    OFF illuminates amber when lights are off.

11. WING & RUNWAY TURNOFF Switch - blue

    Turns on respective scan lights for the engines and wing surfaces. Turns on the runway turnoff lights for ground operation to supplement available lighting.

    LEFT ON illuminates blue when left wing and turnoff lights are selected on.

    RIGHT ON illuminates blue when right wing and turnoff lights are selected on.

12. NOSE LT Switch

    Turns on nose gear landing lights for taxiing and landing. These lights will only come on if landing gear control handle is in DOWN position.

    OFF - Lights are off.

    TAXI - Lights are on with less than full intensity for ground operation. LAND - Lights are on at full intensity for landing.

13. LDG LT Switch (L and R)

    Activates respective primary landing lights mounted on the forward fuselage.

    RET - Lamp are off and the lights are retracted flush with the fuselage.

    EXT OFF - Lights are extended but the lamps are off.

    EXT ON - Lights are extended and the lamps are on.

14. STBY COMP Switch - blue

    Turns on the standby compass light. ON illuminates blue.

15. INSTR & PED PNL FLOOD Rheostats

    Outer rheostat regulates intensity of instrument panel and pedestal switchplate lighting.

    Inner rheostat regulates intensity of instrument panel and pedestal floodlights.

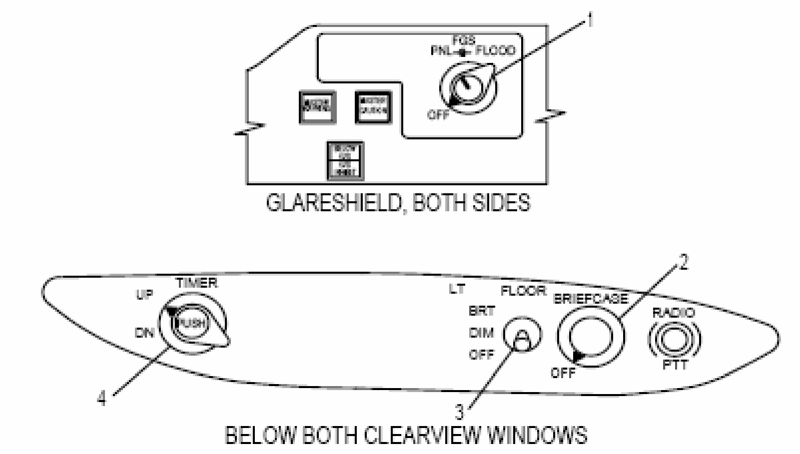
    All associated lighting is off when rheostats are turned completely counterclockwise.

16. THNDRSTRM Switch

    ON - All instrument and control panel floodlights as well as the dome lights go to full intensity. All individual controls are bypassed.

    OFF - Returns lighting control to normal.

Lighting - Light Control Panel



1. FGS PNL and FLOOD Rheostat

   Controls backlighting and floodlighting of flight guidance control panel.

   Outer rheostat regulates intensity of flight guidance control panel backlighting.

Inner rheostat regulates intensity of flight guidance control panel floodlights.

Both rheostats are off when turned completely counterclockwise. Light intensity increases by turning in a clockwise direction.

2. BRIEFCASE Rheostat

   Controls on/off and intensity of briefcase area lighting.

3. LT FLOOR Switch

   BRT - Floor lights go to full intensity.

   DIM - Floor light intensity is reduced.

   OFF - Turns floor lights off.

4. TIMER Knob

   Push one starts the clock timer on ND. Push two stops the clock timer. Push three resets clock timer to 00:00.

   UP - Timer on ND counts up from 0.

   DN - Timer counts down from a preselected time. Preselected time is set on the MCDU Approach page and will also appear on the ND.

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Description and Operation

General

Warning and alerting consists of Electronic Instrument System (EIS), Central Aural Warning System (CAWS), and Ground Proximity Warning System (GPWS).

Electronic Instrument System (EIS) Alerting

The EIS alerting system displays alerts on the CRTs in the cockpit.

The system also displays the consequences, if any, of the alerts. The EIS alerting system consists of:

- MASTER WARNING and MASTER CAUTION lights (MW/MC)
- The Engine and Alert Display (EAD)
- The System Display (SD)
- The System Display Control Panel (SDCP)

Alerts are categorized into four levels (3, 2, 1, and 0). Alert levels have unique display characteristics to allow immediate crew recognition of the alert level.

Alerts are presented in three columns in the lower 1/3 of the EAD. Each column allows alerts up to 17 characters long, including leading triangles for level 3 alerts. The first two columns may contain 6 alerts, but the third column is limited to only 4 because the two bottom lines are dedicated for reminder messages.

The EAD alerts are filtered. Only the root cause alert will be displayed. Additional alerts which occur as a result of the initial failure are inhibited.

Pushing the associated system cue switch on the SDCP will cause the associated system synoptic page to be displayed on the SD and also resets the MASTER CAUTION or MASTER WARNING lights if they are illuminated and no other lights are illuminated.

On any SD page a PRESS (associated cue switch) AGAIN TO CONTINUE message tells the pilot that alerts or consequences on subsequent SD pages can be accessed by pushing the associated cue switch. The associated cue switch part of the message flashes until all pages have been reviewed. The secondary engine page automatically appears on the SD for alerts associated with the secondary engine page parameters (see Engines chapter).

Level 3 Alerts - Boxed Red

Level 3 (red) alerts indicate emergency operational conditions that require immediate crew awareness and immediate corrective or compensatory action by the crew. Level 3 alerts are characterized as follows:

- Tritone for most level 3 alerts.
- Red MASTER WARNING lights illuminate.
- Boxed red alert on the EAD with a red triangle in the first position.
- Alert is positioned starting at top left corner of the alert list on the EAD.
- Associated cue switch will illuminate white on the SDCP.
- Level 3 alerts are acknowledged but not reset by pushing the associated cue switch.
- Cue switches are resettable by acknowledging associated alerts.
- MASTER WARNING lights are resettable by pushing either the MASTER WARNING light or by pushing associated cue switch.

Level 2 Alerts - Boxed Amber

Level 2 (amber) alerts indicate abnormal operational system conditions that require immediate crew awareness and subsequent corrective or compensatory action by the crew. Level 2 alerts are characterized as follows:

- Amber MASTER CAUTION lights illuminate.

- Boxed amber alert on the EAD.
- Will be positioned below any level 3 alert in alert list on the EAD.
- Associated cue switch will illuminate white on the SDCP.
- Alert is acknowledged and possibly reset by pushing associated illuminated cue switch on the SDCP.
- A boxed amber reminder message will appear on the EAD when a level 2 alert has been reset.
- Cue switches are resettable by acknowledging associated alerts.
- MASTER CAUTION lights are resettable by pushing either MASTER CAUTION light or the associated cue switch.

Level 1 Alerts - Amber

Level 1 alerts (amber) may require maintenance prior to takeoff, a logbook entry, or confirmation of desired system configuration. A list of level 1 alerts and the required pilot action can be found in the MD-11 FCOM Volume II. Level 1 alerts are characterized as follows:

- Amber MASTER CAUTION lights illuminate.
- Amber alert appears on the EAD.
- Alert will be positioned below any level 3 or 2 alerts in the alert list on the EAD.
- Associated cue switch will illuminate white on the SDCP.
- Alert is acknowledged and possibly reset by pushing associated illuminated cue switch on the SDCP.
- An amber reminder message will appear on the EAD when a level 1 alert has been reset.
- MASTER CAUTION lights are resettable by pushing either the MASTER CAUTION light or the associated cue switch on the SDCP.

Some level 1 alerts are maintenance alerts that appear on the SD status page only and will not illuminate an SDCP cue switch or the MASTER CAUTION lights.

Level 0 Alerts - Cyan

Level 0 (cyan) alerts are generally operational or aircraft systems status information. Level 0 alerts are characterized as follows:

- A cyan alert on the EAD.
- Alert will be positioned above the space for reminder messages at the bottom right of the EAD.

Consequences

When some level 3, 2, or 1 alerts are displayed, statements called CONSEQUENCES appear (aligned with the associated alert) in the lower third of the associated SD synoptic. The SD consequences are the effects of the failure and/or the required crew action. If the affected system is operating in automatic mode, the crew could safely complete the flight by referring only to the SD consequences. For maximum system recovery, however, required checklist procedures should be integrated with the SD consequences.

Reminder Messages

When level 2 or 1 alerts have been reset by pushing the associated cue switch on the SDCP, the alert is removed from the alert list on the EAD and a reminder message consisting of the associated system name (FUEL, HYD, etc.) is shown in a dedicated location within the two bottom lines of the right column on the EAD. These reminder messages are amber and boxed for level 2 alerts and amber and unboxed for level 1 alerts. In some cases the EAD reminder message will flash (serving as a pseudo MASTER CAUTION light).

Inhibits

Takeoff Inhibits - Level 3 alerts and associated MASTER WARNING lights are inhibited from V1 to 400' RA, but no longer than 25 seconds in-air. Level 2 or 1 alerts and associated MASTER CAUTION lights are inhibited at throttle advance or 80 knots or V1 -20 knots. The takeoff inhibits are released at 400' RA (or in-air for 25 seconds), or 1000' barometric altitude above the departure airport (or in-air for 120 seconds). Level 0 alerts are not inhibited.

Takeoff inhibit exceptions are as follows:

- The level 3 ENGINE FIRE alerts are not inhibited during takeoff, but the associated MASTER WARNING lights are inhibited at V1.
- The level 3 NO MASKS and CABIN ALTITUDE alerts are inhibited from throttle advance to 400' RA.
- The level 2 TIRE FAIL alert and associated MASTER CAUTION lights are inhibited from V1 to 400' RA
- The level 1 FUEL DUMP ON alert is not inhibited.

Landing Inhibits - Level 3 alerts and associated MASTER WARNING lights are not inhibited during landing. Level 2 or 1 alerts and associated MASTER CAUTION lights are inhibited from 1000' barometric altitude above field elevation to 80 knots ground speed (but no longer than 120 seconds), or from 100' RA to 80 knots ground speed (but no longer than 25 seconds). Level 0 alerts are not inhibited. The level 1 FUEL DUMP ON alert is not inhibited.

Takeoff Essential Items Checklist

During taxi, takeoff items are checked sequentially. The EIS provides a dedicated space at the bottom of the center column on the EAD for display of the takeoff essential items checklist. When this checklist is displayed, any alerts are displaced.

The takeoff essential items checklist consists of the following ordered list of conditions and white boxed messages:

CONDITION	MESSAGE
STAB not in green	STAB TRIM
Flaps not in takeoff	FLAPS
Slats not in takeoff	SLATS
Park brake on	BRAKES
Spoilers not armed	SPOILERS

The checklist is sequentially checked from the top. Only the highest condition not met is displayed. When a condition is met, the EIS continues down the list displaying the next condition not met. When all takeoff conditions have been satisfied, a green takeoff-checklist-complete box is displayed in the essential items checklist area.

Before takeoff, if takeoff flap setting does not match flap value on the FMS TAKEOFF page:

- The green takeoff-checklist-complete box will not appear and,
- The flap takeoff warnings will activate if throttles are advanced for takeoff.

With the exception of the spoilers, takeoff essential items that have not been satisfied will cause the checklist display (message and box) to turn red when the aircraft begins the takeoff roll. The essential items checklist is removed when airspeed exceeds 80 knots.

Landing Essential Items Checklist

During the approach phase, the EIS initiates a check of essential landing items. This checklist is displayed in the same position and manner as the takeoff essential items checklist.

The landing essential items checklist consists of the following ordered list of conditions and white messages:

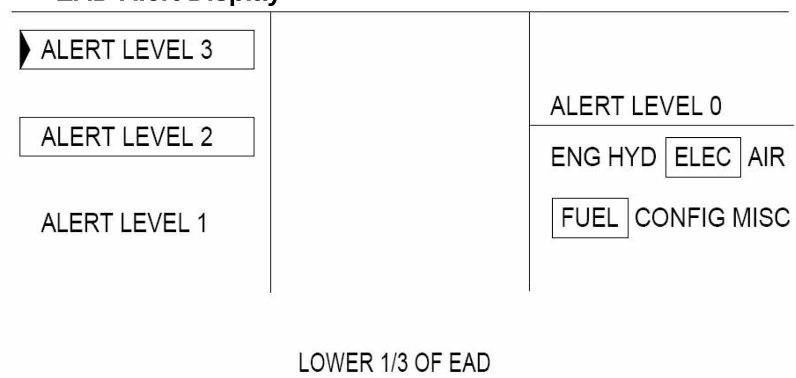
CONDITION	MESSAGE
Landing gear not down	LANDING GEAR
Flaps not in landing	FLAPS
Spoilers not armed	SPOILERS

The checklist is sequentially checked from the top. Only the highest condition not met is displayed. When a condition is met, the EIS continues down the list displaying the next condition not met. When all landing conditions have been satisfied, a green landing-checklist-complete box is displayed in the essential items checklist area.

If the landing essential items checklist box displays LANDING GEAR in white with the gear handle down, observe the primary gear lights. If the primary gear lights indicate safe, landing gear is down and locked.

The essential items checklist is removed when the aircraft is on the ground.

EAD Alert Display



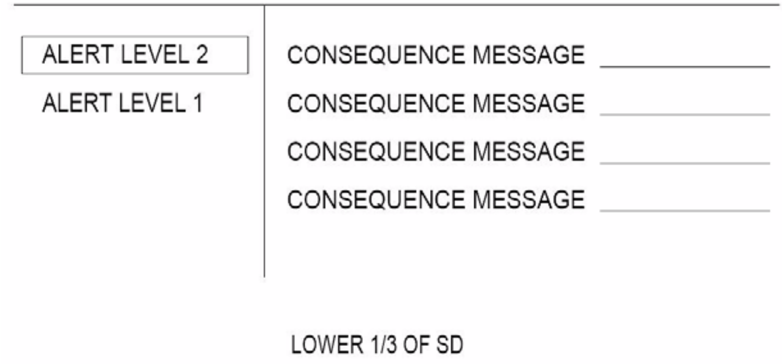
Alerts are presented in three columns in the lower 1/3 of the EAD. Each column allows alerts up to 17 characters long, including leading triangles for level 3 alerts. The first two columns may contain six messages, but the third column is limited to only four messages because the two bottom lines are dedicated for reminder messages. Alerts are presented in the following order:

- Level 3 alerts are displayed in red, boxed in red, and have leading triangles. They are presented at the top of the left most column on the EAD. There is no priority within level 3 alert messages. The latest is added to the top of the list.
- Level 2 alerts are shown in amber and boxed in amber. They are presented below any level 3 alerts. There is no priority within level 2 alerts. The latest is added to the top of the group of level 2 alerts.
- Level 1 alerts are displayed in amber and are presented below any level 3 or level 2 alerts. There is no priority within level 1 alerts. The latest is added to the top of the group of level 1 alerts.
- Level 0 alerts are displayed in cyan and are presented above the dedicated reminder message area (fifth line of the right column). There is no priority within level 0 alerts. The latest is added to the top of the group of level 0 alerts.

When level 1 or 2 alerts have been reset by pushing the associated cue switch on the SDCP, the alert is removed from the alert list on the EAD and a reminder message consisting of the associated system name FUEL, HYD, etc., is shown in a dedicated location within the two bottom lines of the right column on the EAD. These reminder messages are amber and are boxed for level 2 alert messages and amber and unboxed for level 1 alerts.

Where one failure may create multiple consequential alerts only the highest order alert is displayed on the EAD. The other alerts are inhibited.

SD Alerts and Consequences Display



Pushing a cue switch on the SDCP causes the associated system page to be displayed on the SD and resets the MASTER WARNING or MASTER CAUTION lights (if illuminated) provided no other alert conditions exist that would illuminate the MASTER WARNING or MASTER CAUTION lights.

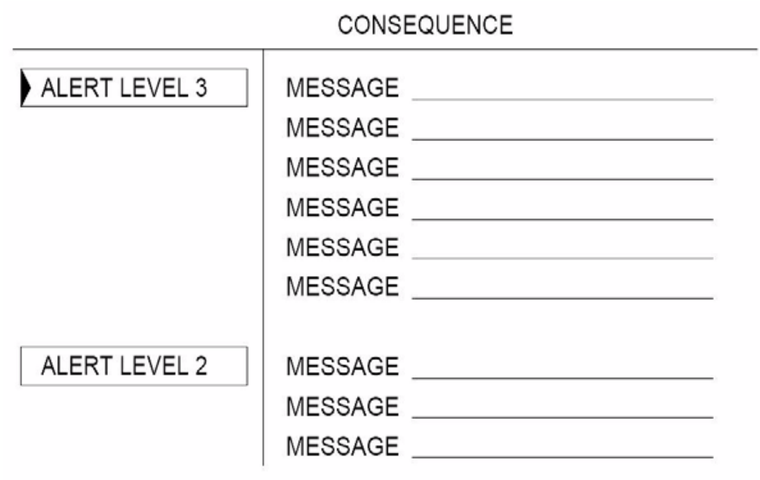
The secondary engine page is automatically called up when secondary engine parameter alerts appear or when a secondary engine page parameter changes from amber to red (except APU data and cabin rate).

Each systems page (except MISC) contains a schematic for that system on the upper 2/3 of the SD. The bottom 1/3 is for alerts related to that system and the alert consequences. Only levels 3, 2, and 1 alerts are shown on the system pages.

Alerts are shown in the left column. The alerts are grouped by level and appear in the same order as they appeared on the EAD.

Consequences are shown in the right column. Consequences are aligned with the generating alerts (alignment available on the CONSEQUENCE page). Consequences are shown in white and may have a maximum of 34 characters.

SD Consequence Page

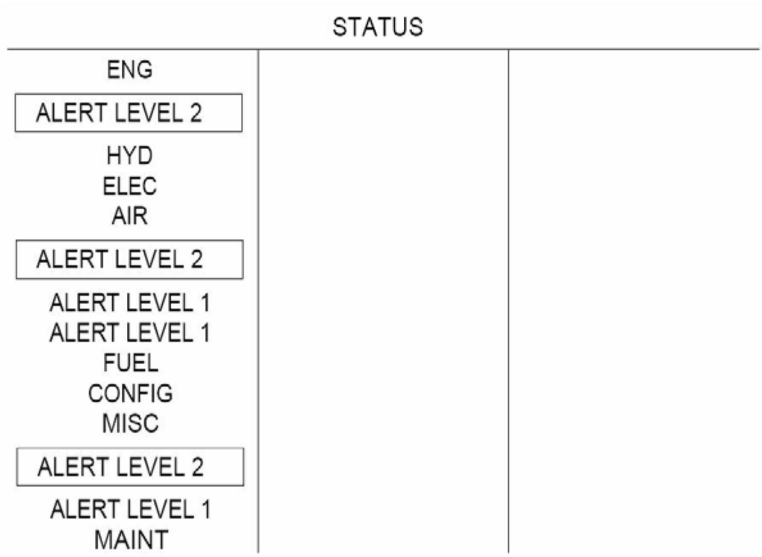


The consequence page is selected to appear on the SD by pushing the CONSEQ switch on the SDCP. The CONSEQ page shows a compilation of all consequences depicted on the individual synoptic pages.

The alerts are grouped by level and appear in the same order as they appear on the EAD. The consequences associated with an alert are displayed adjacent to that alert.

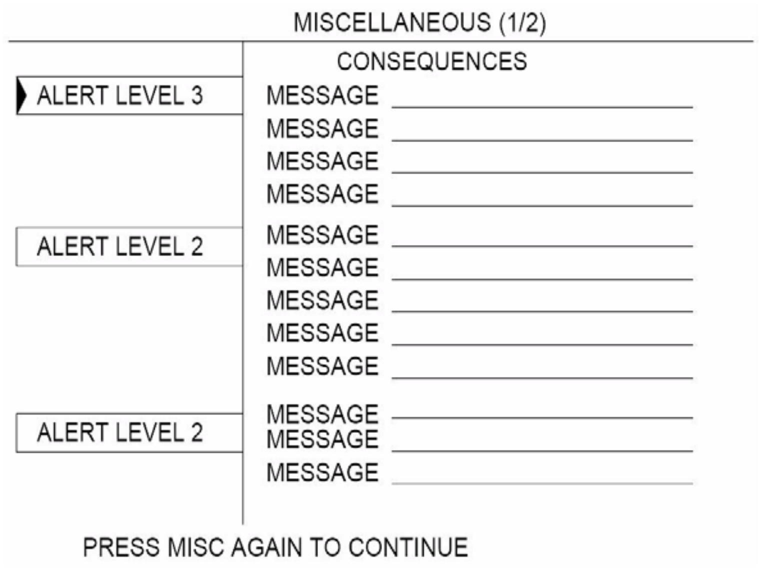
This page and all subsequent pages can display up to 21 alerts and 21 consequences. When additional pages are required, the message PRESS CONSEQ AGAIN TO CONTINUE will appear at the top of the page.

SD Status Page



The STATUS page displays a list of all alerts included on the systems pages and is selected by pushing the STATUS switch on the SDCP. The alerts are shown in three columns in the same format as on the EAD. The alerts are grouped per system in the same order as the cue switches on the SDCP and the reminder messages on the EAD (ENG, HYD, ELEC, AIR, FUEL, CONFIG, and MISC). A separate section for maintenance alerts is after the MISC system alerts. This section is titled MAINT. MAINT alerts appear only on status page one and can only be level 1. Within each system group, the alerts are grouped by level and appear in the same order as they appeared on the EAD. Above each group of alerts appears the system label, preceded by a blank line if not at the top of the page. This system label will appear as a place holder even if no alerts are associated with that system. This page and all subsequent pages can display up to 51 alerts. When there are additional pages, the message PRESS STATUS AGAIN TO CONTINUE will appear at the bottom of the page if there are additional pages.

SD Miscellaneous Page



The miscellaneous system page is selected to appear on the SD by pushing the MISC switch on the SDCP. The miscellaneous system page displays alerts and consequences for various uncategorized systems in text form only. The consequences are grouped with the alerts in the same manner as the consequences page. The first miscellaneous systems page may have a maximum of 17 alerts and 17 consequences.

Additional pages may be made available for the display of consequences and may display up to 17 alerts and 17 consequences. When additional pages are required, the message PRESS MISC AGAIN TO CONTINUE will appear at the bottom of the page.

The miscellaneous page is for alerts (levels 3, 2, and 1 only) and consequences (levels 3 and 2).

Central Aural Warning System (CAWS)

The CAWS function provides aural warnings of an unsafe condition or situation. The CAWS consists of a controller installed in the avionics rack. The controller receives and process signals from selected sources for activation of the appropriate aural warnings. The CAWS operates on 28-volt dc power.

An additional interface links the controller to the Display Electronic Units (DEU) that send data to the Display Units (DU) in the cockpit. A CAWS FAULT alert will be displayed when a fault is detected in the CAWS.

The audio signals generated in the CAWS controller feed into the Digitally Controlled Audio System (DCAS) audio management units 1 and 2. These units then send the signal to the appropriate speakers and headphones.

The aural warnings are tones such as horns, chimes and bells accompanied with voice warnings from selected warnings and alerts. The voice warning and its associated tone warning is cycled, a one-second tone followed by a one-second voice warning for the duration of the warning period.

The CAWS can automatically sequence each aural warning when two or more warnings occur at the same time. The latest warning will interrupt the warning in progress. Sequential operation will continue with the latest warning included in the sequence.

Some warnings are inhibited during certain phases of flight.

Landing Gear Warning

The CAWS will provide an aural warning tone and voice (option) for an unsafe landing configuration. An unsafe configuration is defined by either of the following conditions:

1. Any gears not down and locked and flaps in landing configuration.
2. Any gears not down and locked, any throttle(s) retarded to idle, airspeed less than 210 knots, and flaps not in landing configuration (less than 31.5 degrees).

For condition 1 above, if the wing flaps exceed 31.5 degrees, the only way that the aural warning can be silenced is by extension of the landing gear to the down and locked position.

The aural warning for condition 2 can be silenced manually with the GEAR HORN OFF button on the forward pedestal if the flap angle does not exceed 31 degrees. The landing gear warning function will activate whenever the throttles are retarded to idle.

There is a delay of 16 seconds in the gear horn actuation when the gear is in transit (being raised) and flaps are in landing range. This allows time for the flaps to retract without sounding the horn during a missed approach.

Engine Fire Warning

The CAWS will provide an aural warning tone and voice (option) when a fire is detected by the engine fire detection system. Refer to the Fire Protection chapter for a description of the engine fire detection system.

Altitude Advisory Warning

The CAWS will sound an aural warning tone and voice (option) and turn the PFD precision altitude amber to caution the flight crew if the aircraft approaches a preselected altitude or deviates from the preselected altitude. The altitude advisory operates independently from the engagement of the flight director or autopilot. The altitude advisory function receives input from both Flight Control Computers (FCC). This dual advisory circuit will annunciate the first advisory signal received.

Takeoff Warning

A takeoff warning aural signal (intermittent horn identical to cabin altitude warning) and applicable voice warnings will warn the flight crew of an unsafe takeoff configuration. The warnings will sound when either throttle 1 or 2 is advanced for takeoff with the ground shift mechanism in the ground mode and any one of the following conditions exist:

CONDITION	VOICE WARNING
Parking brake on	BRAKES
Flaps not in takeoff position	FLAPS
Slats not in takeoff position	SLATS
Spoiler handle not forward	SPOILERS
Stabilizer not in takeoff range	STABILIZER

Cabin Low Pressure Warning

The CAWS will provide an aural warning tone and voice (option) for detected cabin low pressure.

The warning will automatically actuate when the cabin altitude exceeds 10,000 feet. The warning will cycle three times and reset when the altitude switch resets.

Overspeed Warnings

The CAWS will provide an aural warning tone and voice (option) when an overspeed condition is detected by either Central Air Data Computer (CADC). The CAWS will also provide an aural warning whenever the aircraft exceeds the maximum speed with the slats extended. The clacker will sound when airspeed exceeds 280 knots and the slats are extended.

Autopilot Disconnect Warning

The CAWS will provide an aural warning tone and voice (option) when a disconnect signal is received from either FCC.

Horizontal Stabilizer Motion Warning

During flight, a horn and voice warning STABILIZER MOTION (option) will sound to alert the flight crew that the horizontal stabilizer is in motion. The warnings sound after each continuous movement of more than 2 degrees stabilizer travel at a rate greater than 0.08 degrees per second for manual trim and after continuous movement of more than 2 degrees stabilizer when in the automatic pitch trim mode.

Cockpit Timer Aural Tone

An aural tone will sound when the cockpit timer has counted down to zero.

Radio Altitude Voice Warnings

The CAWS will monitor the two radio altimeters and will sound airline selected voice warnings when either altimeter sends the signal.

Ground Proximity Warning System (GPWS)

The GPWS provides visual and aural warnings associated with the following flight conditions:

Mode 1 - Excessive Descent Rate

Mode 1 provides a warning for excessive descent profiles with respect to altitude AGL during cruise and approach AGL. Two different warning boundaries are possible:

- Mode 1 outer boundary - Penetration will activate the amber GROUND PROX message on the PFD and produce the voice warning SINKRATE.
- Mode 1 inner boundary - Penetration will activate the red GROUND PROX message on the PFD and produce the voice warning PULL UP (WHOOP WHOOP PULL UP - option).

Mode 2 - Excessive Terrain Closure Rate

Mode 2 provides a warning based on RA and how rapidly that RA is decreasing. Mode 2 has two areas of application as follows:

- Mode 2A - This mode is applied when the landing flaps are not down and the aircraft is not on the glideslope. Upon penetration, the amber GROUND PROX message is activated and a voice warning TERRAIN - TERRAIN sounds. If the condition persists, the voice warning PULL UP (WHOOP WHOOP PULL UP - option) will be announced. The upper boundary of the alert envelope varies as the airspeed increases from 220 kts to 310 kts.

- Mode 2B - Enables for three conditions: landing flaps are set for landing, aircraft is on the glideslope during an ILS approach, or the aircraft is in the first 60 seconds after takeoff. When the aircraft penetrates the alert envelope with either gear or flaps not in landing configuration, the amber GROUND PROX message is activated on the PFD and the voice warning TERRAIN TERRAIN is generated. If the condition persists, the voice warning PULL UP (WHOOP WHOOP PULL UP - option) will be generated. If the aircraft penetrates the alert envelope with both gear and flaps in landing configuration, the voice warning TERRAIN is repeated until the envelope is exited.

Mode 3 - Altitude Loss After Takeoff

Provides a warning for significant altitude loss after takeoff or after a go-around from below 245 feet AGL with gear up and flaps are not in the landing configuration. Penetration of the boundary will result in the amber GROUND PROX message activated on the PFD and a voice warning DON'T SINK.

Mode 4 - Unsafe Terrain Clearance

Mode 4 exists in three forms:

- Mode 4A - Insufficient Terrain Clearance, Gear Up. Active during cruise and approach with the landing gear not in landing configuration. Upper boundary is at 500-feet RA. If the aircraft penetrates this boundary with the landing gear still up and at an airspeed less than 190 kts, the voice warning will be TOO LOW GEAR and the amber GROUND PROX message will appear on the PFD. Above 190 knots the upper boundary increases linearly with airspeed to a maximum of 1,000 feet RA altitude at 250 knots or more. Penetrating this boundary produces a repetitive TOO LOW TERRAIN voice warning.
- Mode 4B - Insufficient Terrain Clearance, Flaps Up. When the landing gear is lowered, mode 4B is active. Upper

boundary has decreased to 245 feet RA. If the aircraft penetrates this boundary at an airspeed below 159 kts and flaps not in landing configuration, the voice warning will be TOO LOW FLAPS and the amber GROUND PROX message will appear on the PFD. Above 159 kts the boundary increases linearly (same as mode 4A) and the voice warning is TOO LOW TERRAIN.

- Mode 4C (with EGPWS installed) - Insufficient Terrain Clearance at Takeoff. Provides a warning based on minimum RA clearance during takeoff. A value equal to 75 percent of the current RA is stored in a filter. If the RA begins to decrease, the maximum attained value is stored. If the altitude decreases below the stored value, a TOO LOW TERRAIN voice warning will be generated and the amber GROUND PROX message will be displayed on the PFD.

Mode 5 - Descent Below Glideslope

Mode 5 provides two levels of warning when aircraft descent is below the glideslope on an ILS approach.

- Mode 5 soft alert - Alert occurs when the aircraft is more than 1.3 dots below the glideslope. This alert is called soft because the volume level of the alert is less than the volume of other warnings. This soft alert envelope has a typical upper limit of 1,000 feet. Voice warning GLIDESLOPE is generated and the BELOW G/S switch is illuminated.
- Mode 5 hard alert - Alert occurs when the aircraft is below 300 feet RA with more than 2 dots below the glideslope. It is called a hard alert because the volume level is raised to that of the other warnings. Provides the same warnings as the soft alert.

Mode 5 warning can be cancelled by the flight crew by pushing the BELOW G/S switch on the glareshield at any time below 1,000 feet RA. The warning is reset by climbing above 1,000 feet or descending below 30 feet.

Mode 6 - Altitude Callouts/Excessive Bank Angle Warning

Mode 6 provides optional callouts for descent through predefined radio altitudes between 2,500 and 10 feet AGL and excessive roll or bank angle warning.

Bank angle warning provides over-banking protection during approach, climbout, and cruise. Additionally, the warning protects against wing or engine strikes during landing.

The bank angle warning limits are determined by two factors as follows:

- The basic bank angle limits that vary linearly from 6 degrees at 0 feet (and below) RA to 40 degrees at 150 feet RA and above and
- The roll rate adjustment of 1.5 degrees added for every 1 degree roll rate (limited to +/- 6 degrees).

If RA data is invalid, the bank angle warning limit will be 40 degrees.

When bank angle exceeds the warning limits, voice warning BANK ANGLE are generated twice, and then suppressed unless the roll angle increases by an additional 20%.

Airport Envelope Modulation

The airport envelope modulation feature provides improved alert/warning protection at some key locations throughout the world while improving margins against nuisance warnings at others. Near certain airports, modes 4 and 5 are expanded to provide warnings consistent with normal approaches. Near other airports, modes 1, 2, and 4, are desensitized to prevent nuisance warnings that result from unusual terrain or approach procedures.

Selected Warning Options

10/20/30/40/50 voice warning - standard.

Standard Annunciations Table

*NOTE: * indicates selectable option. ** indicates selectable option to delete warning.*

Altitude Alert

AURAL - C-chord and ALTITUDE voice.*

- Logic - approaching or deviating selected altitude.
- Inhibit - takeoff (80 KTS and 400' RA) and landing (100' RA to 80 KTS)

VISUAL - amber box flashes on PFD altitude scale.

- Logic - approaching or deviating selected altitude.
- Inhibit - none.

REMARKS - options: 1. no light at acquisition. 2. tone/voice at acquisition. 3. inhibit with flaps in landing. 4. inhibit with FMS approach.

Autopilot Disconnect

AURAL - warbler and AUTOPILOT voice.*

- Logic - AP disconnect in all flight regimes (signal from FCC).**
- Inhibit - none

VISUAL - red flashing AP OFF on PFD.

- Logic - AP disconnect full flight regime (signal from FCC).
- Inhibit - none. REMARKS- none.

Horizontal Stabilizer in Motion

AURAL - horn and STABILIZER MOTION voice.*

- Logic - horizontal stabilizer in continuous motion (2 degrees or more).
- Inhibit - Aircraft on ground.

VISUAL - display on secondary engine page and configuration synoptic.

- Logic - current status of stabilizer.
- Inhibit - none.

REMARKS - none.

Minimums

AURAL - MINIMUMS voice.*

- Logic - signal from DEUs when a/c descends thru the set minimum value.
- Inhibit - none.

VISUAL - white minimums bug turns amber on PFD.

- Logic -a/c descends thru the set minimum value.
- Inhibit - none.

REMARKS - none.

Approach Minimums

AURAL - APPROACH MINIMUMS voice.*

- Logic - signal from DEUs when a/c descends thru the set minimum + 100'.
- Inhibit - none.

VISUAL - none

REMARKS - none.

Cabin Altitude

AURAL - tone and CABIN ALTITUDE voice.*

- Logic - cabin altitude more than 10,000' (signal from cabin pressure switch).
- Inhibit - takeoff (80 KTS to 400' RA) and landing (100' RA to 80 KTS).

VISUAL - MASTER WARNING lights and red CABIN ALTITUDE alert.

- Logic - cabin altitude more than 10,000' (signal from CPCs thru ESC).
- Inhibit - takeoff (V1 to 400' RA).

REMARKS - visual indications of CAB ALT are in red on overhead panel.

Landing Gear Not Down in Approach

AURAL - tone and LANDING GEAR voice.*

- Logic - gear not down and locked and flaps in land mode, throttles retarded, airspeed less than 210 KTS, 1,200' RA or below and flaps not in land mode.
- Inhibit - takeoff (80 KTS to 400' RA) and landing (100' RA to 80 KTS).

VISUAL - white LANDING GEAR on EAD.

- Logic - any landing gear not down and locked in approach.
- Inhibit - none.

REMARKS - visual indication for landing gear is in red/green above gear handle with independent back-up on configuration page.

Landing Gear Not Down in Landing

AURAL - tone and TOO LOW GEAR (GPWS) voice.

- Logic - airspeed less than 159 KTS and a/c below 245', and airspeed less than 190 KTS and a/c below 500'.
- Inhibit - windshear condition or DITCH switch enabled.

VISUAL - flashing red GROUND PROX on PFD.

- Logic - gear not down and locked and airspeed less than 159 KTS and a/c below 145', and airspeed less than 190 KTS and a/c below 500'.
- Inhibit - windshear condition or DITCH switch enabled.

REMARKS - none.

Engine(s) Fire

AURAL - continuous bell and ENGINE (1, 2, or 3) FIRE voice.*

- Logic - engine fire detected.
- Inhibit - takeoff (V1 to 400' RA) and landing (100' RA to 80 KTS).

VISUAL - MASTER WARNING lights and red ENG (1, 2, 0r 3) FIRE alert.

- Logic - engine fire detected.
- Inhibit - MASTER WARNING lights inhibited on takeoff (V1 to 400' RA).

REMARKS - visual indication on engine FIRE handles and on FUEL switches.

Overspeed

AURAL - clacker and OVERSPEED* and SLAT OVERSPEED voice.*

- Logic - airspeed above Vmo/Vmo plus 4 KTS or above 280 KTS with slats extended.
- Inhibit - takeoff (80 KTS to 400' RA) and landing (100' RA to 80 KTS).

VISUAL - red and white bar on airspeed tape on PFD.

- Logic - airspeed above Vmo/Vmo plus 4 KTS.
- Inhibit - none.

REMARKS - none.

Takeoff Configuration Slats Warning

AURAL - tone and SLATS voice.*

- Logic - slats not in takeoff range, a/c on ground and throttle 1 or 2 advanced for takeoff.
- Inhibit - takeoff (V1 to 400' RA) and landing (100' RA to 80 KTS).

VISUAL - red SLAT message on EAD.

- Logic - takeoff roll and slats not in takeoff range.
- Inhibit - a/c airborne.

REMARKS - visual is white during taxi and turns red when flight phase changes to takeoff roll.

Takeoff Configuration Flaps Warning

AURAL - tone and FLAPS voice.*

- Logic - flaps not in takeoff range, a/c on ground and throttle 1 or 2 advanced for takeoff.
- Inhibit - takeoff (V1 to 400' RA) and landing (100' RA to 80 KTS).

VISUAL - red FLAPS message on EAD.

- Logic - takeoff roll and flaps not in takeoff range.
- Inhibit - A/C Airborne

REMARKS - visual is white during taxi and turns red when flight phase changes to takeoff roll.

Takeoff Configuration Stabilizer Warning

AURAL - tone and STABILIZER voice.*

- Logic - stabilizer not set for takeoff, a/c on ground and throttle 1 or 2 advanced for takeoff.

- Inhibit - takeoff (V1 to 400' RA) and landing (100' RA to 80 KTS).

VISUAL - red STAB TRIM message on EAD.

- Logic - takeoff roll and stabilizer not set for takeoff.
- Inhibit - a/c airborne.

REMARKS - visual is white during taxi and turns red when flight phase changes to takeoff roll.

Takeoff Configuration Brakes Warning

AURAL - tone and BRAKES voice.*

- Logic - parking brake is set, a/c on ground and throttle 1 or 2 advanced for takeoff.
- Inhibit - takeoff (V1 to 400' RA) and landing (100' RA to 80 KTS).

VISUAL - red BRAKES message on EAD.

- Logic - takeoff roll and parking brake is set.
- Inhibit - a/c airborne.

REMARKS - visual is white during taxi and turns red when flight phase changes to takeoff roll.

Takeoff Configuration Spoiler Warning

AURAL - tone and SPOILER voice.*

- Logic - spoiler not down, a/c on ground and throttle 1 or 2 advanced for takeoff.
- Inhibit - takeoff (V1 to 400' RA) and landing (100' RA to 80 KTS).

VISUAL - red SPOILER message on EAD.

- Logic - takeoff roll and ground spoilers disarmed in approach for takeoff.
- Inhibit - none.

REMARKS - none.

Radio Altitude Call-outs

AURAL - 2,500, 1,000, 500, 400, 300, 200, 100 voice* and 50-40-30-20-10 voice**

- Logic - voice annunciation when a/c descends thru respective altitude.
- Inhibit - none.

VISUAL - radio altimeter window displayed on PFD.

- Logic - radio height of 2,500' and below.
- Inhibit - none.

REMARKS - 2,500, 1,000, 500, 400, 300, 200, and 100 voices are individually selectable. 50-40-30-20-10 voice is standard with option to delete it.

Ground Proximity Mode 1

AURAL - SINKRATE voice (outer boundary) or WHOOP WHOOP PULL UP voice (inner boundary).

- Logic - excessive descent rate (inner or outer boundary).
- Inhibit - windshear condition or DITCH switch enabled.

VISUAL - GROUND PROX flashing red on PFD.

- Logic - excessive closure rate to terrain (logic from GPWS).
- Inhibit - windshear condition or DITCH switch enabled. REMARKS - none.

Ground Proximity Mode 2

AURAL - TERRAIN or WHOOP WHOOP PULL UP voice.

- Logic - excessive closure rate to terrain.
- Inhibit - windshear condition or DITCH switch enabled.

VISUAL - GROUND PROX flashing red on PFD.

- Logic - excessive closure rate to terrain (logic from GPWS).
- Inhibit - windshear condition or DITCH switch enabled.

REMARKS - if condition persists after two messages, voice changes to WHOOP WHOOP PULL UP.

Ground Proximity Mode 3

AURAL - DON'T SINK voice.

- Logic - altitude loss after takeoff.
- Inhibit - windshear condition or DITCH switch enabled.

VISUAL - GROUND PROX flashing red on PFD.

- Logic - altitude loss after takeoff (logic from GPWS).
- Inhibit - windshear condition or DITCH switch enabled.

REMARKS - none.

Ground Proximity Mode 4

AURAL - TOO LOW TERRAIN twice or TOO LOW FLAPS or TOO LOW GEAR

- Logic - unsafe terrain clearance or gear/flaps not in landing configuration.
- Inhibit - windshear condition or DITCH switch enabled.

VISUAL - GROUND PROX flashing red on PFD.

- Logic - unsafe terrain clearance (logic from GPWS) or gear/flaps not in landing configuration.
- Inhibit - windshear condition or DITCH switch enabled.

REMARKS - none.

Ground Proximity Mode 5

AURAL - GLIDESLOPE voice.

- Logic - descent below glideslope.
- Inhibit - windshear condition or DITCH switch enabled.

VISUAL - none.

- Logic - none.
- Inhibit - none.

REMARKS - amber BELOW G/S switches on glareshield illuminate. Warning may be cancelled by pushing the BELOW G/S switch below 1,000'.

Level 3 Alerts

AURAL - level 3 tritone.

- Logic - any level 3 alert.
- Inhibit - takeoff (V1 to 400' RA) - 25 sec. override.

VISUAL - MASTER WARNING lights and red boxed alert on EAD.

- Logic - any level 3 alert.
- Inhibit - takeoff (V1 to 400' RA) - 25 sec. override.

REMARKS - none.

Level 2 Alerts

AURAL - none (except for TIRE FAIL alert).

- Logic - n/a.
- Inhibit - n/a.

VISUAL - MASTER CAUTION lights and amber boxed alert on EAD.

- Logic - any level 2 alert.
- Inhibit - takeoff (V1-20 to 400' RA) and landing (100' RA to 80 KTS) - 25 sec. override.

REMARKS - none.

Level 1 Alerts

AURAL - none.

- Logic - n/a.
- Inhibit - n/a.

VISUAL - MASTER CAUTION lights and amber alert (not boxed) on EAD.

- Logic - any level 1 alert.
- Inhibit - takeoff (V1-20 to 400' RA) and landing (100' RA to 80 KTS) - 25 sec. override.

REMARKS - none.

Level 0 Alerts

AURAL - none.

- Logic - n/a.
- Inhibit - n/a.

VISUAL - cyan alert on EAD.

- Logic - any level 0 alert.
- Inhibit - none.

REMARKS - none.

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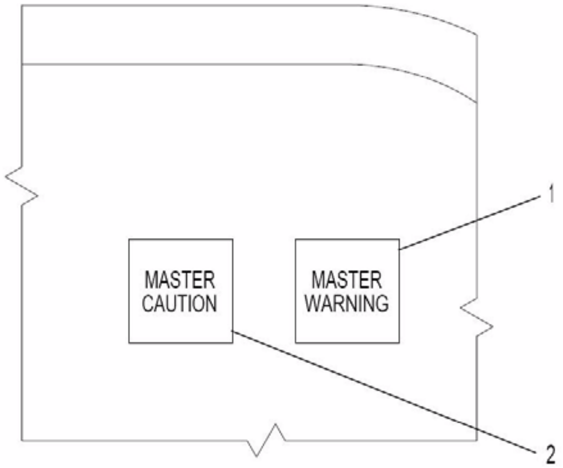
Controls and Displays

Master Warning and Master Caution Lights



GLARESHIELD, LEFT AND RIGHT SIDE

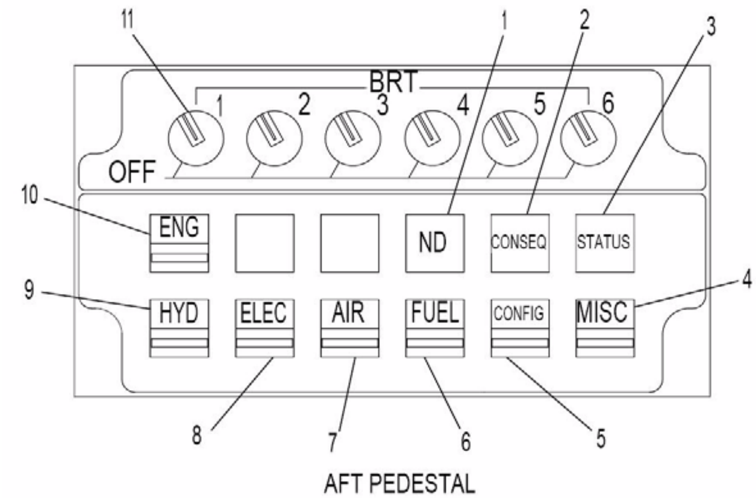
1. MASTER WARNING Lights (2) - red

   Both lights will illuminate red when a level 3 alert has appeared on the EAD. Pushing either light will extinguish both MASTER WARNING lights and reset the system for subsequent alerts. The MASTER WARNING lights can also be extinguished and reset by pushing the associated system cue switch on the SDCP when it is illuminated.

2. MASTER CAUTION Lights (2) - amber

   Both lights will illuminate amber when a level 1 or 2 alert has appeared on the EAD. Pushing either light will extinguish both MASTER CAUTION lights and reset the system for subsequent alerts. The MASTER CAUTION lights can also be extinguished and reset by pushing the associated system cue switch on the SDCP when it is illuminated.

System Display Control Panel



1. ND Switch - white

   Pushing this switch with 1 or more DUs inoperative causes the existing SD to become an ND. If all DUs are operative, THIRD NAV DISPLAY NOT AVAILABLE message will appear on DU4.

2. CONSEQ Switch - white

   When pushed, the COSEQUENCES page will appear on the SD. The CONSEQUENCES page displays consequences associated with level 2 and level 3 alerts. The alerts are grouped by level and appear in the same order as they appear on the EAD. The consequences associated with an alert are displayed adjacent to that alert. When additional consequences pages are required, PRESS CONSEQ AGAIN TO CONTINUE message will appear at the bottom of the page.

3. STATUS Switch - white

   When pushed, the STATUS page will appear on the SD. The STATUS page displays a list of all alerts included on the systems pages. The alerts are shown in three columns in the same format as on the EAD. A separate section for maintenance alerts is after the MISC system alerts. This section is titled MAINT. MAINT alerts appear on STATUS page 1 and can only be level 1.

The STATUS pages can display up to 51 alerts. When additional STATUS pages are required, PRESS STATUS AGAIN TO CONTINUE message will appear at the bottom of the page.

4. MISC Cue Switch - white

   When pushed, the MISCELLANEOUS page will appear on the SD. The MISCELLANEOUS page displays alerts (level 3, 2, and 1 only) and consequences. The consequences are not grouped with the alerts in the same manner as the systems page. The MISCELLANEOUS page has maximum of 17 alerts and 17 consequences. When additional pages are required, PRESS MISC AGAIN TO CONTINUE message will appear at the bottom of the page.

5. CONFIG Cue Switch - white

   Illuminates when an alert related to the flight controls or landing gear appears on the EAD. Pushing the CONFIG cue switch causes the flight controls synoptic page to be displayed on the SD and resets the MASTER CAUTION or MASTER WARNING provided no other alert condition exist that would illuminate the MASTER CAUTION or the MASTER WARNING lights.

6. FUEL Cue Switch - white

   Illuminates when an alert related to the fuel system appears on the EAD. Pushing the FUEL cue switch causes the fuel synoptic page to be displayed on the SD and resets the MASTER CAUTION or MASTER WARNING lights provided no other alert condition exist that would illuminate the MASTER CAUTION or MASTER WARNING lights.

7. AIR Cue Switch - white

   Illuminates when an alert related to the air system appears on the EAD. Pushing the AIR cue switch causes the air synoptic page to be displayed on the SD and resets the MASTER CAUTION or MASTER WARNING lights provided no other alert condition exist that would illuminate the MASTER CAUTION or MASTER WARNING lights.

8. ELEC Cue Switch - white

   Illuminates when an alert related to the electrical system appears on the EAD. Pushing the ELEC cue switch causes the electrical synoptic page to be displayed on the SD and resets the MASTER CAUTION or MASTER WARNING lights provided no other alert condition exist that would illuminate the MASTER CAUTION or MASTER WARNING lights.

9. HYD Cue Switch - white

   Illuminates when an alert related to the hydraulic system appears on the EAD. Pushing the HYD cue switch causes the hydraulic synoptic page to be displayed on the SD and resets the MASTER CAUTION or MASTER WARNING lights provided no other alert condition exist that would illuminate the MASTER CAUTION or MASTER WARNING lights

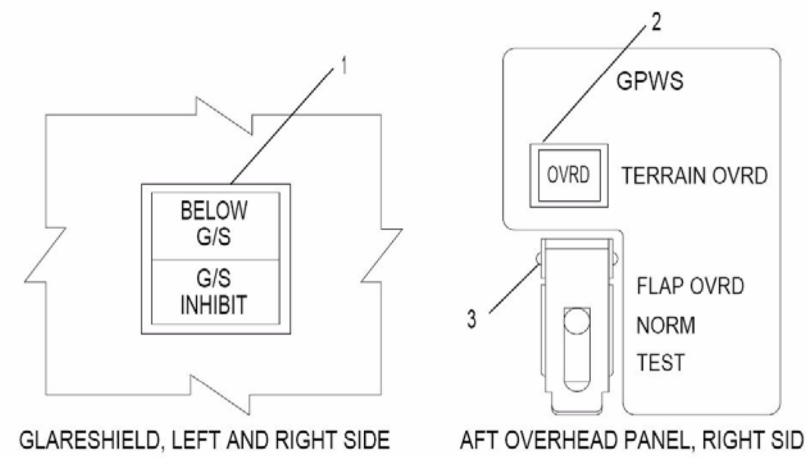
10. ENG Cue Switch - white

    Illuminates when an alert related to the engines or APU appears on the EAD. Pushing the ENG cue switch causes the secondary engine page synoptic page to be displayed on the SD and resets the MASTER CAUTION or MASTER WARNING lights provided no other alert condition exist that would illuminate the MASTER CAUTION or MASTER WARNING lights. The secondary engine page is automatically called up on the SD for alerts associated with secondary engine page parameters.

11. BRT Knobs (6)

    Each knob controls the respective DU brightness. Turning the knob fully counterclockwise through a detent will turn off the respective DU. When a DU is turned off with this knob, the DU will go to low power condition. This will allow the DU to cool and be available for later use.

GPWS/EGPWS Controls/Indicators



1. BELOW G/S Switch - Amber

   Illuminates to indicate corrective action required due to excessive deviation from glideslope. Light is accompanied by GLIDESLOPE voice warning. G/S INHIBIT will illuminate when the switch is pushed and the warnings are inhibited.

2. TERRAIN OVRD Switch

   Installed on aircraft with EGPWS. Push to illuminate the blue OVRD legend and disable the enhanced features during takeoff, approach or landing with any of the following:

   - Airport has no approved instrument approach procedure
   - Longest runway is less than 3,500 feet
   - Airport is included in the current list of airports with insufficient data for correct EGPWS operation

   Basic GPWS modes are not affected. Enhanced features can also be disabled automatically by the EGPWS computer.

3. GPWS Switch

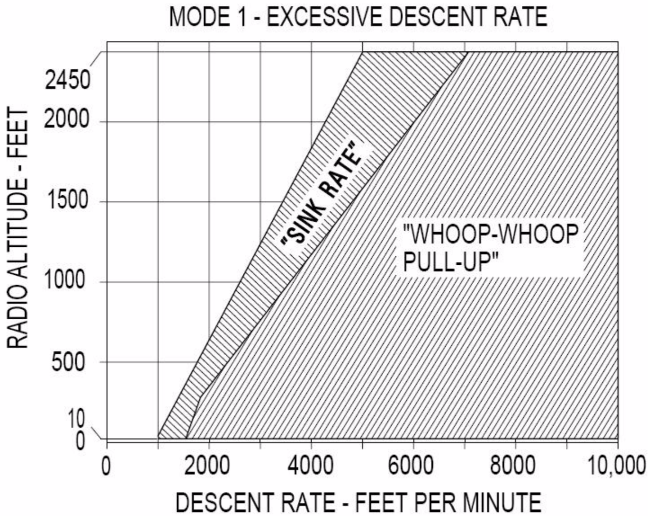
   FLAP OVRD - GPWS is prevented from actuating during a landing with flaps not in landing configuration.

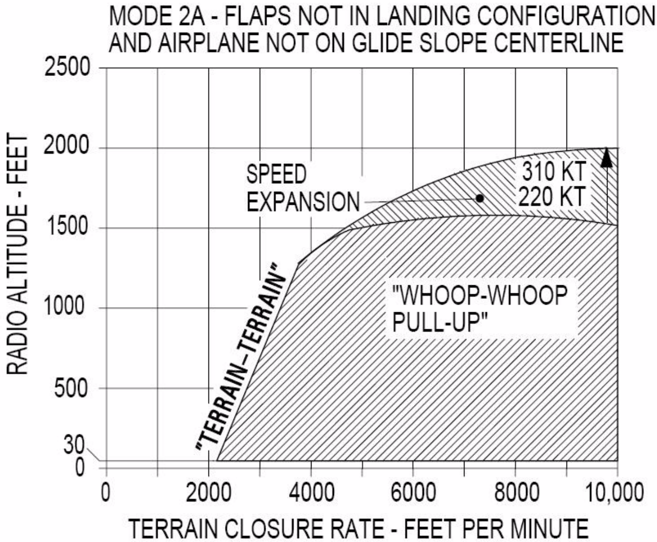
NORM - GPWS annunciates dangerous situations and remains silent during normal flight conditions.

TEST - GPWS executes a self test. Hold the switch at TEST for approx. 5 seconds. The following sequence of events will occur:

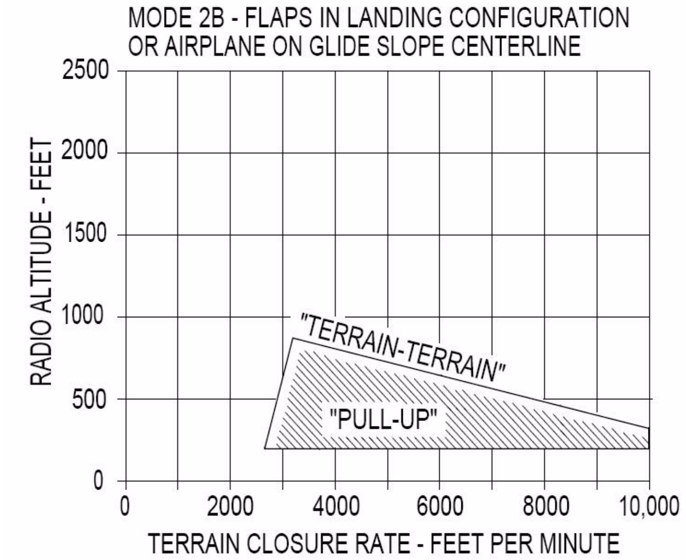
- GPWS FAIL alert is displayed on the SD MISC page.
- BELOW G/S lights illuminate on glareshield.
- GLIDESLOPE voice warning will sound.
- GROUND PROX will flash in red on PFD.
- PULL UP voice warning will sound.
- GROUND PROX message extinguishes on PFD.
- SINK RATE voice warning will sound.
- PULL UP voice warning will sound.
- TERRAIN voice warning will sound.
- PULL UP voice warning will sound.
- DON'T SINK DON'T SINK voice warning will sound.
- TOO LOW TERRAIN voice warning will sound.
- TOO LOW GEAR voice warning will sound.
- TOO LOW FLAPS voice warning will sound.
- TOO LOW TERRAIN voice warning will sound.
- GLIDESLOPE voice warning will sound.
- GPWS FAIL alert extinguishes on the SD MISC page.

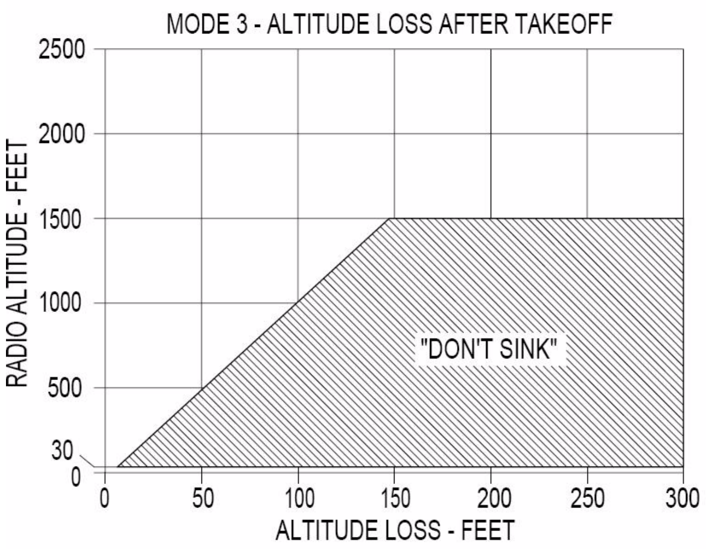
GPWS/EGPWS Envelope (Sheet 1)



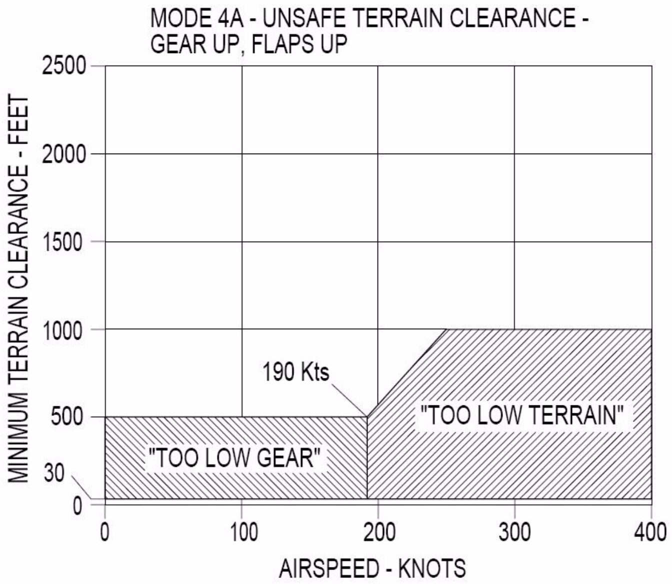


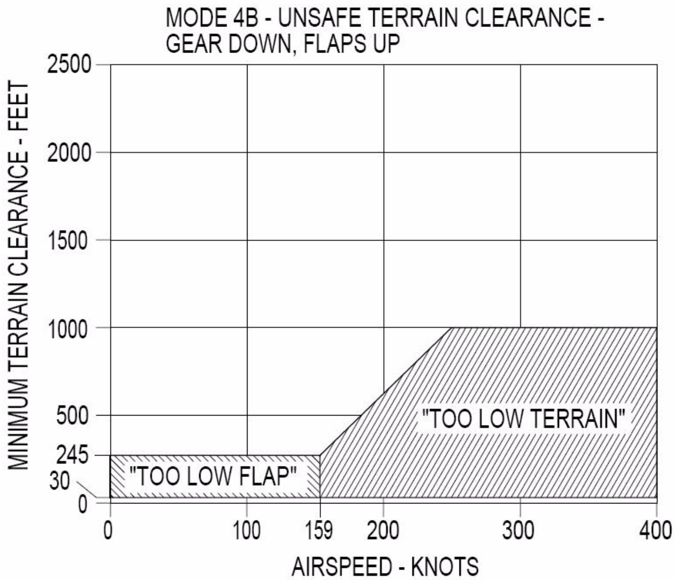
GPWS/EGPWS Envelope (Sheet 2)



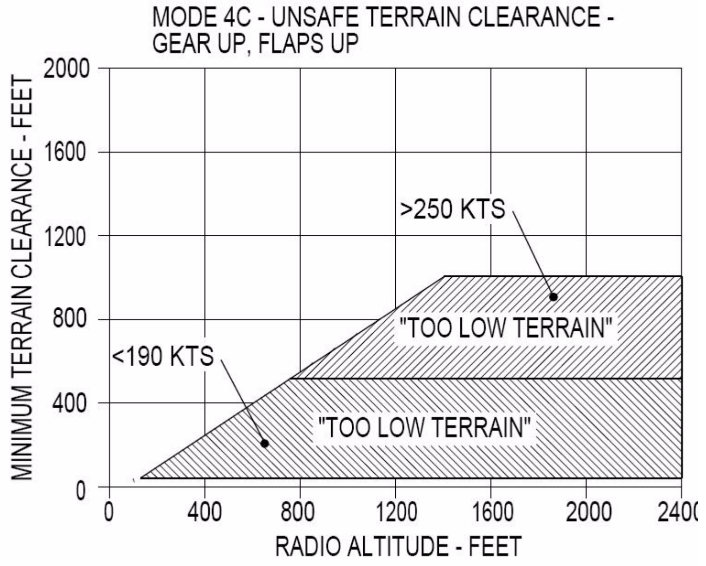


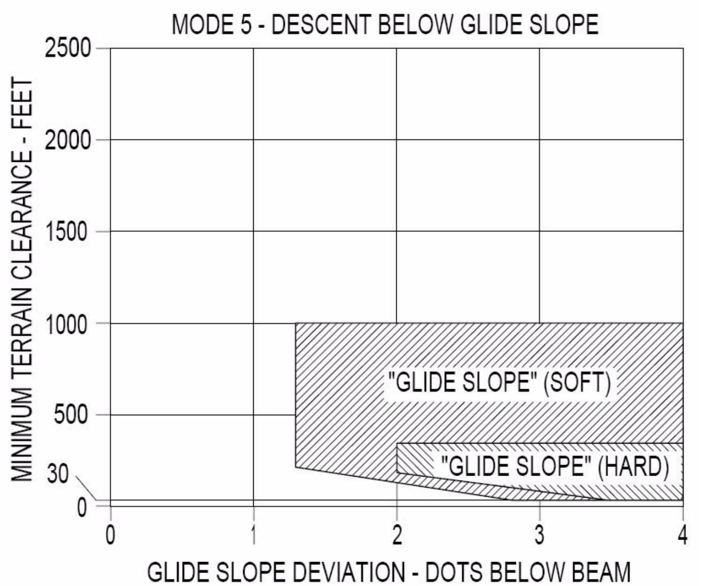
GPWS/EGPWS Envelope (Sheet 3)



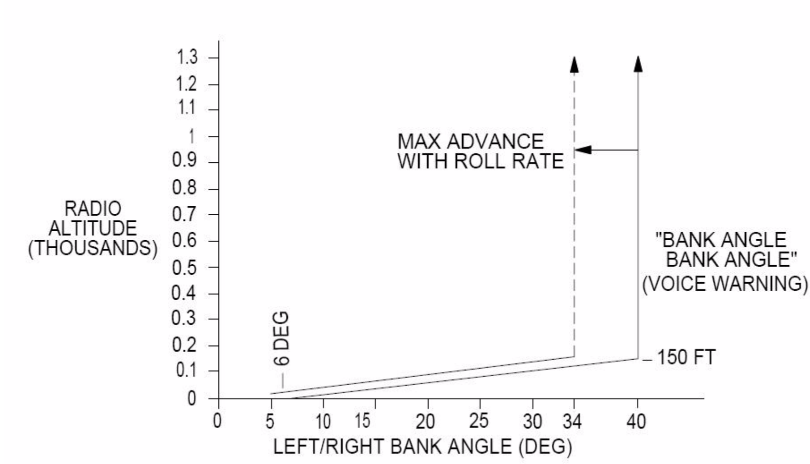


GPWS/EGPWS Envelope (Sheet 4)





GPWS/EGPWS - Bank Angle Warning Limits



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Alerts

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

Amber Alerts (Level 1)

- GPWS FAIL (MISC) - GPWS has failed. This alert normally appears during the GPWS test or if the DITCHING switch is selected. If EGPWS is installed, it indicates the ground proximity and terrain awareness functions have failed.
- GPWS FAULT (MISC) - One or more of the GPWS modes (except terrain) is inoperative. Applies only if EGPWS is installed.
- TERRAIN FAIL (MISC) - Terrain awareness function has failed, ground proximity is still operative. Applies only if EGPWS is installed.
- TERRAIN NOT AVAILABLE (MISC) - Terrain awareness function is disabled automatically due to an inadequate navigation sensor position. Applies only if EGPWS is installed.

Cyan Alerts (Level 0)

- GPWS FLAP OVRD - GPWS switch is in FLAP OVRD position. This will prevent ground proximity warnings when flaps are less than landing flap on approach.
- TERRAIN OVRD - Terrain awareness override is selected by the pilot. Applies only if EGPWS is installed.

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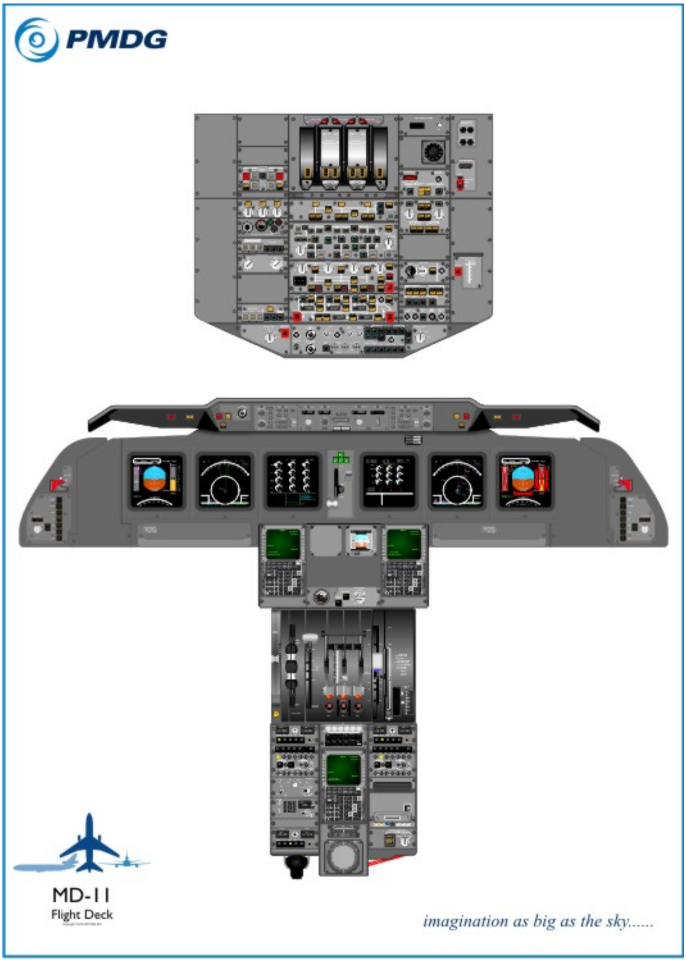

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