This manual was compiled for use only with: PMDG 747-400 Queen of the Skies simulation. The information contained within this manual is derived from multiple sources, and is not subject to revision. This manual is not be used for training or assumed to provide operating procedures for use on any aircraft. The manual is for entertainment purposes as required by the simulator software.

It is a violation of the owner’s copyright to distribute this document or any portion thereof without permission of the author.
Welcome to the most advanced airliner simulation ever produced by PMDG!

This product represents a State-Of-The-Art approach to desktop airliner simulations for Microsoft Flight Simulator™ Building on three years of intensive development experience for Flight Simulator, PMDG is proud to bring you one of the most visually immersive and complex simulations available for the desktop airliner enthusiast.

Since the release of PMDG 737: The Next Generation in July of 2003, PMDG products have gained worldwide recognition for our innovative use of new ideas to realistically portray the technology and challenge of commercial aviation. PMDG’s simulations are designed for use by those interested in learning about the complexity of modern commercial airliners and their operation.

The simulation you have purchased represents nearly 18 months of research, testing and development work involving many resources and experts from around the globe, including many of today’s largest 747-400 operators.

We are certain that you will enjoy our immersive new Virtual Cockpit technology as well as the application of high level mathematical and scientific modeling practices designed to bring you a realistic airplane from the flex of the wings to the manner in which the simulation flies.

All of us at PMDG are grateful that you have purchased this product and we stand committed to support you in your enjoyment of this software. If you find yourself in need of support, please email us or visit our customer support forum for help. PMDG staff is available to assist customers through these two venues.

Thank you again for your support of PMDG.

The Development Team
Precision Manuals Development Group
http://www.precisionmanuals.com
The Team Behind The Team

We receive many emails each month from individuals who wish to join our beta team. We are frequently told that our “hiring minimums” for the beta team are higher than most airlines for their air crewmembers. We take great pride on the cohesion and dedication of our beta team members, and we place significant demands on their time, their expertise and occasionally their patience.

We would like to thank the following individuals for their contributions to this project:

Captain Steve Weiher
Captain Nikos Aposporis
Captain John Bunting
Captain Alexei Nicolov
Captain Joe Batt  (By the time you read this Joe- you’ll have that stripe!)
FO Robbie Burton
FO Dean Constantinidis
IR Ozzy
Ryan Maziarz
Randy Smith,
Fred Clausen,
George Morris
Terry Yingling
Andre Reynolds
George Dorkofikis
Jerome Zimmerman
Panos Ilipoulos
Marc Brodeick
Sam Kalachoras
Mats Johansson
Andrev Thomsen
Lee Hetherington
Travis Waycott
Kyprianos Biris
Marcus Schneider
Dennis Di Franco

And of course, the many fine folks from The Boeing Company and Alteon who have helped make this project a wonderful example of desktop simulation software.
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PMDG strives for completeness and innovation in our products. On occasion we will issue free updates to our software, and we strongly encourage all customers to download and install these updates as they ensure the trouble-free operation of your software and add functionality that we may not have been able to offer in the initial release version of the product.

**Note:** Occasionally we may also update and expand this manual to cover additional topic areas or to add additional depth to existing aircraft functions. You can obtain the most current version of the manual free by visiting the PMDG Downloads page at [www.precisionmanuals.com](http://www.precisionmanuals.com).

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<td>FMC-001.0</td>
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Manual Updates
Version 1.0

This manual is issued in its original format with all information being deemed current and accurate at the time of publication. If updates are issued for this manual, update information will be presented on this page to facilitate the pilot remaining easily current with new information.

Updates:

This manual is an original edition. No updates were required.
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Options and Customization

When airlines purchase an airplane a significant amount of customization goes into each aircraft in order to provide the airline customer with the exact options and capability that they require.

When modeling aircraft for Microsoft Flight Simulator, it is often difficult to include provision for many of the options that individual airlines purchase, but at PMDG we have tried hard to provide our customers with the ability to individualize their airplane!

When you run the airplane for the first time, you will notice that we have added a PMDG menu item along the top menu bar within Microsoft Flight Simulator. The PMDG menu item is the place where you can find an array of options and customizations to further enhance your PMDG 747-400 experience!

The PMDG menu provides access to a host of options that can be selected by the user to add the specter of aircraft system and engine failures or to tweak the performance and appearance of the cockpit to match the user’s favorite airline configuration!

To further enhance the custom experience, PMDG has produced dozens of liveries representing airlines operating the 747-400 worldwide. These liveries are provided at no cost to you, and can be downloaded from www.precisionmanuals.com

PMDG has elected not to charge for airline liveries in order to provide additional value to the base product that you have already purchased. Users should feel free to download the PMDG 747-400 PaintKits that are also available from the PMDG web site. These paintkits were developed by PMDG’s livery artists in order to assist users who wish to add their own customizations to the PMDG line of airplanes.

Users are free to distribute the artwork that they create, but should carefully refrain from distributing any files that are included in the base PMDG 747-400 package, as these files are all copyright protected and watermarked for easy identification. PMDG aggressively prosecutes cases of theft and we offer rewards for individuals providing information that leads to successful prosecution of theft. (If you have any questions on this policy, please contact us!)

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PMDG has made every reasonable effort to respect the copyrights of Microsoft, The Boeing Company and other contributors to the 747-400. We have received significant support from throughout the airline industry and in receiving this help we have endeavored to ensure that all information used in the development of this product was legally presented and legally used.

PMDG does not condone the distribution of copyrighted PDF documents belonging to The Boeing Company, Honeywell or airline operators. These documents are legally restricted from distribution by their copyright owners unless otherwise specified. For this reason we have expended significant effort to produce this manual for your use. We ask that you please join us in respecting international copyright law and help us to protect our copyrights as well as those of Microsoft, The Boeing Company and others. Theft of copyrighted material ultimately hurts the entire community.
GETTING THE MOST FROM YOUR PMDG 747-400

Introduction: At PMDG we have a reputation for bringing a high degree of realism to desktop simulation. All of us at PMDG are simulation enthusiasts who have elected to bring our "day job" specializations (Airline Transport Pilot, Aviation Maintenance, Software Development, Aeronautical Engineering, 3D Design and Animation, Graphic Design and Computational Mathematics) to the simulation community in the form of a comprehensive and sophisticated simulation of a modern airliner.

For many years, phrases like: “most realistic,” “most accurate,” “Certified by Real Pilots,” or “Most Accurate Ever” have been widely used by software developers to describe their offerings to the desktop simulation community. While some of these claims have merit, our own experience has generally led us to believe that marketing is always marketing, and that the hype of realism and accuracy is hardly ever realized in the final package. As a result, the community at large has become desensitized to such effusive terms and the market as a whole suffers from inflated expectations and promises.

At PMDG, we believe strongly that the marketing should be factual and backed up by the accuracy and value of the end product. Given the years of airline industry and aeronautical engineering experience represented by the PMDG development team, we feel that our products are unique in their ability to accurately portray not just the “book values” of a particular airplane, but also the nuances and subtleties that are normally unavailable through manuals and guesswork.

To this end, we have gone to great lengths to simulate the sophisticated environment that is the modern airliner cockpit. Using many of the same tools employed to teach pilots and mechanics how to support the 747-400 airplane, we have worked to build a simulation that capitalizes on the strengths of the Microsoft Flight Simulator 9.0 environment while simultaneously working around the simulator’s weaknesses through the use of innovative technology and development.

Invariably there have been times when we needed to make choices between realism and usability. While Microsoft Flight Simulator is a wonderful and dynamic platform for modeling airliners, there are some aspects of Microsoft Flight Simulator that just do not function as well as we would like, and we have worked hard to overcome them while also enhancing the realism of the 747-400 experience. To the greatest degree possible we have attempted to document these shortcomings within this manual.

The PMDG 747-400 is the second “from scratch” product that PMDG has produced for the Microsoft Flight Simulator Community. In the two years since the release of our first Microsoft Flight Simulator based product, the PMDG 737, we have spent many hours investigating and learning from reports made by our customers. With an eye toward eliminating many of the interface or simulation behavior nuances that our customers did not like in the 737, we feel that this product successfully expands upon the strengths of our PMDG 737 while eliminating most of the issues that created concern for our customers.

In the following section we outline some of the many options that we have included to further your enjoyment of the simulator. Additionally, we outline some of the “oddities” that you might come across within Microsoft Flight Simulator, along with an explanation of their existence. We hope you will find this information useful and that it will enhance your enjoyment of the PMDG 747-400!

The PMDG Development Team
20JUL05
The PMDG Menu:

The PMDG menu has been added to the normal menu bar within Microsoft Flight Simulator in order to simplify user interaction with PMDG products. From this menu the user can choose an assortment of options as described below.

**PMDG Menu:**

The PMDG menu is an interface from which the user can customize their PMDG 747-400’s operation, equipment and reliability. The user can also save and load cockpit states from this menu after saving flights in progress.

**IMPORTANT NOTE:** If you have more than one PMDG product, the PMDG menu will only provide access to those options and items that affect the PMDG airplane currently being used. If you see items that are grayed out (unavailable) this is your indication that the item is not available in the 747-400, or in the 737 if that applies to your case.

**PMDG Menu Options:**

- **General:** Provides access to an Options menu for customizing the 747-400, as well as a frame rate tool for the virtual cockpit and a keyboard command interface menu.
- **Panel State:** Provides access to Save/Load state functions, as well as the Failures menu.
- **Failures menu:** Provides access to the Failure and mechanical dependability menu.

Each of the menu options is described in detail in this chapter. Thorough understanding of the options presented via these menus will help to ensure you maximum enjoyment from the PMDG 747-400 simulation.
Save Panel State Menu:

The PMDG Save Panel State Menu is used to save the current state of the panel, switches and aircraft systems from within Microsoft Flight Simulator. The Save Panel State menu presents the user with a list of previously saved files, and a NEW button to allow the current panel state to be saved for future loading.

When the cockpit panel state is saved, the current position of switches and key systems in the aircraft are saved for future loading of the flight situation.

**Keeping your saved flights in synch:** We recommend using the MSFS FLIGHT/SAVE menu for saving a flight or scenario. If you save your flight using the MSFS Save Situation menu, your current cockpit state will be saved simultaneously. When you later reload this scenario, you will be right back where you left off!

**Failures Do Not Save:** It is important to note that some information about the state of the aircraft will not transfer through a saved flight state. The status of failed systems, mechanical failures and emergencies will not be saved and reloaded when a flight is resumed. If you wish to “re-fail” systems that became inoperative on a previous flight, simply use the Failures menu to immediately activate the desired equipment failures. When the flight is resumed, the respective systems will be offline again. (For more information on failures, please see the Failures menu description later in this chapter!)
Load Panel State Menu:

The PMDG Load Panel State Menu is used to reload previously saved panel save files. When selected, the Load Panel State menu presents the user with a list of previously saved files. Highlight the desired file and click the OK button to reload that saved panel state.

When the cockpit panel state is loaded, the saved position of switches and key systems are reset according to the parameters that were saved from the original flight.

Keeping your saved flights in synch: We generally recommend matching your Save Panel State files with your Microsoft Flight Simulator saved flights. In this instance, you can reload a saved flight and the PMDG 747-400 panel state and resume the flight normally.

Failures Do Not Re-Load: It is important to note that some information about the state of the aircraft will not transfer through a saved flight state. The status of failed systems, mechanical failures and emergencies will not be saved and reloaded when a flight is resumed. If you wish to “re-fail” systems that became inoperative on a previous flight, simply use the Failures menu to immediately activate the desired equipment failures. When the flight is resumed, the respective systems will be offline again. (For more information on failures, please see the Failures menu description later in this chapter!)
Failures Menu:

Unless the user specifies otherwise, the PMDG 747-400 will be perfectly mechanically dependable by default. If you desire the challenge of managing the aircraft through various types of abnormal conditions the Failures menu will provide you with the ability to customize the mechanical dependability of your aircraft.

The failures menu is broken vertically into halves. The left side of the screen allows the user to select specific systems or subsystem, while the right side of the screen allows the user to set parameters for how selected failures will occur.

System Failure List: There are more than 145 potential failure scenarios that can be triggered by the user in the PMDG 747-400. These failure scenarios are presented in the menu on the left side of the Failures Menu.

By using the “Sort By” pull-down menu, the user can change the display to see failures listed by System grouping, (Electrical, Fire, Hydraulic, etc) or by Category (Transient, Nuisance, Minor, Severe.)

Clicking on the + boxes expands the failure list display to show individual system components that can be failed by the user.

Activating Failures: There are three ways that a user can fail systems in the PMDG 747-400:

• Immediate Failure
• Timed Failure
• Random Failure
**Activating Immediate Failures:** Immediate Failures are mostly self explanatory. Select the desired system component from the left side of the Failures Menu, then check the ACTIVATE box on the right side of the menu. When the OK button is pressed, the selected system will be rendered inoperative in the simulator.

![Image of Failures Menu]

Note that in this image the blue header title on the top, right side of the menu has changed to describe the component that has been selected for failure. Pressing the ACTIVATE button will immediately render Autopilot 1 inoperative in the simulator.

**Activating Timed (Armed) Failure:** Similar to using the ACTIVATE checkbox to immediately fail a system, the ARMED checkbox is used to arm a particular system for failure at a time in the future.

![Image of Timed Failure Menu]

The Hrs, Min, and Sec selector windows are used to set the time from present for the desired failure to occur.

**Random Failures:** Many users are interested in the simulation of random events during the course of a flight in order to practice proper decision making skills and event handling techniques.
PMDG has provided a comprehensive random failures module that can simulate a rate of failures for specific system categories or the entire airplane as a whole, depending upon user preference.

Random failures can be assigned to limit themselves to a specific system category, (Electric, Hydraulic, etc), or to a specific failure category (Transient, Minor, Severe, etc) or they can be assigned to encompass any of the 141 possible failure scenarios.

Activate Random Failures: To activate random failures, simply choose ALL SYSTEMS in the Sort By menu, or select the desired system/category on the left side of the Failures Menu.

Then, select the TRIGGER checkbox on the right side of the menu.

Determine the Failure Rate: Random failures require that the user select a “rate” at which failures will occur. For simplicity, this rate is described as the number of events/10 hours of airplane operation.

It should be noted that selecting 1/10 will not give you precisely one failure in a ten hour period. The figure is an rolling average of failures / flight time. As such, it is possible to have multiple successive failures in close proximity to one another, but over an extended period, the rate of failures will average 1 failure for 10 hrs of flight time.

(Example: 2 failures that occur 1 minute apart might be the only failures you see during 20 hours in flight. As such, they fit the 1/10 failure rate.)

Placing Limits On Failures: You can place limits on the types of failures you experience and the total number of events you might experience during any given flight. You can eliminate the occurrence of Sever Failures for example, by setting Random Failures active individually in the Nuisance, Transient and Minor categories, as opposed to setting failures active for All Systems.

Additionally, if you wish to limit the total number of failures on any given flight, you can do so by selecting the STOP AFTER checkbox, and enter a number into the EVENTS FIRED window.

For example, if you wished to have a failure rate of 5 events / 10 hours of flight time, but only wanted a maximum of 4 failures per any given flight, you can set this limitation by using the STOP AFTER checkbox.
Failures That Make Things Worse: When activating failures within the airplane, it is important that the user be prepared to use the AOM in order to troubleshoot and handle subsequent failures correctly. Some types of failures, if not handled correctly, can lead to subsequent and often more critical systemic failures.

Use the Abnormal Checklists provided in this manual for correctly troubleshooting and resolving problems with the aircraft.

Failures Triggered Outside of the Menu: Some aircraft systems are more delicate than others when handled roughly. The engines, for example are sensitive to abusive movement of the throttles, impact forces, heavy G-loading, over revving, etc. It is possible to damage the engines on the aircraft even without activating failures via the Failures Menu.

In the event that misuse or poor treatment of the airplane results in a failure, follow the appropriate Abnormals Checklist (Also known as a QRH: Quick Reference Handbook) item to resolve the problem.

Proper care and handling of the airplane is important in all regimes of flight.
Options Menu:

The Options menu is where the user can customize the PMDG 747-400 experience so as to match their expectations for cockpit equipment setup, interface, and operation of the airplane.

The PMDG Options menu for the PMDG 747-400 is shown below:

On the left side of this menu are listed six categories in which there are options for the user to alter as desired. The categories and their function are as follows:

PFD – ND: Modify the appearance and function of the Primary Flight and Navigation Displays.
AFDS: Modify the behavior of the Autopilot Flight Director System.
IRS: Modify the behavior of the Inertial Navigation System.
Colors: Modify the colors displayed on the PFD/ND/FMC-CDU.
Sounds: Adjust various settings for the sound presentation within the simulator.
Various: Numerous other options available to the user.

PFD – ND Menu:

The PFD – ND menu page allows the user to select the display type installed in the cockpit, as well as numerous options related to the data displayed during flight.

Display Type: Two options are provided for the cockpit display type in the PMDG 747-400:
There are subtle differences between the older style CRTs and the newer technology LCDs being installed in the 747-400. PMDG has provided users with the ability to choose between the two display types based upon personal preference. The primary difference between the two display types is the manner in which graphics are displayed on the screen.

A brief summary of differences between the two display types follows:

**CRT vs. LCD Differences: Primary Flight Display**

<table>
<thead>
<tr>
<th>CRT DISPLAY</th>
<th>LCD DISPLAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOC/GS scales drawn inside the ADI</td>
<td>LOC/GS Scales drawn outside the ADI</td>
</tr>
<tr>
<td>CRS Indicator shown</td>
<td>CRS Indicator not shown</td>
</tr>
<tr>
<td>Flight Path Vector Drawn in original format</td>
<td>Flight Path Vector drawn in new format</td>
</tr>
<tr>
<td>Target Heading Cue: Rectangular</td>
<td>Target Heading Cue: Inverted Triangle.</td>
</tr>
<tr>
<td>Flight Mode Annunciation background: black</td>
<td>Flight Mode Annunciation background: grey</td>
</tr>
<tr>
<td>Bank Angle Indication to 45 degrees</td>
<td>Bank Angle Indication to 60 degrees</td>
</tr>
</tbody>
</table>

**CRT vs. LCD Differences: Navigation Display**

<table>
<thead>
<tr>
<th>CRT DISPLAY</th>
<th>LCD DISPLAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Heading Cue: Rectangular</td>
<td>Target Heading Cue: Inverted Triangle.</td>
</tr>
<tr>
<td>PLAN Mode drawing original format</td>
<td>PLAN Mode drawing in new format</td>
</tr>
</tbody>
</table>

**Show conformal compass rose digits:** The 747-400's primary flight display has a compass rose quadrant on the bottom of the display. The magnetic heading figures displayed around the edge of this compass rose place a significant strain on display processing power because there are so many of them. As a result, we have simplified the display mathematics by keeping the numbers vertical as they rotate around the edge of the compass. You can use this selector checkbox to alter the display to make the numbers rotate realistically with the compass card. Checking this box will have a significant impact on some users frame rates. If you do not have a high powered system, leave this box UNCHECKED.

**Flight Director Type:** Two options are provided for the display of the flight director in the PMDG 747-400. The Cross-Hair option provides independent pitch and roll cues for the flight director, while the single cue, commonly known as the “Flying V” provides a single combined pitch/roll cue.
**Optionals:** There are two optional data display formats that the user can select or de-select from display on the Primary Flight Display.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Show Rising Runway</td>
<td>Enables the display of a graphical runway on the Primary Flight Display during instrument approaches.</td>
</tr>
<tr>
<td>Show GS</td>
<td>Enables the display of the aircraft’s current Ground Speed on the Navigational display.</td>
</tr>
</tbody>
</table>

Note: The grayed-out options are not available in the PMDG 747-400, but represent options present in other PMDG products that are not utilized in the PMDG 747-400.

**ND Options:** The navigation display has a few options that can be used to both de-clutter the display and help improve frame rates for the displays in both 2D and VC modes.

- **Clip Flightplan to Compass Border:** The displays in this airplane are modeled as closely to the actual aircraft as possible. Some of the animation methods used can be extremely mathematically intensive and may result in lower performance on some processors. One mathematical method that is particularly taxing to slower computers is the circular animation calculations required to display the flight path only within the compass confines on the Navigation Display. By un-checking this option, the flight path magenta track will be shown all the way to the edge of the Navigation Display. While less realistic, this will result in a drastic reduction in the amount of mathematics required when drawing the navigation display. Often times this results in higher frame rates for some users. *If you find you are getting slow frame rates, try deseleting this option.*

- **ARPT shows runways longer than:** This option allows the user to customize the way airports are displayed on the Navigation Display. Commonly, airlines buy only the airport navigation data for airports capable of servicing their aircraft. For the 747-400, we recommend setting the Airport display to only show airports with runways greater than 6,000 feet in length. Lowering this number will display a greater number of airports, (not all of which you may be able to use!) and raising the number will lower the number of airports displayed.
AFDS Options Menu:

The Autopilot Flight Director System (AFDS) options menu provides a series of selections that allow the user to enable or disable behaviors that are optional components in the 747-400, and/or vary slightly by airline or operator.

A/P Controls Override Option:

This option allows the user to enable the use of "Override Steering" capability to override momentarily autopilot commands through the use of flight control input via the joystick/yoke/throttle.

If selected, it is possible to override steering commands to the autopilot by deflecting the flight controls slightly. When the controls are released the Autopilot will return to following commands from the flight director.

If this option is de-selected, manipulation of the controls while the autopilot is engaged will simply disengage the autopilot and return control of the airplane to the pilot.

TO/GA Options:

There are two options available that dictate how the airplane will behave when a TakeOff/Go Around (TO/GA) command is issued to the Autopilot Flight Director. The behavior of the actual airplane varies according to operator, so PMDG has provided both options to the user.

Wings Level: When TO/GA is selected, the steering cues provided to the pilot will ignore the lateral track mode and/or the heading bug, and instead command a wings-level departure profile for the initial TO/GA element. To resume tracking a lateral navigation mode or heading bug, the item needs to be re-selected on the Autopilot.

Follow HDG Select: When TO/GA is selected, the steering cues provided to the pilot will ignore any previously selected lateral navigation modes in favor of following the heading bug.

Glideslope:

Depending on regulatory restrictions, airline operating procedures, and crew training, some airlines include an option with their aircraft to allow for the capture of the Glideslope prior to the capture of the localizer. Checking this box will allow such activity when the aircraft is placed in approach mode. Please use caution when checking this option to prevent controlled flight into terrain accidents.
Flight Management System Options:

Pause at T/D: Selecting this option will instruct the simulation to pause when the aircraft reaches the Top of Descent point on an FMC flight plan. This option allows users to leave the airplane unattended without having to worry about missing their descent point and approach at the end of the flight.

IRS Options Menu:

The Inertial Reference System on the 747-400 takes 10 minutes to align itself for proper navigation. Understanding that not all users are interested in waiting such an extended period, we have provided a couple of options related to the alignment time for the IRS.

When loading an “in progress” flight, or a default scenario in which the airplane is already fully powered and running, the IRS will default to an already aligned and active state.

For users who save flights with the airplane powered down, you may choose from the menu above how you wish to interact with the IRS alignment time requirement. You can choose from instant alignment to an alignment period of the length you desire (in seconds!)

Global Navigation Systems, also known as Global Positioning Systems are rapidly taking their place in the cockpit of modern airliners and serving as a primary navigation source.

The PMDG 747-400 is GPS/GNS enabled by default.
Colors Options Menu:

PMDG has pre-selected the correct colors for use on the displays of the PMDG 747-400.

In the instance that the user wishes to modify the color settings to suit their display monitor or personal tastes, we have provided the ability to do so through the color options menu.

Color modifications made through this menu are retained for future flights and must be returned to their original settings manually by the user.

Sounds Options Menu:

In order to maximize the realism of the PMDG 747-400 simulation, we have invested significant time in the development of sounds and audio ambiance.

We have provided the user with the option to enable or disable many of the possible audio experiences in the cockpit in order to suit personal tastes.

De-selecting any of the options above will prevent that sound group from being played within the simulator. It is important to note that as a result of Microsoft Flight Simulator’s internal sound logic, it is necessary to select the “Allow sounds to play in external and VC views” option if you wish to hear most of the cockpit related sounds while outside of the 2D cockpit. We recommend leaving this box selected.

If you find that the ambient noise level is too high relative to other settings, you can adjust the volume to suit your tastes.
**Fuel Menu Item:** The fuel system on the 747-400 is easily the most complicated of all the airplane’s mechanical systems. The fuel system used by Flight Simulator 9.0, however, is an overly simplistic design that does not lend itself well to simulating a complex system such as that used by the 747-400.

In order to accurately simulate the complexity of the 747-400 fuel system, it became necessary for us to make some design decisions in order to ensure that the system would operate with stability and predictability. One of these decisions was to provide you with a “fuel loader” that will automatically load any fuel quantity within the airplane’s certified capacity.

To load fuel onto the airplane, you can use the FUEL menu item:

![Fuel Loader](image)

To adjust the desired fuel quantity, you may select any of the four radio buttons along the bottom of the menu, or you may use your mouse wheel to scroll the total quantity figure up/down in the window. The arrow up/down buttons are useful for small adjustments.

When you press the APPLY NOW button, the PMDG 747-400 will be fueled to the quantity specified. Additionally, the fuel management card logic will correctly distribute fuel in accordance with standard operating procedures for the 747-400, and correctly configure the fuel crossfeed valves for the loaded quantity.

*Please note that you should not attempt to load fuel onto the PMDG 747-400 using any other utility, including the default Flight Simulator menus, as unpredictable behaviors may be triggered up to and including the inability of fuel to reach the engines. For more information on the fuel system and its design, please see the Chapter 12 Fuel System overview.*

**Various Menu Items:**

The various page of the PMDG Options menu contains various items that allow the user to customize their 747-400 experience.

**TCAS Options:**

![TCAS Options](image)

**TCAS:** The TCAS option set allows the user to customize the manner in which TCAS interfaces with the simulator and the amount of information displayed. TCAS can display traffic by using the traffic information interface provided by FSUIPC, or directly from within the FS2004 Internal Structure. (If flying online- use the FSUIPC interface.)

The TCAS module can limit the amount of traffic displayed to the user on the Navigation Display. Adjust this value to suit personal taste.
The TCAS2 system used on the 747-400 automatically suppresses the display of aircraft traffic that is not immediately in conflict with the airplane. As such, the only time traffic will be displayed is when it presents the potential for a traffic conflict and/or a resolution advisory. Some users may wish to be able to see non-conflicting traffic, however and selecting the Show All Non-Threatening Traffic option will allow the user to see all surrounding traffic rather than only conflict traffic.

**Weight Display Options:**

- **Weight Indicators**
  - Weight in Lbs.
  - Weight in KGs.

This selection allows the user to choose a weight format in keeping with their region or preference.

**Panel Switcher Options:**

- **Panel Switcher**
  - Allow undockable Overhead Panel
  - (MULTI-MONITOR users ONLY!)

Users who wish to display the overhead or other panels on a second monitor should select this option in order to allow the undocked display panels on a second monitor. Leave this option unchecked if you are not planning to display any of the panels on a second monitor.

**Ground Power / Pneumatic Air Availability:**

- **Ground Conditions**
  - Ground Air/Power Available

This option allows the user to select whether ground electric/pneumatic services are available to the aircraft. Note that the aircraft MUST be parked in order to use these services, and upon selection/de-selection, it may take up to two minutes for ground crews to connect your aircraft!

**Reset Buttons:**

- **Reset Buttons**
  - Brake Temp
  - Fire Bottles
  - EDG Drive

There are some items in the cockpit that you may interact with that cannot be “reset” if you accidentally trigger them.

The following items can be “reset” from this menu:

**Brake Temp:** If you abort takeoff, the brakes will accumulate temperature based on a real-world physical model for energy transfer and heat dissipation by the brakes. If you overheat the brakes and wish to simulate the extended cool down period, you may do so. However- you may also reset them instantly using this button.

**Fire Bottles:** As discussed, you can recharge a discharged fire bottle using this button.

**EDG Drive:** Occasionally in the performance of some checklists it might become necessary to disconnect the constant speed drive that powers the generator on any given engine. In the event that you are simulating failures for practice handling of the Abnormals Procedures, you can reset the IDG drive from this menu. IDG’s on the actual aircraft can only be reset by maintenance.
Display Frame Rate Tuning Menu:

In order to assist users in the quest for optimal frame rates, PMDG has provided users with the ability to tune the update rates for the cockpit display screens.

The cockpit displays in any Microsoft Flight Simulator based aircraft are a key point of focus when it comes to detail and frame rates. Super-smooth updates to the cockpit displays are useless if the scenery outside the window is completely frozen. Likewise, fluid frame rates outside of the airplane aren’t helpful if the cockpit displays are updating slowly!

To assist users with easily tuning and finding a balance between smoothness and frame rates, we have provided a frame rate tuning menu to provide users with the ability to quickly adjust and experiment with the update rates of the cockpit displays.

A basic rule of thumb is that faster cockpit display updates will impact overall frame rates negatively. A slower cockpit display update rate will improve frame rates in the simulator.

It is up to each user to find the correct “balance” for their system.

You can adjust the sliders manually, and use the check box to display the update rates right on the gauges within the simulator.

We have set the default display rate to 15 fps for the cockpit displays, as we felt that this provided a good balance for the majority of customers.

Performance on “Less Powerful” Machines: During the development of the PMDG 747-400, we have continually tested the airplane on a range of hardware setups to ensure that no design decisions will have a strong negative impact on the frame rates of customers using machines that are normally in the “mid range” of performance. While we cannot obviously predict what frame rates will be on all machines, we have identified some specific options that you can adjust in order to maximize your frame rates in both 2D and VC cockpits.

PMDG Frame Rate Tuning Suggestions:

1) Leave the compass rose digits “un-slanted.” You can do this by ensuring that the checkbox in this graphic (found on the PMDG/OPTIONS/PFD-ND menu) is NOT CHECKED.
2) The 747-400, like most airliners, limits the display of information on the Navigation Display to the area of the display that is within the borders of the compass. This is done to prevent cluttering the information displayed around the outside of the navigation display. This is a mathematically intensive process, and by leaving the “Clip Flight Plan Data to Compass Border” box NOT CHECKED you will see an improvement in frame rates.

3) We have provided many free add-on liveries to enhance your enjoyment of the PMDG 747-400. The livery installers are capable of installing the livery of your choice in DXT3 format, or 32Bit format. DXT3 format is a very slight reduction in quality from 32Bit textures- but offers a dramatic improvement in frame rates.

**Sound Recommendations:** At PMDG we have put a significant amount of time and effort into developing a sound package that is truly immersive in nature. You will notice that each of the three engine types for the 747-400 sound different from the cockpit, and that the general cockpit ambient noise level has been tuned for realism with the help of experienced 747-400 cockpit crews.

We have tuned the sound package for optimum quality and realism, provided that you set your Flight Simulator 9 sound settings up as we recommend below:
PMDG’s 2D PANEL VIEW SWITCH:

As with previous PMDG products, we have provided a number optional panel views to enhance the 2D cockpit user's experience. In order to simplify navigation between these panels, we have included a “Panel Switch” device that manages the navigation between panel views without the need to utilize the Microsoft Flight Simulator menu system.

When first loading the PMDG 747, the Panel Switcher is located at the top, center of the screen. The device has nine buttons to facilitate view navigation and a push-pin icon in the upper left corner to aid in moving or pinning the device at the user’s discretion.

Panel Switching Device

![Panel Switching Device]

Each button includes text to describe its function, and an indicator light to show when the selected view is active. The buttons on the Panel Switching Device function as follows:

**CAPT**: Changes view between Main 2D Panel from Captain’s viewpoint and Main 2D panel with enlarged display gauges.

**OVHD**: Displays overhead panel pop-up.

**F/O**: Cycles view between Main2D Panel from First Officer’s viewpoint and Main 2D FO Panel with enlarged display gauges.

**THR**: Displays throttle console panel pop-up.

**FMC**: Displays FMC-CDU #1 as a pop-up. (FMC-CDU #2 can be accessed via the Views menu.)

**EICAS**: Displays the EICAS screen and the EICAS control panel as pop-ups.

**COM**: Displays the center console radio/communications panel pop-up.

**CHR**: Displays the chronometer panel pop-up.

**MISC**: Displays a panel with various miscellaneous switches.

**Showing / Hiding Panel Switcher Device**: The Panel Switcher Device is moveable throughout the screen by left click/dragging it to the desired location.

Additionally, the Panel Switcher Device can be removed from view by clicking on the pushpin in the upper left corner. This will release the device for removal after 10 seconds without any activity. To return the device to view, you can select it from the VIEWS/INSTRUMENT PANELS menu. To keep the device in view, simply set the pushpin by clicking on the upper left corner.

The Panel Switcher Device can also be shown/hidden by clicking on the center column.

*Note that when moving the Panel Switcher, you might accidentally hide it behind other panels!*

**Hiding Panels**: All pop-up panels have been provided with a “closure X” in the upper right corner. Clicking on the X will remove the panel from view.

Note that the CAPT and FO panels are not considered pop-up panels, so they do not have closure X click-spots and you can close the EICAS display by clicking on the screen.
Virtual Cockpit:

The Virtual Cockpit included with PMDG 747-400 is the most advanced yet brought to market for Microsoft Flight Simulator. Traditionally, Virtual Cockpits have used mostly flat, planar representations of the 2D cockpit bitmaps in order to simulate switch movement and interaction within the Virtual Cockpit.

The PMDG 747-400 Virtual Cockpit is designed to accurately simulate the cockpit environment from the simplest detail to the most complex. The 3D model was designed using the manufacturer’s engineering specifications for the 747-400 airplane, and as such represents faithfully the size and space of the cockpit accurately.

There are 1200 moving parts on the PMDG 747-400. The vast majority of these parts are in the cockpit to allow users to interact with a true 3D representation of the cockpit. Out of window views provide accurate view angles and the perspective from different seats in the cockpit are true to the 747-400 airplane.

With the addition of third party software such as Active Camera, we expect that many users will find for the first time that the PMDG 747-400 Virtual Cockpit is a true representation of “what it’s like” on the flight deck of the world’s most storied jumbo jet.

A tremendous amount of programming time and skill was dedicated to ensuring that frame rates in the VC were nearly indistinguishable between the 2D and VC cockpits. It is our hope that enhancing the frame rates from the Virtual Cockpit, along with ensuring smooth update rates on the VC displays will make most simmers into “True Believers” when it comes to operating the airplane from a 3D cockpit.

When demonstrated for The Boeing Company, PMDG’s cockpit modeling technology for the 747-400 was considered to be resoundingly impressive for its ability to accurately model the 3D cockpit environment.

We invite you to explore the cockpit, using the mouse as your hands. You will find many interesting and unique animations, including:

- All seats can move fore and aft on their tracks.
- Jumpseats require a single click (click anywhere on seat) and will travel to there fore-most and aft-most positions automatically.
- Captain and First Officer seat require a click-hold-drag, and can be moved to any position along their track.
- All seat armrests can be stowed with a single click.
- Yokes: Click anywhere on the upper portion of the column, and the yokes will move slightly to enhance your view of the panel.
- Rudder pedal adjustment: Click the crank behind each yoke to adjust the rudder pedal distance.
- Main Cockpit Door: The cockpit door can be opened or closed with a single click, for access to the upper deck passenger cabin.
- Sun Shades on each window can be opened or closed independently with a single click.
- Library Table can be extended or retracted with a single click.

A multitude of other non-essential animations await your discovery in the cockpit. Nothing to do while crossing the pond?
**Interacting with 2D and VC cockpit Panels:** Microsoft Flight Simulator has traditionally been heavily dependant upon mouse click-spots to move switches and knobs. Often times, the click spots are only partially intuitive and/or heavily dependent upon left clicking the correct location for the results that you want.

When designing the PMDG 747-400, we sought to bring a more intuitive approach to the cockpit’s user-mouse interface. We have standardized the methods used to push buttons and rotate knobs in the 2D and VC environments, so as to make the entire process simple and intuitive.

Following is an overview to help you understand this new, but intuitive method for interacting with the 2D and Virtual Cockpit panels:

**QPushButtons:** Left click to operate these buttons to on/off.

**Guarded Switches:** Guarded switches have two actions:
- Right click to open/close the switch guard.
- Left click to operate the button underneath.
  (Note: Main Battery switch guard is spring loaded to CLOSED.)

**Knobs:** Knobs are rotated left/right, or may be rotated completely in rotation. When you are attempting to use a knob, you will be presented with a Left/Right arrow icon as a reminder to use the Left/Right click functions of your mouse to rotate the knob in the desired direction.

**Knobs with Embedded Push Buttons:** Some knobs rotate to perform a function, but also have an embedded push button function for other functionality. Examples of this can be found on the EFIS Mode Control panel where the buttons are obvious in the middle of the knobs. Other examples of this are found on the AFDS MCP altitude knob, for example. You can hover the mouse until you get a Left/Right arrow to adjust the value using left/right clicks. Then, hover the mouse over the center of the button until you see a hand icon. This will allow you to “press on the top of the knob” to activate the feature of that knob. Some knobs may have multiple features (the HDG SEL knob for example also has an Up/Down arrow that can be used to adjust the Bank Angle selector, for example.

**Recommendations for interacting with knobs:** The interaction with the knobs in the 2D cockpit is very straight forward. Simply move the mouse around until you see either a hand icon (presses a button) or an up/down or left/right icon that indicates you can use the mouse to interact with a right/left click.
In the Virtual Cockpit we are unable to provide arrow icons similar to those in the 2D cockpit. This is a limitation of the simulator that could not be overcome using methods practical for the 747-400 simulation. As such, you will find that the interaction is nearly identical, but sometimes it may be necessary to change your position slightly in the VC in order to “click on the top of the knob” without causing it to rotate. This may take some trial and error at first, but will quickly become a simple way to interact with the airplane.

**Differences Between 2D/VC:** We tried very hard to standardize the 2D and VC cockpits to ensure that the interface remains intuitive. We would like to bring one difference to your attention with respect to *unlocking the fire handles*.

In the 2D cockpit, you must click on the base of the fire handle to unlock the handle for operation.

![Handle Unlock Click Spot, 2D cockpit](image)

In the Virtual Cockpit, however, you must click on the panel UNDER the handle to unlock the handle.

![Handle Unlock Click Spot, Virtual Cockpit](image)
**Pushback Interface:** On the 2D cockpit’s Center Console COM panel (COM on the panel switching device) we have included a pushback gauge for users that wish to have a realistic pushback process from the terminal.

To activate pushback, simple right click on the RESET button in the middle of the pushback gauge:

Using right and left clicks, you can then adjust your pushback distance and direction as displayed in the window.

**DIST:** Distance to be pushed.

**DEG:** Right and Left clicking on the degrees knob will select the direction in which the nose should be pointed when the pushback is concluded. The number will be preceded with an L or an R to signify that the nose will point LEFT or RIGHT of its current direction. For example, L30 will indicate that at the conclusion of the pushback the nose will point 30 degrees left of where it pointed at the beginning of the pushback.

To commence the pushback, left click the RESET button. The pushback is conducted using voice prompts. Follow the instructions of your ground crew and the pushback will be conducted automatically.
Limitations within the Simulator

Overview: In the process of developing this highly sophisticated simulation, it became apparent to us that many of the “Default Microsoft Flight Simulator” functions are simply not effective for use when producing a realistic simulation of a complex airliner. As such, we have developed a simulation that to that largest degree possible does not use any default Microsoft Flight Simulator functionality.

Systems that have been completely customized for realism and functionality include:

- Autopilot Functions
- Fuel System
- Engine Performance Model
- Nearly All Mechanical Subsystems

Limiting our dependence upon Microsoft Flight Simulator has allowed us to use this very popular simulation platform as a worldwide operating environment without being severely limited by the original design of the simulation. Occasionally however, this means that we had to accept certain limitations on our simulation in order to accomplish our goals.

The vast majority of limitations we have found will never be experienced by must users. A few should be kept in mind however, as they are essential and important to the simulation:

Time Acceleration Limit:
- Time Acceleration should be limited to 8x to ensure proper autopilot function.
- Time Acceleration should be limited to 8x to ensure proper fuel system function.

(The mathematical iterations required for damping and control law become prohibitive for most desktop machines when run at speeds at greater than 8x, so we have not tuned the autopilot or fuel system for operation at acceleration rates faster than 8x.)

External Load/Fueling Programs:
- Do not use any non PMDG product to alter the aircraft.cfg file.
- Do not use any non PMDG product to alter the fuel load of the airplane.
- Do not use any non PMDG product to alter the loading of the airplane.

(PMDG uses actual manufacturer data to model the Cl/Cd, moment influence and drag models for our aircraft. Using this data, the aircraft’s reference point is placed realistically ahead of the nose of the airplane as per the manufacturers specifications. Most MSFS addon aircraft use the erroneous MSFS concept of placing the model’s reference point in the center of the airplane. This results in reduced realism and impacts negatively the accuracy of the airplane’s behavior.)

Do not use non PMDG visual Models:
- The PMDG 747-400 has 1200 animated parts. With the exception of a few basic functions, all 1200 parts are controlled by PMDG’s internal simulation operation and are not controlled by Microsoft Flight Simulator. If you attempt to replace the PMDG 747-400 visual model with a non PMDG model, you will lose nearly all animation and function for the external model.

Engine Variants:
- To model properly all systems, sensors and displays for each engine model takes approximately two months of intensive research and work. In order to increase the realism of the airplane’s performance we have focused this initial release only on the GE-CF6 engine performance. Additional engine performance models (and their requisite instrumentation) are planned. Please see the Engine Overview in Chapter 12 for more information.
PMDG 747-400 Load Manager

Overview: In the process of modeling PMDG aircraft, we use a different format than most developers in the implementation of the flight model. Microsoft Flight Simulator assumes incorrectly that the “reference point” from which the airplane is described is located at some point within the airplane. When engineers design and build aircraft however, the reference point used to describe the airplane and it’s various physical, inertial and lift centric properties is located in front of the nose of the airplane.

We make this decision because we are using actual mathematical models for everything from the control laws of the autopilot system and autothrottles, to the manner in which the lift/drag curve is modeled for the simulation. This process allows PMDG to put a flight model/autopilot control process in place that exceeds the capabilities and performance of those that are based upon the center-of-rotation method used traditionally in modeling MSFS airplanes.

There is a particular down-side to this affinity for accuracy, however. Occasionally users write to us to explain that various commercial addons or free addons to load anything from passengers to cargo to fuel do not work correctly with their PMDG airplane. This is an unfortunate effect of our modeling decisions and we are sorry for any inconvenience that it might cause.

As will be discussed in various places in this manual, PMDG recommends that you use only those tools that we have provided with this package to interact with the loading of cargo, passengers and fuel into this airplane. You can access fuel loading from the PMDG/OPTIONS/FUEL menu, or from the PMDG LOAD MANAGER application.

Load Manager: The PMDG Load Manager is a comprehensive application to allow you fine control over the loading of your PMDG 747-400.

Using the Load Manager you can select whether your aircraft is a single, double or three class airplane. You can then select the desired load quantity for the airplane by manually filling seats, or by selecting from pre-configured loads.

You can load passengers as well as below deck cargo, then configure your required fuel for the flight, using a simple menu interface.
The PMDG Load Manager can be configured to operate in Standard Units or Metric Units based upon user preference. By using the load configuration buttons near the top of the screen you can select your desired load level, or randomize the load entirely. Current passenger and cargo weights are displayed in the lower quadrant of the Load Manager:

In addition to the displayed weights, the Maximum Takeoff Weight and Current Takeoff Weight are displayed, along with the maximum Zero Fuel Weight (airplane + load before fuel is added) and your current Zero Fuel weight based upon the load you have selected.
On the right side of the lower quadrant you are presented with your currently selected fuel weight, and a second window that describes the maximum fuel weight that you can carry based upon your selected passenger and cargo load. If your current Zero Fuel Weight is low, you may carry a full load of fuel. If your Zero Fuel Weight is heavy, you will be limited in the amount of fuel that you can carry. (On some routes it is not possible to carry a full fuel load if you are also carrying a full passenger and cargo load….so you must trade one for the other!)

Pressing “Save to File” will update your aircraft.cfg file with the load you have selected and this will be reflected within Microsoft Flight Simulator when you load your PMDG 747-400.
# TAKEOFF

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TAKEOFF SPEED CALCULATION (B747-400)

Overview: The FMC-CDU, when initialized for correct aircraft weight, will provide base V1/Vr/V2 speeds for Dry/Clean runway conditions and Wet/Cluttered runway conditions. Speeds may be manually calculated using the charts and tables on the following pages.

To determine the correct V1, Vr, V2 speeds and the correct Engine-Out Pitch Attitude:

1) Find departure airport Elevation (Mean Sea Level) and Temperature.
2) Enter the Temperature – Altitude Region chart using the departure field elevation and current airport temperature. (Altitude from left and temperature from the bottom.)
3) Determine the letter region (A-L) where these two figures intersect on the chart. (If in the non lettered region to the right of the chart, takeoff is not advised.)
4) Determine the desired thrust setting (Full, 5%, 15% derate) and flap setting (10/20) for takeoff.
5) Using the V1,Vr,V2 table appropriate for your takeoff thrust and flap setting, read your takeoff speeds from the appropriate letter region column based upon aircraft weight.
6) On the same chart, record the pitch angle that appears in column A based upon your aircraft weight.
7) Return to this page, and adjust your calculated speeds to account for runway slope (always 0 in MSFS) and headwind/tailwind component using the Slope / Wind Adjustment for V1 below. (Negative number indicates a tail wind, positive indicates a headwind.)
8) Using the Engine Out Pitch Adjustment chart, modify the target Engine Out pitch attitude based on the Region Letter from step three.
9) Read the CG position from the TAKEOFF REF page of the FMC-CDU. Then, using the Stabilizer Trim Setting chart, determine the proper trim setting for takeoff.

Example: Use the following example as an exercise for manually calculating takeoff speeds:

Departure Airport Altitude / Temp: 5,000 MSL / 20C
Aircraft Weight: 350,000kgs (770,000lbs)
Flap and Thrust setting for takeoff: Flaps 20 / Max Thrust
Runway Slope / Wind Component 0.0 slope / 10 knot headwind
CG position as reported by FMC 23%

Results from above steps:
Letter Region from Temperature – Altitude Chart D
Speeds from Flaps 20 – Max Thrust Chart V1 – 148, Vr – 161, V2 – 171
Adjustment for Headwind: +1 knot to V1/Vr
Final Takeoff Speeds: V1 – 149, Vr – 162, V2 – 171
Engine Out Pitch Attitude for takeoff: 14 – 1 = 13 degrees
Stabilizer Trim Setting: 6 degrees*

*Interpolate trim setting if required figures are between positions on the chart.
Temperature – Altitude Region Chart:

Using airport altitude and temperature for the departure airport, determine the Letter Region by finding the point where the two figures intersect on the chart.

Slope / Wind Adjustment for V1:

If runway slope information is available, then adjust V1 according to this chart. Use this chart to adjust V1 based on wind conditions for takeoff (Tail wind is negative, headwind is positive.)

Engine Out Pitch Angle Adjustment:

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Read the Engine Out pitch angle from the \( V1VrV2 \) chart, (column A under Att.) then adjust using your Letter Region.

Stabilizer Trim Setting:
### FLAPS 20 – MAXIMUM RATED THRUST

#### TAKEOFF 1 - 5

**WEIGHT**

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| MAX THRUST |

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| Temperature – Altitude Region |

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*If in the shaded area of the table, please consult the Minimum Vmcg/Vr table on page 1-11. If Vmcg and Minimum Vr values are higher than this chart’s V1/Vr values, then use the Minimum Vmcg/Vr data in place of V1/Vr.*
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### FLAPS 20% 5% DERATED THRUST

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### FLAPS 20%

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## FLAPS 10
### FLAPS – 5% DERATED THRUST

### Temperature – Altitude Region

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Revision – 26JUL05
DO NOT DUPLICATE
PMDG747-400 AOM
### FLAPS 20 – 15% DERATED THRUST

#### Temperature – Altitude Region

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*If in the shaded area of the table, please consult the Minimum Vmcg/Vr table on page 1-11. If Vmcg and Minimum Vr values are higher than this chart’s V1/Vr values, then use the Minimum Vmcg/Vr data in place of V1/Vr.
### FLAPS 10 – 15% DERATED THRUST

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*If in the shaded area of the table, please consult the Minimum Vmcg/Vr table on page 1-11. If Vmcg and Minimum Vr values are higher than this chart’s V1/Vr values, then use the Minimum Vmcg/Vr data in place of V1/Vr.

Revision – 26JUL05
DO NOT DUPLICATE
PMDG747-400 AOM
### ADDITIONAL ADJUSTMENTS

**Minimum Allowed Vmcg / Vr Speed**

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If in the shaded area of the \( V1/Vr/V2 \) table, cross reference the Vmcg and Minimum Vr values from this table. If this tables values are higher than \( V1/Vr \), use the figures from this table in place of \( V1/Vr \).

**What is this?:** In some specific takeoff configurations, it is possible for the airplane to be rotated below the “Minimum Controllable Ground Speed.” Minimum Controllable Ground Speed, or Vmcg, is the minimum speed at which the flight controls have enough aerodynamic effectiveness that control of the aircraft can be maintained using ONLY the aerodynamic controls in the event of an engine failure during the takeoff roll. Below Vmcg, control effectiveness will be insufficient to control the airplane, and as such it is important that the airplane not be rotated below this speed.
TAKEOFF THRUST SETTINGS

TAKEOFF THRUST N1 (B747-400)

When planning takeoff without all three packs operating, or with Engine Nacelle Anti Ice (NAI) ON, adjust N1 based on the table below:

%N1 ADJUSTMENT

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*NO ADJUSTMENT REQUIRED BELOW 7500 FT.

DO NOT OPERATE WITH NACELLE ANTI-ICE "ON" AT TEMPERATURES ABOVE 10 °C (50 °F)

MAX TAKEOFF %N1

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-2000
-1000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000

When planning takeoff without all three packs operating, or with Engine Nacelle Anti Ice (NAI) ON, adjust N1 based on the table below:
Reduced N1 Takeoff Thrust Settings (B747-400)

Whenever possible, crews should conduct takeoffs using a derated takeoff N1 thrust setting as selected via the THRUST LIM page in the FMC. This will result in reduced engine wear, reduced maintenance costs and reduced fuel burn. In addition, reduced thrust takeoffs normalize the takeoff acceleration rates giving the crew adequate time to assess takeoff conditions even when the aircraft is lightly loaded. When a derated N1 thrust setting is selected via the FMC, it is to be considered the minimum thrust required under selected conditions.

Reduced Takeoff N1 should not be used when:
- Braking action is reported to be less than ‘Good.’
- The probability of windshear exists.
- Runway is wet or cluttered.
- Takeoff is to be made with a tailwind.
- Antiskid system is inoperative.
- Any brake is deactivated

In situations where the crew enters an Assumed Temperature into the THRUST LIM page and the crew-entered temperature exceeds the ambient temperature, the FMC will automatically compute the reduced takeoff thrust required.

Crews should always enter an assumed temperature to determine V speeds if derated takeoff N1 settings are being used. If the V speeds determined using the assumed temperature are less than the minimum V speeds according to the V1 Minimum Speeds Table, then use the minimum V speeds.
MAX CROSSWIND COMPONENT (747-400)

To Use: Determine Runway Heading of runway to be used. Obtain Reported Wind Direction/Speed. Calculate number of degrees difference between Runway Heading and Wind Direction. Result will be between 0 degrees (pure headwind) and 90 degrees (pure crosswind).

Enter grid on tangent line which represents difference between Runway Heading and Wind Direction, move inward toward lower left corner until reaching wind speed arc for Reported Wind Speed. From this point, read wind speed from left border to determine Headwind Component, and read wind speed from bottom border to determine Crosswind Component. Labeled vertical lines represent demonstrated crosswind limitations of aircraft.

MAX AUTOLAND HEADWIND: 25kts
MAX AUTOLAND TAILWIND: 10kts
TAKEOFF PERFORMANCE / SAFETY VERIFICATION

Limitations:
- Maximum Zero Fuel Weight (MZFW): 535,000lbs 242,671kg
- Maximum Takeoff Gross Weight (MTOG): 875,000lbs 396,893kg
- Maximum Taxi Weight (MTW): 877,000lbs 397,800kg
- Minimum Zero Fuel Weight (ZFW): 397,000lbs 180,076kg
- Maximum Crosswind Component: See Table

V Speed Determination:
Determine runway condition, N1 setting and flap setting to be used for takeoff. Use V speeds for associated Aircraft Takeoff Gross Weight (ATOG). These speeds will normally be displayed by the FMC after correct weights and runway conditions have been verified in the PERF INIT page.

In the event that standing water, slush and wet or dry snow is present on the usable portion of the runway, use the Wet/Cluttered Runway table speeds, and adjust the FMC calculated speeds if necessary. When departing from a Wet/Cluttered Runway do not use a derated thrust for takeoff. All takeoffs from wet/cluttered runways will be made at the standard thrust setting for the aircraft weight and temperature conditions.

Minimum V Speed Conditions:
For some high temperature, high altitude conditions or tailwind takeoffs, it may be necessary to adjust the V1/Vr speeds calculated by the FMC and V Speed Tables in order to ensure a proper safety margin. Use the Minimum Vmcg / Vr Table to make such adjustments. Care should be taken not to adjust V1 below the values outlined in the minimum allowable V1 Table or control of the aircraft may be lost in the event of an engine failure after V1.

Engine N1% Safety Check:
The FMC will normally provide the crew with accurate target N1 settings for the takeoff regime of flight. Crews should exercise caution not to exceed the maximum allowable N1 settings for the engines (117.5%). Crews should cross reference the FMC calculated N1 takeoff setting displayed on the THRUST LIM page against the MAX Takeoff %N1 table to ensure safe N1 settings are used.

Takeoff Safety Considerations:
The “Eighty Knots” PNF callout is designed to alert the crew that they are entering the high speed phase of the takeoff roll. Once this has occurred, the Captain’s should only elect to reject a takeoff in a situation where the failure involved may prevent the aircraft from being safely flown. A minor, or non critical failure does not constitute a valid reason to reject a takeoff while in the high speed regime, as it may place the aircraft in greater danger than a continuance of the takeoff roll.

Conditions which warrant a decision to reject the takeoff include, but are not limited to, engine failures, engine or onboard fires, flight control failures or any other failure which calls into question the aircraft’s ability to fly. Crews should not assume that a ‘Go’ decision has been made upon passing 80 knots, however, as a decision relative to the nature of a failure and it’s proximity to V1 must still be made.
## CRUISE

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CRUISE FLIGHT

Overview: Correct planning for cruise flight is extremely important for the safe and timely operation of any aircraft. This becomes particularly true when operating the 747-400. The tremendous range and endurance capabilities of the aircraft allow for transition through many different flight environments during a single operation and it is not uncommon for flight planning to occur fifteen to twenty hours prior to scheduled arrival at a destination airport. The time involved in long range flying may allow for significant changes in weather or ATC conditions during the course of a flight, so to ensure safe and consistent results, it is important that crews thoroughly understand the inter-relation of the variables involved in cruise flight planning.

The three variables most directly affecting the aircraft’s cruise flight performance are: Planned Landing Weight, Cruise Altitude and Cruise Speed. Increasing or decreasing any one of these variables may have a significant impact on fuel consumption and range capability of the aircraft. Proper determination of aircraft load weights combined with well thought out selection of flight level and Mach cruise speeds are integral to accurate performance planning.

Definitions: Following are a number of definitions used in flight planning.

Destination: The airport of intended landing for the flight.

Alternate: The airport which has been selected by the crew as an alternate landing airport in case the Destination airport is unusable due to weather conditions, ATC or other factors.

Basic Operating Weight: The weight of the aircraft minus any passengers, baggage, cargo or usable fuel. This weight figure includes items such as the weight of the aircraft structure, hydraulic fluid, air conditioning fluids, residual fuel, residual oil, crew, crew luggage, potable water, passenger accommodation fluids, and normal passenger service equipment normally carried on board.

Payload: Weight of all passengers, bags or cargo to be carried aboard the aircraft during flight

Zero Fuel Weight: The weight of the unfueled aircraft after all passengers, bags and cargo have been loaded. (BOW + Payload = ZFW) This number yields the weight of the aircraft prior to any useable fuel being loaded.

Maximum Zero Fuel Weight: This is the heaviest weight allowed for the airplane before adding fuel weight. MZFW for this airplane as modeled is: 535,000lbs.

Minimum Landing Fuel: This is the absolute minimum amount of fuel that will remain on the aircraft at the time the airplane lands. Specifically, this number represents the weight of usable fuel still remaining on board the aircraft in the worst case scenario. (E.g. the crew is forced to hold enroute, flies an approach to the destination followed by a missed approach, more holding, diverts to the alternate airport and lands.) The Minimum Landing Fuel for the 747-400 is normally 24,000lbs. If for any reason you expect to land with less than this amount of fuel, it should be considered an emergency condition.

Alternate Fuel: The amount of fuel required to the aircraft from the Destination after a missed approach to the alternate airport.

Contingency Fuel: Fuel boarded to allow for airborne holding, off optimum altitude flying, off optimum speed flying, or changes in the route of flight that might increase the fuel burn enroute.

Flight Plan Fuel: This figure represents the fuel load which is required to fly the aircraft from the airport of origin to the airport of destination. This figure should be corrected for winds along the route (see later in this chapter) but does not account for holding, missed approaches or other inefficiencies.
Planned Landing Weight: This figure represents the weight of the aircraft upon touchdown at the destination airport. (Theoretically, this is the weight of the airplane in a perfect scenario, where the crew lands at the destination immediately without holding, missed approaches, etc. Thus it represents the highest potential weight of the aircraft upon landing.)

This weight figure is a critical limitation that should be carefully examined to ensure that it does not exceed 630,000lbs.

This weight is determined by adding:

- Minimum Landing Fuel
- Alternate Fuel
- Contingency Fuel
- Flight Plan Fuel
- Zero Fuel Weight

Planned Landing Weight

This figure is one of the most important figures in your flight plan, as it will be used to determine nearly all other aspects of your cruise altitude, range and fuel load. (See examples later in the chapter!)

Cruise Speed: The Mach speed selected for use during cruise. Mach cruise speed setting can have a significant impact on the fuel flow encountered during flight. Mach .80 is generally used for Long Range Cruise flight, while Mach .86 is considered a High Speed Cruise. Fuel increases dramatically with an increase in mach speed.

Maximum Gross Taxi Weight: The maximum weight at which the aircraft may be dispatched for taxi. This is a structural limit weight which is determined by the manufacturer to prevent over-stressing structural members within the aircraft. This airplane is modeled with an 877,000lb MGTW.

Maximum Gross Takeoff Weight: This figure denotes the maximum weight at which the aircraft may be allowed to commence the takeoff roll. This figure is a structural limit weight designed to prevent over-stressing of structural members within the aircraft. This airplane is modeled with an 875,000lb MTOW.

Maximum Gross Landing Weight: This figure denotes the maximum weight at which the aircraft may be allowed to land. This figure is a structural limit weight designed to prevent over-stressing of structural members within the aircraft. This airplane is modeled with a 630,000lb MGLW.

Maximum Planned Takeoff Weight: Unlike Max Gross Takeoff Weight, this figure is a variable figure and changes with each flight. This weight limit can be caused by insufficient runway length at the departure airport, for example but most commonly is experienced on short flights when the airplane is carrying a large payload over a shorter range.

For example, we know that the MGLW for the airplane can never be more than 630,000lbs. We also know that the maximum weight of the airplane before any fuel is loaded must not exceed 535,000lbs.

If we are planning a flight with the MZFW at 535,000lbs, we must take care to ensure that we will land with 95,000lbs of fuel, or less. (535,000lbs + 95,000lbs = 630,000lbs)

More information on how to determine Maximum Allowable Takeoff Weight is provided later in this chapter.

Maximum Planned Landing Weight: This figure is a variable figure specific to each flight. This weight could be a limit factor caused by insufficient runway length at the destination airport, or high density altitude at the destination airport.

Weight Restrictions: During flight planning, it is important that the aircraft weight is maintained within the parameters of Maximum Gross Landing Weight, Maximum Gross Takeoff Weight, and Maximum Taxi Weight. As the fuel planning schematic is being filled in, crews should verify weight compliance. If a maximum structural weight or maximum operational weight is exceeded, the crew should either consider reducing aircraft weight by removal of passengers or cargo. If passengers or cargo cannot be removed, a reduced fuel load should be boarded, with plans made for an en-route fuel stop.
Fuel Planning Schematic 747-400
(STANDARD UNITS)

Basic Operating Empty Weight: 394,000lbs

Payload: ______________

Zero Fuel Weight: ______________
(Must be less than 535,000)

Zero Fuel Weight: ______________
+ Minimum Landing Fuel: ______________
+ Alternate Fuel: ______________
+ Contingency Fuel: ______________

Planned Landing Weight: ______________
(Must be less than 630,000)

Planned Landing Weight: ______________
+ Flight Plan Fuel: ______________

Planned Gross Takeoff Weight: ______________
(Must be less than 875,000)

Planned Gross Takeoff Weight: ______________
+ Taxi Fuel Burn Off: ______________

Planned Taxi-Out Weight: ______________
(Must be less than 877,000)

Schematic should be used to ensure compliance with structural weight limits.

Crews should verify that planned takeoff and planned landing weights are not limited by reduced runway lengths or high density altitudes.
Basic Operating Empty Weight: 179,090kgs

Payload: ________________

Zero Fuel Weight: ________________
(Must be less than 242,671kg)

Zero Fuel Weight: ________________
+ Minimum Landing Fuel: ________________
+ Alternate Fuel: ________________
+ Contingency Fuel: ________________

Planned Landing Weight: ________________
(Must be less than 285,763kg)

Planned Landing Weight: ________________
+ Flight Plan Fuel: ________________

Planned Gross Takeoff Weight: ________________
(Must be less than 397,727kg)

Planned Gross Takeoff Weight: ________________
+ Taxi Fuel Burn Off: ________________

Planned Taxi-Out Weight: ________________
(Must be less than 398,636kg)

Schematic should be used to ensure compliance with structural weight limits.

Crews should verify that planned takeoff and planned landing weights are not limited by reduced runway lengths or high density altitudes.
**FUEL LOAD PLANNING**  
(Standard Units)

**DISTANCE:** When Trip Length in Nautical Air Miles falls between levels on mileage scale, interpolate time and fuel required for trip. Example: 5400 NAM @ FL410 equals 11:15 and 230,000.

Table is based on following speed schedule:

- **CLIMB:** 250 KIAS to 10,000 feet; 300 KIAS to FL310; Mach .80 above FL310
- **CRUISE:** M.86 at Optimum Altitude for aircraft weight (or step climb procedure)
- **DESCENT:** Mach .80 to FL340; 300 KIAS between FL340 and 10,000; 250KIAS below 10,000ft

**WEIGHT:**  
Table is valid only for a planned landing weight of 475,000lbs. For every 10,000lbs deviation above (below) 475,000 lbs, add (subtract) fuel burnout correction shown in “Adjust:” row on bottom of table.

Example: For 4800 NAM @ FL410 and 505,000lbs planned landing weight, fuel required would equal 198,000lbs + [(700lbs/hr x 3) x 10:00hrs] = 198,000lbs + 21,000lbs = 219,000lbs total fuel required.

Table Represents M.86 Cruise at Optimum Altitude (or use of Step Climb Procedures)

<table>
<thead>
<tr>
<th>Trip Length NAM</th>
<th>Pressure Altitude (Feet)</th>
<th>True Airspeed (Knots)</th>
<th>Flight Time (Hours:Minutes) and Fuel Burn (Pounds x 1000)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FL410 / 479</td>
<td>FL390 / 479</td>
<td>FL370 / 479</td>
</tr>
<tr>
<td>8800</td>
<td>17:31</td>
<td>380.0</td>
<td>17:31</td>
</tr>
<tr>
<td>8400</td>
<td>16:43</td>
<td>356.0</td>
<td>16:43</td>
</tr>
<tr>
<td>8000</td>
<td>15:54</td>
<td>338.0</td>
<td>15:51</td>
</tr>
<tr>
<td>7600</td>
<td>15:02</td>
<td>316.0</td>
<td>15:00</td>
</tr>
<tr>
<td>7200</td>
<td>14:12</td>
<td>298.0</td>
<td>14:12</td>
</tr>
<tr>
<td>6400</td>
<td>12:31</td>
<td>258.0</td>
<td>12:31</td>
</tr>
<tr>
<td>6000</td>
<td>11:43</td>
<td>238.0</td>
<td>11:42</td>
</tr>
<tr>
<td>5600</td>
<td>10:48</td>
<td>222.0</td>
<td>10:48</td>
</tr>
<tr>
<td>5200</td>
<td>9:12</td>
<td>186.0</td>
<td>9:12</td>
</tr>
<tr>
<td>4800</td>
<td>8:21</td>
<td>169.0</td>
<td>8:21</td>
</tr>
<tr>
<td>4400</td>
<td>7:30</td>
<td>152.0</td>
<td>7:30</td>
</tr>
<tr>
<td>4000</td>
<td>6:43</td>
<td>136.0</td>
<td>6:43</td>
</tr>
<tr>
<td>3600</td>
<td>5:48</td>
<td>121.0</td>
<td>5:48</td>
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<tr>
<td>3200</td>
<td>4:13</td>
<td>103.0</td>
<td>4:13</td>
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<tr>
<td>2800</td>
<td>3:21</td>
<td>88.0</td>
<td>3:21</td>
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<tr>
<td>2400</td>
<td>2:30</td>
<td>73.0</td>
<td>2:30</td>
</tr>
<tr>
<td>2000</td>
<td>1:41</td>
<td>62.0</td>
<td>1:41</td>
</tr>
<tr>
<td>1600</td>
<td>1:06</td>
<td>46.5</td>
<td>1:06</td>
</tr>
<tr>
<td>1000</td>
<td>1:06</td>
<td>34.0</td>
<td>1:06</td>
</tr>
</tbody>
</table>

Adjust: 700lbs/hr  880lbs/hr  1000lbs/hr  860lbs/hr  680lbs/hr  320lbs/hr
**FUEL LOAD PLANNING**

*(Metric Units)*

**DISTANCE:** When Trip Length in Nautical Air Miles falls between levels on mileage scale, interpolate time and fuel required for trip. **Example:** 5400 NAM @ FL410 equals 11:15 and 104,100kgs fuel.

Table is based on following speed schedule:

**CLIMB:** 250 KIAS to 10,000 feet; 300 KIAS to FL310; Mach .80 above FL310

**CRUISE:** M.86 at Optimum Altitude for aircraft weight (or step climb procedure)

**DESCENT:** Mach .80 to FL340; 300 KIAS between FL340 and 10,000;
250KIAS below 10,000ft

**WEIGHT:** Table is valid only for a planned landing weight of 216,000Kgs.
For every 4,500Kgs deviation above (below) 216,000 Kgs, add (subtract) fuel burnout correction shown in “Adjust:” row on bottom of table.

**Example:** For 4800 NAM @ FL410 and 230,400kgs planned landing weight, fuel required would equal 89,800kgs + [(317Kg/hr x 3) x 10:00hrs] = 89,800kgs + 9,510kgs = 99,310kgs total fuel required.

Table Represents M.86 Cruise at Optimum Altitude (or use of Step Climb Procedures)

<table>
<thead>
<tr>
<th>Trip Length NAM</th>
<th>Pressure Altitude (Feet)</th>
<th>True Airspeed (Knots)</th>
<th>Flight Time (Hours:Minutes) and Fuel Burn (Kgs x 1000)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FL410 / 479</td>
<td>FL390 / 479</td>
<td>FL370 / 479</td>
</tr>
<tr>
<td>8800</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8400</td>
<td>17:31</td>
<td>172.4</td>
<td>17:28</td>
</tr>
<tr>
<td>8000</td>
<td>16:43</td>
<td>161.5</td>
<td>16:39</td>
</tr>
<tr>
<td>7600</td>
<td>15:54</td>
<td>153.3</td>
<td>15:51</td>
</tr>
<tr>
<td>7200</td>
<td>15:02</td>
<td>143.3</td>
<td>15:00</td>
</tr>
<tr>
<td>6800</td>
<td>14:12</td>
<td>135.2</td>
<td>14:12</td>
</tr>
<tr>
<td>6000</td>
<td>12:31</td>
<td>117.0</td>
<td>12:31</td>
</tr>
<tr>
<td>5600</td>
<td>11:43</td>
<td>108.0</td>
<td>11:42</td>
</tr>
<tr>
<td>5200</td>
<td>10:48</td>
<td>100.1</td>
<td>10:48</td>
</tr>
<tr>
<td>4800</td>
<td>10:00</td>
<td>98.8</td>
<td>9:58</td>
</tr>
<tr>
<td>4400</td>
<td>9:12</td>
<td>84.4</td>
<td>9:12</td>
</tr>
<tr>
<td>4000</td>
<td>8:21</td>
<td>76.7</td>
<td>8:21</td>
</tr>
<tr>
<td>3600</td>
<td>7:30</td>
<td>69.0</td>
<td>7:30</td>
</tr>
<tr>
<td>3200</td>
<td>6:43</td>
<td>61.7</td>
<td>6:43</td>
</tr>
<tr>
<td>2800</td>
<td>5:48</td>
<td>54.9</td>
<td>5:48</td>
</tr>
<tr>
<td>2400</td>
<td>5:00</td>
<td>46.7</td>
<td>5:00</td>
</tr>
<tr>
<td>2000</td>
<td>4:13</td>
<td>39.9</td>
<td>4:13</td>
</tr>
<tr>
<td>1400</td>
<td>3:21</td>
<td>33.1</td>
<td>3:21</td>
</tr>
<tr>
<td>1000</td>
<td>2:30</td>
<td>28.1</td>
<td>2:30</td>
</tr>
<tr>
<td>800</td>
<td>1:41</td>
<td>21.1</td>
<td>1:41</td>
</tr>
<tr>
<td>400</td>
<td>1:06</td>
<td>15.4</td>
<td>1:06</td>
</tr>
</tbody>
</table>

**Adjust:**

<table>
<thead>
<tr>
<th>Metric Units</th>
<th>Adjust: 317kg/hr</th>
<th>400kg/hr</th>
<th>454kg/hr</th>
<th>390kg/hr</th>
<th>308kg/hr</th>
<th>145kg/hr</th>
</tr>
</thead>
</table>

Revision – 26JUL05

DO NOT DUPLICATE

PMDG 747-400 AOM
Fuel Required to Reach Planned Alternate Destination

<table>
<thead>
<tr>
<th>NAM to Alternate</th>
<th>Time to Alternate</th>
<th>Landing Weight at Alternate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>430 lb to 475 lb [195kg to 215kg]</td>
</tr>
<tr>
<td>100</td>
<td>0:30</td>
<td>6600lb [3000kg]</td>
</tr>
<tr>
<td>200</td>
<td>0:41</td>
<td>11000lb [5000kg]</td>
</tr>
<tr>
<td>300</td>
<td>0:57</td>
<td>14000lb [6400kg]</td>
</tr>
<tr>
<td>400</td>
<td>1:10</td>
<td>17700lb [8000kg]</td>
</tr>
<tr>
<td>500</td>
<td>1:20</td>
<td>21000lb [9500kg]</td>
</tr>
</tbody>
</table>

- Based on Optimum Cruise Altitude Selection
- Table assumes an assured landing at planned alternate with only one approach flown.

**Contingency Fuel**

**Contingency Fuel:** In cases where the flight crew or dispatcher feels that they may encounter airborne holding while en-route, or may be required to fly at other than optimal speeds or altitudes, it may be beneficial to add contingency fuel to the desired fuel load. The amount of fuel boarded should reflect expectations in terms of total time to be spent in airborne holding both while en-route and during the approach phase of flight, and the amount of excess fuel burn that may be required by ATC forcing the aircraft off optimum altitudes and speeds.

**Maximum & Optimum Cruise Altitudes**

<table>
<thead>
<tr>
<th>Altitude</th>
<th>Optimum Wt</th>
<th>Maximum Wt</th>
<th>Time to Burn Fuel Wt</th>
</tr>
</thead>
<tbody>
<tr>
<td>FL420</td>
<td>470,000lbs [213,000kg]</td>
<td>520,000lbs [238,000kg]</td>
<td>-</td>
</tr>
<tr>
<td>FL410</td>
<td>500,000lbs [227,500kg]</td>
<td>550,000lbs [250,000kg]</td>
<td>1:42</td>
</tr>
<tr>
<td>FL400</td>
<td>520,000lbs [238,000kg]</td>
<td>570,000lbs [247,500kg]</td>
<td>1:07</td>
</tr>
<tr>
<td>FL390</td>
<td>550,000lbs [250,000kg]</td>
<td>600,000lbs [272,500kg]</td>
<td>1:35</td>
</tr>
<tr>
<td>FL380</td>
<td>570,000lbs [247,500kg]</td>
<td>630,000lbs [285,000kg]</td>
<td>1:02</td>
</tr>
<tr>
<td>FL370</td>
<td>600,000lbs [272,500kg]</td>
<td>670,000lbs [305,000kg]</td>
<td>1:22</td>
</tr>
<tr>
<td>FL360</td>
<td>630,000lbs [285,000kg]</td>
<td>700,000lbs [315,000kg]</td>
<td>1:24</td>
</tr>
<tr>
<td>FL350</td>
<td>670,000lbs [305,000kg]</td>
<td>740,000lbs [335,000kg]</td>
<td>1:36</td>
</tr>
<tr>
<td>FL340</td>
<td>700,000lbs [315,000kg]</td>
<td>770,000lbs [350,000kg]</td>
<td>1:14</td>
</tr>
<tr>
<td>FL330</td>
<td>740,000lbs [335,000kg]</td>
<td>810,000lbs [367,500kg]</td>
<td>1:27</td>
</tr>
<tr>
<td>FL320</td>
<td>770,000lbs [350,000kg]</td>
<td>840,000lbs [385,000kg]</td>
<td>1:05</td>
</tr>
<tr>
<td>FL310</td>
<td>810,000lbs [367,500kg]</td>
<td>870,000lbs [395,000kg]</td>
<td>1:26</td>
</tr>
<tr>
<td>FL300</td>
<td>840,000lbs [385,000kg]</td>
<td>-</td>
<td>1:00</td>
</tr>
</tbody>
</table>

For purposes of flight planning, crews should plan to follow ICAO step climb procedures in order to most closely mimic a constant optimum altitude climb profile. This will provide for the most efficient fuel burn possible while working within the constraints of the ATC system.

**Time to Burn Fuel Wt Explained:** The Time to Burn Fuel Weight column provides an estimate of how long it will take to burn into the next highest optimum flight level, given performance according to the Four Engine Mach .86 Cruise table. This information will allow crews to plan the time to be spent at each altitude, but can also be used to help estimate the highest altitude that can be reached during cruise flight of a known time duration. [Example: Takeoff at 770,000lbs for a six hour flight will yield an initial cruise altitude of FL320. After six hours of cruise flight, the optimum cruise altitude would be FL360.]
## FOUR ENGINE MACH .86 CRUISE
(Standard Units)

<table>
<thead>
<tr>
<th>FL TAT IAS</th>
<th>TAS</th>
<th>Gross Weight (x1000lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>880.0 840.0 800.0 760.0 720.0 680.0 640.0 600.0 560.0 520.0 480.0 440.0</td>
</tr>
<tr>
<td>420 -26</td>
<td>230</td>
<td>240 250 260 270 280 290 300 310 320 330 340 350</td>
</tr>
<tr>
<td>410 -26</td>
<td>235</td>
<td>245 255 265 275 285 295 305 315 325 335 345 355</td>
</tr>
<tr>
<td>400 -26</td>
<td>240</td>
<td>250 260 270 280 290 300 310 320 330 340 350 360</td>
</tr>
<tr>
<td>390 -26</td>
<td>245</td>
<td>255 265 275 285 295 305 315 325 335 345 355 365</td>
</tr>
<tr>
<td>380 -26</td>
<td>250</td>
<td>260 270 280 290 300 310 320 330 340 350 360 370</td>
</tr>
<tr>
<td>370 -26</td>
<td>255</td>
<td>265 275 285 295 305 315 325 335 345 355 365 375</td>
</tr>
<tr>
<td>360 -26</td>
<td>260</td>
<td>270 280 290 300 310 320 330 340 350 360 370 380</td>
</tr>
<tr>
<td>350 -23</td>
<td>265</td>
<td>275 285 295 305 315 325 335 345 355 365 375 385</td>
</tr>
<tr>
<td>340 -21</td>
<td>270</td>
<td>280 290 300 310 320 330 340 350 360 370 380 390</td>
</tr>
<tr>
<td>330 -19</td>
<td>275</td>
<td>285 295 305 315 325 335 345 355 365 375 385 395</td>
</tr>
<tr>
<td>320 -17</td>
<td>280</td>
<td>290 300 310 320 330 340 350 360 370 380 390 400</td>
</tr>
<tr>
<td>310 -14</td>
<td>285</td>
<td>295 305 315 325 335 345 355 365 375 385 395 405</td>
</tr>
<tr>
<td>300 -12</td>
<td>290</td>
<td>300 310 320 330 340 350 360 370 380 390 400 410</td>
</tr>
</tbody>
</table>

Shaded Area represents approximate Optimum Altitude Profile.

**Adjustments:**

TAS in knots is for standard TAT: Add (subtract) 1 knot/degree C above (below)standard.
## FOUR ENGINE MACH .86 CRUISE

**Metric**

<table>
<thead>
<tr>
<th>FL TAT</th>
<th>IAS</th>
<th>Gross Weight (x1000lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>880.0</td>
<td>840.0</td>
</tr>
<tr>
<td>420 -26 475</td>
<td></td>
<td></td>
</tr>
<tr>
<td>410 -26 475</td>
<td></td>
<td></td>
</tr>
<tr>
<td>400 -26 475</td>
<td></td>
<td></td>
</tr>
<tr>
<td>390 -26 475</td>
<td></td>
<td></td>
</tr>
<tr>
<td>380 -26 475</td>
<td></td>
<td></td>
</tr>
<tr>
<td>370 -26 475</td>
<td></td>
<td></td>
</tr>
<tr>
<td>360 -26 475</td>
<td></td>
<td></td>
</tr>
<tr>
<td>350 -26 475</td>
<td></td>
<td></td>
</tr>
<tr>
<td>340 -26 475</td>
<td></td>
<td></td>
</tr>
<tr>
<td>330 -26 475</td>
<td></td>
<td></td>
</tr>
<tr>
<td>320 -26 475</td>
<td></td>
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<tr>
<td>310 -26 475</td>
<td></td>
<td></td>
</tr>
<tr>
<td>300 -26 475</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Adjustments:

TAS in knots is for standard TAT: Add (subtract) 1 knot/degree C above (below) standard.

---

Shaded Area represents approximate Optimum Altitude Profile.
FUEL PLANNING METHODOLOGY

Overview: Accurate fuel planning is not a difficult process, but does require some understanding of the charts and terms described earlier in this chapter.

This section of the chapter will walk you through a typical fuel planning exercise to help you understand how the process works, and what factors should be considered.

Follow each of the steps below in order, and refer to the definitions at the beginning of this chapter if you need a refresher!

For the purpose of this exercise, a flight is being planned using the following conditions and parameters:

Origin: KSFO
Destination: KIAD
Alternate: KJFK

BOW: 394,000lbs
Payload: 106,000lbs
Zero Fuel Wt. 500,000lbs

Determine Trip Length: To determine the length of our flight, we must make steps beyond simply measuring the distance over the ground. The air through which we will fly is moving, after all, so we must adjust our planning to account for the effects of this wind on our flight.

The approximate distance between San Francisco and Washington DC is 2,400nm.

This geographic distance must then be adjusted in order to account for the effects of wind along the route of flight. The prevailing winds along this route tend to be from the west, which results in a nearly continual tailwind along the route. For the purpose of this exercise, we will assume that the tailwind component is 75knots along the entire route of flight.

Determining the effect of these winds is a two step process:

Step One: Use the Fuel Planning table (page 2-7) and find 2,400nm on the Trip Length column. Moving horizontally to the right, determine the approximate time it will take to fly the route. In this case, a 2,400 NM trip will take approximately 5:00 hours. (You can approximate the time by looking at your desired altitude, or by averaging all the time figures in your row.)

Step Two: Multiply the wind component by the estimated time-in-flight. We have already assumed that the wind along this route is 75knots from behind the airplane. Thus, to determine it’s effect, we multiply:

Time Enroute x Wind Component

5:00hrs -75knots

(Note: Headwinds are positive numbers, tailwinds are negative numbers.)

Thus: (5:00 hours x -75kts) = -375.

By adding this result to the total flight distance, we receive the total Nautical Air Miles to be flown. (2,400nm + -375) = 2,025 NAM.

Nautical Air Miles are miles flown the air mass. Since the air itself is moving in the same direction as our flight, we will fly fewer miles through this air mass than if we were in still air, or headed into the wind. The effect of wind on Nautical Air Miles to be flown is simple to remember: Headwinds make the number larger, Tailwinds make the number smaller.

Estimate Fuel Required: Once again using the Trip Length in NAM column, enter the Fuel Planning table being careful to select the correct flight length in NAM, as well as the planned cruising altitude. In this example, we will select FL390 with a NAM trip distance of 2,000 NAM. This yields a time/fuel estimate of 4:13 minutes in flight and 87,600lbs of fuel on board to complete
the flight. It is important for crews to understand that this is an estimate of fuel required, and that the Fuel Planning Schematic Charts provided earlier in this chapter should be used to plan the actual fuel load.

**Refining Fuel Calculations:** Now that a good fuel load estimate has been calculated, it is time to refine the fuel load to account for all possible stages of the flight.

The most effective way to plan any fuel load is to start at the end of any possible fuel scenario, and work backward to the beginning of the flight.

For example, we will assume that in this instance, the weather at KIAD is marginal and we have selected KJFK as an alternate airport for the trip.

**Step 1: Minimum Landing Fuel:** Working the flight backward, we know that we want to land with at least *Minimum Landing Fuel*. For the 747-400, this is commonly accepted to be 24,000lbs on international flights and 19,000lbs on domestic or short haul flights.

KSFO-KIAD is a short trip for a 747-400, and the East Coast of the United States has plenty of suitable airports for a 747, so we will elect to use 19,000lbs as the *Minimum Landing Fuel* for our flight.

**Note for Advanced Users:** If your flight requires a second alternate due to alternate minimums or dispatches under Exemption 3585, you should work backward from the second alternate airport!

**Step 2: Alternate Fuel:** Currently we need 19,000lbs of fuel on the aircraft at the time of landing, so to this figure we are going to add the amount of fuel it will take us to fly from KIAD – KJFK, our alternate airport.

**Step 3: Contingency Fuel:** To determine if we need contingency fuel depends largely upon weather conditions, known problems in the Air Traffic Control System, and a general “feel” for the operation of the airplane that comes primarily through experience.

For example, if we were planning a flight to arrive at KIAD late in the evening, we are not likely to be concerned about holding or lengthy vectors before landing. On the other hand, KIAD tends to be a very busy airport at 4PM local time, so if we were planning to land at 4:15PM, we would carefully consider the fact that we could expect lengthy vectors for landing, or, in the case of poor weather, holding enroute.

1) How far is it from Destination to Alternate? (200nm between KIAD-KJFK)
2) What will the airplane weigh when it touches down at JFK?

The distance between KIAD-KJFK is 200nm, approximately.

The weight of the airplane upon landing at JFK can be determined easily by adding our 19,000lbs Minimum Landing Fuel to the Zero Fuel Weight of the airplane for this trip:

In this instance, we assume that the airplane will weigh 500,000lbs fully loaded with passengers, bags and cargo, but without fuel on board.

As such, our landing weight at KJFK would be:

\[
\text{ZFW} + \text{Min. Ldg Fuel} = 519,000\text{lbs}
\]

With this information, enter the **Fuel Required to Reach Planned Alternate Destination** table using the distance to the alternate and the estimated landing weight of the aircraft at the Alternate Destination.

The table indicates that we need 11,600lbs of fuel to reach our alternate on this flight.

Thus, our total required fuel thus far is:

\[
19,000\text{lbs} + 11,600\text{lbs} = 30,600\text{lbs}
\]

**Step 3: Contingency Fuel:** To determine if we need contingency fuel depends largely upon weather conditions, known problems in the Air Traffic Control System, and a general “feel” for the operation of the airplane that comes primarily through experience.

For example, if we were planning a flight to arrive at KIAD late in the evening, we are not likely to be concerned about holding or lengthy vectors before landing. On the other hand, KIAD tends to be a very busy airport at 4PM local time, so if we were planning to land at 4:15PM, we would carefully consider the fact that we could expect lengthy vectors for landing, or, in the case of poor weather, holding enroute.
For the purpose of this planning exercise, we are assuming that the weather at KIAD is poor enough to require the use of an alternate airport in our flight planning, so we will also assume that we are planning to land at 4:15PM during the peak of the afternoon arrivals.

As such, we will elect to add an extra :45 of fuel to ensure we have enough fuel to account for possible holding, slow-downs and lengthy vectors to final approach.

A good rule of thumb for loading contingency fuel is to expect holding fuel burn at a rate of 18,000lbs / hour.

This being the case, we will elect to add :45 minutes of fuel, or: 13,500lbs.

At this point, we have boarded all of the fuel required for any "unusual events" such as holding, diversion and landing at an alternate airport.

Our fuel required thus far is:

\[ 19,000 + 11,600 + 13,500 = 44,100\text{lbs} \]

Incidentally, if we depart KSFO and are able to land at KIAD without holding or diverting to our alternate, we should have all 44,000lbs of fuel still in the tanks upon landing at KIAD.

If you are filling in the Fuel Planning Sheet from page 2-3, you will notice that:

- Zero Fuel Weight 500,000
- Minimum Landing Fuel 19,000
- Alternate Fuel 11,600
- Contingency Fuel 13,500

\[ \text{Planned Landing Weight} = 544,100 \]

\[ \text{Planned Takeoff Weight} = 631,700 \]

**Step 5: Takeoff Weight:** Calculating the takeoff weight is a simple matter, given the information we have already determined:

- Zero Fuel Weight 500,000
- Minimum Landing Fuel 19,000
- Alternate Fuel 11,600
- Contingency Fuel 13,500

\[ \text{Planned Landing Weight} = 544,100 \]

\[ \text{Planned Takeoff Weight} = 631,700 \]

**Step 6: Determine Initial Cruise Altitude:**

The 747-400 is a large airplane with a broad range of capabilities. When lightly loaded, the airplane can fly easily at altitudes up to 41,000 feet. When heavily loaded, the airplane will begin the trip by leveling off at 31,000 feet until some fuel weight is consumed.

It is not difficult to determine the proper initial cruising altitude once the Planned Takeoff Weight is known.

Use the Maximum and Optimum Cruise Altitudes table (page 2-9) to determine the initial cruising altitude for the flight.

Using our Planned Takeoff Weight of 631,700lbs, move down the Optimum Altitude column until finding 630,000lbs. (Rounding numbers when using this table is satisfactory.)

From the Altitude column, we can see that our initial “Most Optimum” cruise altitude will be 36,000 feet.
We can now calculate how high we should climb during the course of our flight to KIAD in order to continue flying at the “Most Optimum” altitudes for the airplane’s weight.

To do this, observe the times written in the far right column of the table. According to these figures, it will take 1:24 to burn enough fuel for us to consider moving to a higher altitude in order to maintain the optimum altitude during flight.

Repeating this exercise a few times, we know that our flight is supposed to take approximately 4:13, so we can continue moving up this column as follows:

\[ 1:24 + 1:22 + 1:02 = 3:48. \]

In other words, 1:24 into our flight, we should climb from FL360 to FL 370. Then, 1:22 later, we should expect to climb to FL 380, and 1:02 later expect a climb to FL390.

For this flight, we would expect then, to climb initially to FL360, then climb progressively to FL390 before commencing our descent into KIAD.

We have one more factor to consider, however!

Eastbound flights are required to operate at odd altitudes, while westbound flights are operated at even altitudes. Thus, FL360 is not available to us when headed eastbound, so we must limit our climb to FL350 initially, until we have burned enough fuel to reach FL370. (1:24 into our flight!)

The process of finding an optimum altitude is made far easier by the Step Climb calculations within the FMC-CDU, and these are explained in detail in the chapter detailing use of the FMC.

The fuel burned during cruise flight can be calculated by simply subtracting the figures in the Optimum Altitude column, or by manually determining the fuel burn at each altitude through use of the Four Engine Mach .86 Cruise table.

By simply adding the figures in the Optimum Altitude chart, it would appear that approximately 80,000lbs of fuel would be burned for this example. This coincides very closely to the initial estimated figure of 88,700lbs.

A second, slightly more complex method to calculate the required fuel is to use the Four Engine Mach .86 Cruise table. By entering the table using the initial cruise altitude (FL350) and initial aircraft cruise weight (631,700lbs in this example) it can be determined that the aircraft will burn fuel at a rate of approximately 21.6, or 21,600lbs/hour. (This figure is interpolated between the 640,000lb and 600,000lb columns.)

This fuel burn figure can then be used to determine how long it will take to burn enough fuel that it will be necessary for the aircraft to climb in order to reach the next highest optimum cruise altitude. In this example, this would be the difference between 631,700lbs at the initial cruise altitude of FL350 and the 600,000lb optimum weight at FL370. (31,700lbs)

\[ 31,700lbs / 21,600lbs/hr = 1:28 \]

Following the same process, the fuel to be burned prior to climbing to each successive higher altitude can be determined.

This process can be followed through each planned step climb to ultimately yield the total fuel required for the flight.

It is important, however, to consider that it is not always possible to simply climb to the next highest cruise altitude while burning fuel. For example, if ATC restrictions will limit initial cruising altitude to FL320, or if ATC climb restrictions will hold the flight to a lower altitude than is considered optimal, fuel burn will be higher than predicted on either the Fuel Planning Table or Maximum and Optimum Altitudes table. (This is why we boarded contingency fuel! Use it!)

It is important that crews plan their fuel loads based on the most reasonable expectations for the flight. If it is expected that the aircraft will be held to a lower altitude, planning the fuel load appropriately will ensure the aircraft arrives with sufficient reserves at the planned and/or alternate destinations.
In all cases, crews should continually monitor actual fuel burn against planned fuel burn. On long-range segments over water, or unpopulated areas, early detection of inaccuracy in fuel planning is essential to safety of flight.

**FMC Fuel Management:** Use of the FMC is covered in detail later in this chapter, but while we are considering fuel planning here is a trick you can use to keep you safe while flying:

While entering flight data into the FMC, many crews may find it beneficial to enter a RESERVES figure into the INIT PERF page of the FMC. This figure should generally consist of:

Minimum Landing Fuel + Alternate Fuel + between :30 and 1:00 of fuel.

In the case of our flight to KIAD, we would enter a value of:

Minimum Landing Fuel: 19,000
Alternate Fuel: 11,600
½ Contingency Fuel: (22mins) 6,250

FMC RESERVES entry: 37,850

Once this number is entered into the RESERVES line of the FMC-CDU, the onboard fuel system monitoring will immediately alert the crew if it appears that they will land with less than 37,850lbs on board at the destination.

The alert will come in the form of an INSUFFICIENT FUEL warning in the FMC-CDU. This alert does not indicate that you have insufficient fuel to reach your destination or alternate, it simply serves to remind you that at the time you land, you will have less than half of your Contingency fuel, plus whatever fuel is required to reach your alternate.

In this circumstance, the crew should pay close attention to events unfolding on the approach, as any unplanned delay or missed approach will mean that they could be critically short of fuel upon landing at the alternate airport.
# LANDING

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## MINIMUM MANEUVERING AND LANDING REFERENCE SPEEDS

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**Bolded speeds** within the shaded areas are above the maximum structural landing weight.

All speeds are for International Standard Atmospheric conditions and may vary slightly according to local temperature, humidity and altimeter setting.
GO-AROUND THRUST SETTINGS - N1

N1 Go-Around thrust settings are provided for crew use in the event that the automated FMC based TO/GA system is unavailable/inoperative.

When hand flying an approach, crews are encouraged to use maximum available thrust to initiate the Go-Around procedure. Lower thrust settings may compromise the safety of the aircraft during the critical transition from approach to go-around.

Use of the TO/GA switch, when possible, is the best method of thrust management in the event of a Go-Around.

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(Weights listed in thousands of pounds.)
[Match airport temperature to airport pressure altitude to obtain Performance Limit Weight.]}

**FLAPS 25**

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RUNWAY LIMIT WEIGHTS [Lbs]

(Weights in thousands of pounds.)

[Match runway length to airport pressure altitude to obtain Runway Limit Weight.]

### FLAPS 25

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### FLAPS 30

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**ACTUAL ALLOWABLE LANDING WEIGHT [Lbs] (B747-400)**

**Use:** Obtain both Runway and Performance Limit Weights from tables on 3-5 and 3-6. Enter weights (in XXX.X format) into appropriate columns below. Add or subtract from weights as described in the sub-boxes of each associated column. When reaching the bottom, compare the final Performance Limit Weight and Runway Limit Weights. Use the highest weight as the maximum landing weight for the given runway. **BE SURE NOT TO EXCEED 630.0 (630,000lbs MAX GROSS LANDING WEIGHT).**
PERFORMANCE LIMIT WEIGHTS [Kgs]
(Weights listed in thousands of Kgs.)
[Match airport temperature to airport pressure altitude to obtain Performance Limit Weight.]

FLAPS
25

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RUNWAY LIMIT WEIGHTS [Kgs]
(Weights in thousands of Kgs.)
[Match runway length to airport pressure altitude to obtain Runway Limit Weight.]

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<th>1500M Runway</th>
<th>1800M Runway</th>
<th>2100M Runway</th>
<th>2400M Runway</th>
<th>2700M Runway</th>
<th>3000M Runway</th>
</tr>
</thead>
<tbody>
<tr>
<td>3000M</td>
<td>225.8</td>
<td>279.1</td>
<td>334.3</td>
<td>361.5</td>
<td>397.0</td>
<td>397.0</td>
</tr>
<tr>
<td>2700M</td>
<td>232.6</td>
<td>289.1</td>
<td>339.5</td>
<td>366.6</td>
<td>397.0</td>
<td>397.0</td>
</tr>
<tr>
<td>2400M</td>
<td>240.1</td>
<td>299.1</td>
<td>340.9</td>
<td>371.5</td>
<td>397.0</td>
<td>397.0</td>
</tr>
<tr>
<td>2100M</td>
<td>247.6</td>
<td>308.3</td>
<td>349.9</td>
<td>376.8</td>
<td>397.0</td>
<td>397.0</td>
</tr>
<tr>
<td>1800M</td>
<td>255.7</td>
<td>317.6</td>
<td>354.9</td>
<td>381.8</td>
<td>397.0</td>
<td>397.0</td>
</tr>
<tr>
<td>1500M</td>
<td>263.6</td>
<td>327.1</td>
<td>359.9</td>
<td>387.2</td>
<td>397.0</td>
<td>397.0</td>
</tr>
<tr>
<td>1200M</td>
<td>271.7</td>
<td>334.6</td>
<td>365.2</td>
<td>392.8</td>
<td>397.0</td>
<td>397.0</td>
</tr>
<tr>
<td>900M</td>
<td>279.9</td>
<td>339.6</td>
<td>370.2</td>
<td>397.0</td>
<td>397.0</td>
<td>397.0</td>
</tr>
<tr>
<td>600M</td>
<td>288.2</td>
<td>344.5</td>
<td>375.2</td>
<td>397.0</td>
<td>397.0</td>
<td>397.0</td>
</tr>
<tr>
<td>300M</td>
<td>296.5</td>
<td>349.5</td>
<td>380.6</td>
<td>397.0</td>
<td>397.0</td>
<td>397.0</td>
</tr>
<tr>
<td>S.L.</td>
<td>330.6</td>
<td>354.3</td>
<td>385.8</td>
<td>397.0</td>
<td>397.0</td>
<td>397.0</td>
</tr>
</tbody>
</table>
ACTUAL ALLOWABLE LANDING WEIGHT [Kgs] (B747-400)

**Use:** Obtain both Runway and Performance Limit Weights from tables on 3-5 and 3-6. Enter weights (in XXX.X format) into appropriate columns below. Add or subtract from weights as described in the sub-boxes of each associated column. When reaching the bottom, compare the final Performance Limit Weight and Runway Limit Weights. Use the highest weight as the maximum landing weight for the given runway. BE SURE NOT TO EXCEED 285.8 (285,800Kgs) MAX GROSS LANDING WEIGHT.

---

**Performance Limit Weight:** Enter PLW per PLW lookup table for appropriate flap setting.

**Runway Limit Weight:** Enter RLW per RLW lookup table for appropriate flap setting.

**Wind Correction:**
- +.5 / Knot of Headwind
- -1.8 / Knot of Tailwind
- UP TO +35/-10 Kts MAX

**Auto Speed Brake INOP Correction:**
- If Auto Spoiler Deployment is not functioning, then -27.2

**Maximum Allowable Landing Weight for Runway**

**Structural Landing Limit Weight.**
DO NOT EXCEED 285.8
RUNWAY WEIGHT LIMIT OVERVIEW (B747-400)

The Landing Runway Limit Tables provided here are calculated based on a normal approach, flown at the specified flap setting and VREF speed with a 50 foot (15 meter) threshold crossing, no wind, no spoilers, no reverse thrust, minimal aircraft float, and maximum braking. Crews should keep in mind that these figures were acquired using a new aircraft with new brakes and tires, so actual performance of an in-service aircraft may vary slightly. Runway Limit Weights in excess of the known structural weight limit are included for emergency use should a forced landing in excess of the Structural Limit Weight be required. Inclusion of these figures does not imply permission to land the aircraft above the Structural Limit Weight, and crews are encouraged to land the aircraft in such a condition only as a matter of last recourse.

If required to land the aircraft while still above the Structural Limit Weight, crews should anticipate a hot-brake condition, and ensure that adequate ground safety precautions are taken prior to arrival.

AUTOBRAKE SYSTEM ISSUES (B747-400)

Unlike a simple anti-skid system, the autobrake system used aboard the 747-400 aircraft is designed to modulate brake pressure to all sixteen main gear brake systems in order to provide the aircraft with a specific rate of deceleration. This rate of deceleration will be provided and maintained regardless of the use of spoilers or reverse thrust. The rate of deceleration is provided according to the settings below:

<table>
<thead>
<tr>
<th>Setting 1</th>
<th>Setting 2</th>
<th>Setting 3</th>
<th>Setting 4</th>
<th>MAX AUTO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting 1</td>
<td>Setting 2</td>
<td>Setting 3</td>
<td>Setting 4</td>
<td>MAX AUTO</td>
</tr>
<tr>
<td>4ft [1.2 M]/Second/Second</td>
<td>5ft [1.5 M]/Second/Second</td>
<td>6ft [1.8 M]/Second/Second</td>
<td>7.5ft [2.3 M]/Second/Second</td>
<td>11ft [3.4 M]/Second/Second</td>
</tr>
</tbody>
</table>

When used, spoilers and reverse thrust will reduce the total energy that would otherwise be absorbed by the brake systems. By reducing the amount of energy absorbed into the brake pads, spoilers and reverse thrust reduce the overall wear of the brake systems and aircraft tires. As such, crews are encouraged to use reverse thrust commensurate with safety and control of the aircraft on all landings.

LANDING SPEED TERMINOLOGY (B747-400)

__REF:__ The calculated reference speed for a specific flap configuration. (e.g. 30REF for a flaps 30 approach.) This speed is used to calculate the actual target speeds at which the aircraft will be flown. 30REF, 25REF speeds etc can be found on the Landing Speeds Table (3-3).

**Target Speed:** The speed at which the approach should be flown. Target speed should equal 25REF+5 or 30REF+5 knots. To this figure, add 1/2 steady wind plus the full gust factor (up to a maximum of 20 knots.)

**Threshold Speed:** Speed crossing the threshold. Equal to 25REF or 30REF plus the full gust factor, up to a maximum of 20kts.

**Autoland Target Speeds:** The speed at which the Autoland/Autothrottle approach is flown. Equal to 25REF+5 or 30REF + 5 knots, regardless of wind conditions. The Autothrottle corrects for normal wind gust conditions through the airspeed and acceleration sensing system. **When performing hand flown approaches with the autothrottle activated, apply normal wind and just corrections.**
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# PERFORMANCE REQUIREMENTS AND LIMITATIONS

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  MINIMUM TURNING RADIUS: .......................................................15
PERFORMANCE REQUIREMENTS AND LIMITATIONS

OVERVIEW: The following list of items have been accumulated from the aircraft manufacturer’s known limitations and requirements for operating the 747-400 aircraft, as well as from industry operators of the 747-400 and regulatory bodies responsible for the safe operation civil aircraft. This body of knowledge is brought together in this section in order to condense the various aircraft requirements and performance limitations to a single reference for crew use.

The following list of items is not considered to be conclusive of all operating conditions, and crews should use sound judgment and Standard Operating Principles to ensure the safe operation of the aircraft.

The following list is organized alphabetically by major subject matter.

AVIONICS

<table>
<thead>
<tr>
<th>Autoland - Maximum Wind Component</th>
<th>Wind Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>True Headwind Component</td>
<td>25 Knots</td>
</tr>
<tr>
<td>True Tailwind Component</td>
<td>10 Knots</td>
</tr>
<tr>
<td>Maximum Crosswind Component</td>
<td>25 Knots</td>
</tr>
<tr>
<td>Maximum One Engine-Out Crosswind</td>
<td>5 Knots</td>
</tr>
<tr>
<td>Maximum CAT III Autoland Crosswind</td>
<td>10 Knots</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Autopilot - Minimum Altitude to Engage</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>After Takeoff Autopilot Engagement</td>
<td>250ft [76 meters] AGL or greater</td>
</tr>
<tr>
<td>Non-Precision Approach</td>
<td>No Lower Than 360ft [110 meters] AGL</td>
</tr>
<tr>
<td>ILS Approach, Single Autopilot</td>
<td>Okay down to 50ft [15 meters] below DH/MDA, but not less than 50ft [15 meters] AGL</td>
</tr>
</tbody>
</table>

Inertial Reference System (IRS)

- The inertial Reference System is capable of providing magnetic heading and track information between 73° North Latitude and 60° South Latitude while in NAV mode.
- Crews are cautioned against operating in darkness or IFR conditions into airports north of 73° North Latitude or airports south of 60° South Latitude if the airport navigation aids are referenced to Magnetic North, as this will result in dangerously unreliable navigation data.
EMERGENCY EQUIPMENT

Emergency Escape Slides - Door Mounted
- Whenever passengers are carried, all door mounted evacuation slides must be armed and engaged prior to taxi, and must remain so until the aircraft is being prepared for passenger deplaning.

Oxygen Pressure - Correct Range

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Crew Oxygen System</td>
<td>1,650 psi</td>
</tr>
<tr>
<td>Passenger Oxygen System</td>
<td>1,600 psi</td>
</tr>
<tr>
<td>Portable Oxygen Bottles</td>
<td>1,600 psi</td>
</tr>
</tbody>
</table>

Oxygen Pressure Reading Adjustments:
- Temperature > 70°F: [Temperature > 21°C]: Add 3 psi per 1°F above 70°F [Add 6 psi per 1°C above 21°C]
- Temperature < 70°F: [Temperature < 21°C]: Subtract 3 psi per 1°F below 70°F [Subtract 6 psi per 1°C below 21°C]

ENGINES

EICAS Engine Instrument Setting Indicators

| Maximum N1 Engine Operating Limitation | RED     |
| Maximum Allowable Thrust (Cautionary) | AMBER   |
| Current/Normal Thrust Settings        | WHITE/GREEN |

EGT and Thrust Maximum

<table>
<thead>
<tr>
<th>Engine Activity</th>
<th>Time Limit</th>
<th>EICAS Marking Color</th>
<th>EGT (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Start</td>
<td>40 Sec</td>
<td>Red Bar</td>
<td>870°C</td>
</tr>
<tr>
<td>Takeoff. G/A</td>
<td>5 min</td>
<td>Red Bar</td>
<td>960°C</td>
</tr>
<tr>
<td>Max. Continuous EGT</td>
<td>None</td>
<td>Amber Bar</td>
<td>925°C</td>
</tr>
<tr>
<td>Standard Flight EGT</td>
<td>None</td>
<td>White/Green</td>
<td>750°C</td>
</tr>
</tbody>
</table>

Engine Indicating and Crew Alerting System (EICAS)
- If EICAS displays limit bars which are more conservative than the above book settings, crews must observe the EICAS limits. EICAS limits are determined based on current atmospheric and altitude conditions.
- Crews are advised not to blank the engine vibration display during takeoff, as this may provide an early indication of engine imbalance and or impending engine failure.

Continuous Engine Ignition
- Continuous Ignition should be selected ON during inflight encounters with heavy precipitation, and during severe turbulence. Continuous Ignition should be ON as a safety concern during takeoff and landing if birds are present in the airport vicinity.
Oil Pressure

| Minimum Idle: 10 | Other than Idle: 20 |

Oil Quantity

| Minimum Before Engine Start | 22 Quarts |

Oil Temperature

<table>
<thead>
<tr>
<th>Engine Activity</th>
<th>Time Limit</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Continuous</td>
<td>None</td>
<td>160°C</td>
</tr>
<tr>
<td>Maximum Temporary</td>
<td>15 Min</td>
<td>175°C</td>
</tr>
<tr>
<td>Maximum for Setting Takeoff Thrust</td>
<td>N/A</td>
<td>50°C</td>
</tr>
</tbody>
</table>

Reverse Thrust

<table>
<thead>
<tr>
<th>Flight Condition</th>
<th>Permissible Use of Reverse Thrust</th>
</tr>
</thead>
<tbody>
<tr>
<td>In Flight</td>
<td>Prohibited</td>
</tr>
<tr>
<td>On Landing Rollout while still &gt;80kts</td>
<td>Full Reverse until 80kts, then reduce to idle.</td>
</tr>
<tr>
<td>On Landing Rollout &lt;80kts.</td>
<td>Idle only.</td>
</tr>
<tr>
<td>Power Back from Gate or Parking</td>
<td>Prohibited per engine manufacturer.</td>
</tr>
</tbody>
</table>

RPM - Maximum Allowable

<table>
<thead>
<tr>
<th>N1</th>
<th>117.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>N2</td>
<td>112.5%</td>
</tr>
</tbody>
</table>

Starter Engagement Limitations

<table>
<thead>
<tr>
<th>Starter Engagement Activity</th>
<th>Required Cooling Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starter Engagement &lt;=5 Minutes</td>
<td>Until Engine De-spools to 0 RPM N2</td>
</tr>
<tr>
<td>Starter Engagement =&gt;5 Minutes</td>
<td>Time Equal to Starter ON time (ex 6min=6min)</td>
</tr>
</tbody>
</table>

- Maximum Continuous Starter Engagement Limit: 15 Minutes without cooling.
- Maximum Starter Re-Engagement RPM: 20% N2

FIRE PROTECTION

Cargo Fire Protection Envelope

| Maximum Recommended Flight Time from Suitable Airport to ensure Cargo Fire protection. | 180 Min |
# FUEL

## Fuel Capacity

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Pounds</th>
<th>Kgs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outboard Wing Tanks (Tanks 1 and 4) (each)</td>
<td>29,100lbs</td>
<td>13,200 kg</td>
</tr>
<tr>
<td>Inboard Wing Tanks (Tanks 2 and 3) (each)</td>
<td>83,800lbs</td>
<td>38,011kg</td>
</tr>
<tr>
<td>Reserve Tanks (Left and Right) (each)</td>
<td>8,800lbs</td>
<td>3,991kg</td>
</tr>
<tr>
<td>Stabilizer Tank</td>
<td>22,900lbs</td>
<td>10,387kg</td>
</tr>
<tr>
<td>Center Tank</td>
<td>119,500lbs</td>
<td>54,204kg</td>
</tr>
<tr>
<td><strong>TOTAL FUEL</strong></td>
<td><strong>386,000lbs</strong></td>
<td><strong>175,087kg</strong></td>
</tr>
</tbody>
</table>

- These are structurally limited fuel quantities which can only be achieved with extremely high density fuel.

## Fuel Imbalance - Maximum Limits

<table>
<thead>
<tr>
<th>Fuel Imbalance</th>
<th>Pounds</th>
<th>Kgs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Allowable Fuel Weight Difference Between Outboard Tanks 1 &amp; 4</td>
<td>3,000lbs</td>
<td>1,361kg</td>
</tr>
<tr>
<td>Maximum Allowable Fuel Weight Difference Between Inboard Tanks 2 &amp; 3</td>
<td>6,000lbs</td>
<td>2,722kg</td>
</tr>
<tr>
<td>Maximum Allowable Fuel Weight Difference Between Inboard and Outboard Tanks after Reaching ‘Fuel Tank to Engine’ Condition</td>
<td>6,000lbs</td>
<td>2,722kg</td>
</tr>
</tbody>
</table>

- Fuel Imbalance Warnings may not appear on EICAS until after limit is exceeded.

## Fuel Jettison

- Do not attempt to Jettison fuel with flaps in transit between 1° and 5°
- Ensure fuel jettison is completed prior to selecting flaps to 25° or 30° to ensure proper FMC calculated landing weights.

## Fuel Loading

- Load inboard and outboard wing tanks equally or within balance limits
- Once outboard wing tanks are full, load inboard wing tanks.
- Once all wing tanks are full, load reserve tanks.
- After all wing and reserve tanks are full, load center tank.
- While initially loading fuel into the center tank, note should be taken of the aircraft balance and tip limits, with fuel being stored in the stabilizer tank in conjunction with the center tank whenever balance limits permit.

## Fuel Temperature

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jet A</td>
<td>-37</td>
<td>+49</td>
</tr>
<tr>
<td>JP5</td>
<td>-43</td>
<td>+49</td>
</tr>
<tr>
<td>Jet A-1</td>
<td>-44</td>
<td>+49</td>
</tr>
</tbody>
</table>

- If fuel temperature approaches minimum temperature in flight, crews should consider a flight level change to warmer altitudes, or increasing speed to increase TAT.
- After bringing fuel temperature up to, or above minimum temperatures, crews should carefully assess the use of higher, colder altitudes for flight.
- In cases where the fuel temperature indicator is inoperative, the fuel tank temperature should be considered to equal True Air Temperature.
### Fuel Usage

<table>
<thead>
<tr>
<th>Fuel Tank Condition</th>
<th>Required Crew Action</th>
<th>FSMC Logic Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Tanks Full</td>
<td>Select all Valve and Pump switches <strong>ON</strong>.</td>
<td><strong>When Flaps Extended:</strong> FSMCs close crossfeed valves 2 &amp; 3. Override pumps fuel engines 1 &amp; 4, main tank pumps fuel engines 2 &amp; 3. <strong>When Flaps Retracted:</strong> FSMCs open crossfeed valves 2 &amp; 3. Override pumps in center tank fuel all engines.</td>
</tr>
<tr>
<td>Center Tank &lt;=36,287 Kgs</td>
<td>None</td>
<td>FSMCs activate transfer from stabilizer tank to center tank (inhibited on ground). Override pumps in center tank fuel all engines.</td>
</tr>
<tr>
<td>Stabilizer Tank Empty.</td>
<td>Confirm Tank quantities. Select both Stabilizer pump switches <strong>OFF</strong>.</td>
<td>Override Pumps in center tank provide fuel to all four engines.</td>
</tr>
<tr>
<td>Center tank quantity reaches 907 Kgs:</td>
<td>Confirm Tank quantities. Select both Center pump switches <strong>OFF</strong>.</td>
<td>A scavenging pump operates automatically to transfer remaining fuel in center tank to main tank 2. (Inhibited on ground.) FSMCs activate override pumps 2 &amp; 3. Main tank 2 fuels engines 1 &amp; 2. Main tank 3 fuels engines 3 &amp; 4.</td>
</tr>
<tr>
<td>Main Tank 2 or 3 quantity reaches 18,144 Kgs:</td>
<td>None</td>
<td>FSMCs activate transfer from reserve tanks 2 &amp; 3 to associated main tanks.</td>
</tr>
<tr>
<td>Main Tank 2 quantity is equal to or less than main tank 1, or main tank 3 is equal to or less than main tank 4: EICAS message ‘FUEL TANK/ENG’ is displayed.</td>
<td>Confirm tank quantities. Select override pump switches <strong>OFF</strong> and crossfeed switches 1 &amp; 4 <strong>OFF</strong>.</td>
<td>Main tank pumps fuel associated engines until engine shutdown.</td>
</tr>
</tbody>
</table>

### Landing Fuel - Minimum Allowable

<table>
<thead>
<tr>
<th>Description</th>
<th>Minimum Allowable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel On Board at Touchdown (Ensures adequate boost pump coverage.)</td>
<td>2,000lb 924kg</td>
</tr>
<tr>
<td>Fuel to Execute a Go-Around</td>
<td>4,800lb 2,176kg</td>
</tr>
<tr>
<td>Expected Fuel Quantity Indicator Error (Max designed indicator error.)</td>
<td>2,450lb 1,100kg</td>
</tr>
<tr>
<td>Minimum Desired Landing Fuel Total</td>
<td>9,250lb 4,200kg</td>
</tr>
</tbody>
</table>

- Minimum Desired Landing Fuel Total: Ensures a safe quantity of fuel on board at the time the aircraft crosses the runway threshold. This is a worst case scenario considered with maximum fuel quantity indicator error. Does not include fuel minimums required by Federal Aviation Regulations and sound flight planning.
HYDRAULICS

Auto-Brake System
• Use manual braking when anti-skid is inoperative or upon any indication of system fault.

Flaps/Slots Extension Altitude - Maximum

| Maximum Allowable Extension Altitude | 20,000ft [6,100 M] |

Hydraulic Quantity - Minimum

| Minimum Hydraulic Quantity at Dispatch Time | 72% of system capacity |

Inflight Spoilers

| Visual Meteorological Conditions | Not recommended below 1,000ft [305 M] AGL. |
| Instrument Meteorological Conditions | Use not recommended after FAF |

Tire Pressure

| Nose Gear Tires | 195 - 205 psi |
| Main Gear Tires | 205 - 215 psi |

• Tire mounted pressure indicators are only valid for pressure readings after tires, brakes and wheels have cooled to ambient temperature (allow approximately 1hr after parking for a normal landing, 2hrs after a hard braking condition.)
• Tire pressure requirements are based upon the design structural limit weight of the aircraft.

Tire Pressure Adjustments
• Temperature >70°F: Add 1 psi per 3°F above 70°F
  [Temperature >21°C: Add 2 psi per 3°C above 21°C]
• Temperature <70°F: Subtract 1 psi per 3°F below 70°F
  [Temperature <21°C: Subtract 2 psi per 3°C below 21°C]

ICE AND RAIN

Anti Ice Systems
• Engine and Wing Anti-Ice systems should not be operated when OAT >10°C during ground operations, or when TAT >=10°C during flight.

Engine Anti-Ice
• Engine anti-ice must be selected ON during all ground and flight operations when icing conditions exist or are anticipated.
• Engine anti-ice does not need to be used during climb and cruise segments when the temperature is less than -40°C SAT.
• Engine anti-ice must be activated prior to, and operated during a descent in icing conditions. Engine anti-ice should be activated even if the temperature falls below -40°C SAT during the descent.
• During ground operations lasting more than ten minutes in icing conditions, engine anti-ice capabilities must be reinforced by momentarily selected a thrust setting of 50% N1 for each
engine (separately). Use caution for jet blast and FOD dangers associated with accumulated ice or snow on taxiways and runways.
Known Icing Conditions
- Icing conditions are said to exist for taxi, takeoff and landing operations when:

| Outside Air Temperature | 10°C (50°F) or below |

and/or:

- Visible moisture of any form is present (clouds, fog, visibility of 1 mile or less, snow, rain, sleet or ice crystals).
- Standing water, snow, slush or ice accumulations are present in a form which may be ingested by the engines or freeze to nacelles, blades or sensors.

- Icing conditions are said to exist in flight when:

| Total Air Temperature | 10°C (50°F) or below |

and:

- Visible moisture of any form is present (clouds, fog, visibility of 1 mile or less, snow, rain, sleet or ice crystals).

Rain Repellent
- Do not apply repellent to a dry windshield. If repellent is inadvertently discharged onto window, do not activate windshield wipers. Allow repellent to disperse in the aircraft slipstream.
- Apply repellent only in rain or snow conditions which restrict forward visibility through the cockpit windscreen.
- Crews are required to make appropriate logbook entries if rain repellent is used in flight.

APU Starter Limitations
| Time off between APU start attempts | 1 Minute |

PNEUMATICS

Airplane altitude vs. Cabin Altitude

Avionics/Equipment Cooling (Ground Operations)

<table>
<thead>
<tr>
<th>OAT °F (°C)</th>
<th>Cooling Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>94 to 105°F [34° to 41°C]</td>
<td>At least one air conditioning pack or equivalent ground cooling equipment operating, or at least one forward and one aft entry doors open on opposite sides of the aircraft.</td>
</tr>
<tr>
<td>106 to 120°F [41° to 49°C]</td>
<td>At least one air conditioning pack or equivalent ground cooling equipment operating.</td>
</tr>
<tr>
<td>Greater than 120°F [49°C]</td>
<td>Two air conditioning packs or equivalent ground cooling equipment operating.</td>
</tr>
</tbody>
</table>
Pressurization - Cabin Differential Limits

<table>
<thead>
<tr>
<th>Condition</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Takeoff and Landing</td>
<td>0.11 psi</td>
</tr>
<tr>
<td>Max Differential – Operating</td>
<td>9.4 psi</td>
</tr>
<tr>
<td>Max Differential - During Climb</td>
<td>9.4 psi</td>
</tr>
</tbody>
</table>

**AUTOLAND / INSTRUMENT LANDING SYSTEM**

**Autoland/Instrument Landing System**

<table>
<thead>
<tr>
<th>Equipment</th>
<th>CAT IIIb Autoland Land 3</th>
<th>CAT IIIa Autoland Land 3</th>
<th>CAT II Autoland Land 2</th>
<th>CAT I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autopilots</td>
<td>3 CMD</td>
<td>3 CMD</td>
<td>2 CMD</td>
<td>1 Flight Director or 1 Autopilot</td>
</tr>
<tr>
<td>Electronic ADIs</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>ILS Deviation Indicator</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>Not Required</td>
</tr>
<tr>
<td>Radar Altitude Readout with DH</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>Not Required</td>
</tr>
<tr>
<td>AFDS Mode annunciation</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>Not Required</td>
</tr>
<tr>
<td>Missed Approach Attitude Guidance</td>
<td>Required</td>
<td>Required</td>
<td>Not Required</td>
<td>Not Required</td>
</tr>
<tr>
<td>Autoland Status Annunciators</td>
<td>2</td>
<td>2</td>
<td>1 for Pilot Flying</td>
<td>Not Required</td>
</tr>
<tr>
<td>IRUs (in NAV mode)</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>Not Required</td>
</tr>
<tr>
<td>Autotrottle</td>
<td>1</td>
<td>1</td>
<td>Not Required</td>
<td>Not Required</td>
</tr>
<tr>
<td>AC Electric Power Source</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>Not Required</td>
</tr>
<tr>
<td>Hydraulic Systems</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Rollout Guidance</td>
<td>Required</td>
<td>Not Required</td>
<td>Not Required</td>
<td>Not Required</td>
</tr>
<tr>
<td>Autobrakes</td>
<td>Required</td>
<td>Not Required</td>
<td>Not Required</td>
<td>Not Required</td>
</tr>
<tr>
<td>Windshield Wipers</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>Not Required</td>
</tr>
<tr>
<td>Marker Beacons*</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Not Required</td>
</tr>
<tr>
<td>Reversers</td>
<td>2</td>
<td>Not Required</td>
<td>Not Required</td>
<td>Not Required</td>
</tr>
<tr>
<td>Operative Engines</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Antiskid</td>
<td>Required**</td>
<td>Not Required</td>
<td>Not Required</td>
<td>Not Required</td>
</tr>
</tbody>
</table>

*If approach to be flown requires Marker beacon use to determine DH or AH
** If RVR is below 600ft [180 Meters.]

**Autoland - Flap Setting Limits**
- Autoland is only approved for settings of flap 25 or flap 30.

**Autoland - Approach Glideslope Slope Limits**

<table>
<thead>
<tr>
<th>Glideslope Angle</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>2.50°</td>
</tr>
<tr>
<td>Maximum</td>
<td>3.25°</td>
</tr>
</tbody>
</table>
### SPEEDS

**$V_A$ - Design Maneuvering Speed (KIAS/ Mach)**

<table>
<thead>
<tr>
<th>Sea Lvl</th>
<th>10,000ft [3000M]</th>
<th>20,000ft [6000M]</th>
<th>29,000ft [9000M]</th>
<th>30,000ft [9000M]</th>
<th>34,000ft [10000M]</th>
<th>36,000ft [11000M]</th>
<th>40,000ft [12000M]</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>315</td>
<td>330</td>
<td>336/.86</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**$V_{FE}$ - Flaps Extension Speeds - Maximum (KIAS)**

<table>
<thead>
<tr>
<th>Flaps 1</th>
<th>Flaps 5</th>
<th>Flaps 10</th>
<th>Flaps 20</th>
<th>Flaps 25</th>
<th>Flaps 30</th>
</tr>
</thead>
<tbody>
<tr>
<td>280</td>
<td>260</td>
<td>240</td>
<td>230</td>
<td>205</td>
<td>180</td>
</tr>
</tbody>
</table>

**$V_{LO}$ / $V_{LE}$ - Landing Gear Limit Speeds - Maximum (KIAS / Mach)**

<table>
<thead>
<tr>
<th>$V_{LO}$ - Retraction</th>
<th>270 KIAS / .82M</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{LO}$ - Extension</td>
<td>270 KIAS / .82M</td>
</tr>
<tr>
<td>$V_{LE}$ - Extended</td>
<td>320 KIAS / .82M</td>
</tr>
</tbody>
</table>

Maximum Tire Limit Speed 204 Knots Ground Speed

**$V_{MO}$ / $M_{MO}$ - Maximum Operating Limit Speeds (KIAS / Mach)**

<table>
<thead>
<tr>
<th>20,000ft &amp; Lower [6000M &amp; Lower]</th>
<th>25,000ft [7600 M]</th>
<th>30,000ft [9200 M]</th>
<th>35,000ft [10,700 M]</th>
<th>40,000ft [12,200 M]</th>
</tr>
</thead>
</table>

- $V_{MO}$ / $M_{MO}$ - Shall not be exceeded during any phase of flight.

**$V_{MCG}$ - Minimum Controllable Ground Speed (Same as Minimum Allowable V1 Setting)**

<table>
<thead>
<tr>
<th>Pres. Alt.</th>
<th>&lt;50F &lt;10C</th>
<th>60F 15C</th>
<th>70F 21C</th>
<th>80F 27C</th>
<th>90F 32C</th>
<th>100F 38C</th>
<th>110F 43C</th>
<th>120F 43C</th>
<th>130F 54C</th>
</tr>
</thead>
<tbody>
<tr>
<td>13000ft [4000 M]</td>
<td>106</td>
<td>104</td>
<td>101</td>
<td>97</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>10000ft [3000 M]</td>
<td>108</td>
<td>107</td>
<td>104</td>
<td>100</td>
<td>98</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>8000ft [2400 M]</td>
<td>110</td>
<td>108</td>
<td>107</td>
<td>105</td>
<td>100</td>
<td>96</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>6000ft [1800 M]</td>
<td>113</td>
<td>113</td>
<td>112</td>
<td>108</td>
<td>105</td>
<td>102</td>
<td>97</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>4000ft [1200 M]</td>
<td>117</td>
<td>116</td>
<td>116</td>
<td>115</td>
<td>110</td>
<td>106</td>
<td>102</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>2000ft [600 M]</td>
<td>118</td>
<td>117</td>
<td>117</td>
<td>117</td>
<td>113</td>
<td>110</td>
<td>106</td>
<td>100</td>
<td>--</td>
</tr>
<tr>
<td>S.L.</td>
<td>119</td>
<td>118</td>
<td>118</td>
<td>118</td>
<td>117</td>
<td>115</td>
<td>112</td>
<td>106</td>
<td>100</td>
</tr>
</tbody>
</table>

**Maximum Turbulent Air Penetration Speed**

15,000ft [4600 meters] and higher altitude 290 KIAS / .780M
| 15,000ft [4600 meters] and lower altitude | 250 KIAS |
### Stall Speeds

<table>
<thead>
<tr>
<th>Flap POS</th>
<th>Gear POS</th>
<th>213</th>
<th>231</th>
<th>250</th>
<th>268</th>
<th>286</th>
<th>304</th>
<th>322</th>
<th>340</th>
<th>358</th>
<th>376</th>
<th>394</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 UP</td>
<td></td>
<td>152</td>
<td>159</td>
<td>166</td>
<td>172</td>
<td>178</td>
<td>184</td>
<td>189</td>
<td>196</td>
<td>202</td>
<td>208</td>
<td>214</td>
</tr>
<tr>
<td>1 UP</td>
<td></td>
<td>136</td>
<td>140</td>
<td>147</td>
<td>152</td>
<td>157</td>
<td>162</td>
<td>167</td>
<td>172</td>
<td>177</td>
<td>183</td>
<td>189</td>
</tr>
<tr>
<td>5 UP</td>
<td></td>
<td>129</td>
<td>132</td>
<td>137</td>
<td>143</td>
<td>147</td>
<td>152</td>
<td>157</td>
<td>163</td>
<td>167</td>
<td>176</td>
<td>180</td>
</tr>
<tr>
<td>10 UP</td>
<td></td>
<td>124</td>
<td>130</td>
<td>134</td>
<td>139</td>
<td>143</td>
<td>149</td>
<td>153</td>
<td>159</td>
<td>163</td>
<td>167</td>
<td>172</td>
</tr>
<tr>
<td>20 UP</td>
<td></td>
<td>121</td>
<td>126</td>
<td>129</td>
<td>134</td>
<td>138</td>
<td>143</td>
<td>148</td>
<td>152</td>
<td>156</td>
<td>163</td>
<td>166</td>
</tr>
<tr>
<td>25 DN</td>
<td></td>
<td>116</td>
<td>120</td>
<td>125</td>
<td>129</td>
<td>134</td>
<td>138</td>
<td>142</td>
<td>146</td>
<td>152</td>
<td>156</td>
<td>160</td>
</tr>
<tr>
<td>30 DN</td>
<td></td>
<td>112</td>
<td>116</td>
<td>120</td>
<td>123</td>
<td>128</td>
<td>132</td>
<td>136</td>
<td>140</td>
<td>146</td>
<td>150</td>
<td>152</td>
</tr>
</tbody>
</table>

- ISA Conditions

### Structural Weights

<table>
<thead>
<tr>
<th></th>
<th>Pounds</th>
<th>Kgs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Taxi</td>
<td>877,000lb</td>
<td>397,800kg</td>
</tr>
<tr>
<td>Maximum Takeoff</td>
<td>875,000lb</td>
<td>396,893kg</td>
</tr>
<tr>
<td>Maximum In-flight Landing</td>
<td>650,000lb</td>
<td>294,835kg</td>
</tr>
<tr>
<td>Maximum Landing</td>
<td>630,000lb</td>
<td>285,763kg</td>
</tr>
<tr>
<td>Maximum Zero Fuel</td>
<td>535,000lb</td>
<td>242,671kg</td>
</tr>
</tbody>
</table>

### GENERAL LIMITATIONS

**Certification Status**

The 747-400 is certified under the 747 Type Certificate, in the Transport Category, US FAR Parts 25 and 36.

**Flight Crew Requirements**

<table>
<thead>
<tr>
<th>Minimum</th>
<th>Captain and First Officer</th>
</tr>
</thead>
</table>

**Flight Load Acceleration Limitations**

- Flaps Up: +2.5 g to -1.0 g
- Flaps Down: +2.0 g to 0.0 g

**Pressure Altitude - Maximum**

- Takeoff and Landing: 8,400ft [2,560 Meters]
- Operating: 42,000ft [12,800 Meters]

**Runway Slope Limitations**

<table>
<thead>
<tr>
<th>Maximum</th>
<th>+/- 2%</th>
</tr>
</thead>
</table>

Revision – 26JUL05

DO NOT DUPLICATE

PMDG 747-400 AOM
MINIMUM TURNING RADIUS

Minimum Turning Radius:  47 Meters for 180° Turn
Conducted using a slow continuous turn with functional body gear steering. No differential braking during turn. Nose and Tail will turn within arc traced by wing tip.
# NORMAL PROCEDURES

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<td>FIRST OFFICER’S FLIGHT DECK PREFLIGHT</td>
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<td>CAPTAIN’S FLIGHT DECK PREFLIGHT</td>
<td>8</td>
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<tr>
<td>CAPTAIN’S FLIGHT DECK PREFLIGHT</td>
<td>9</td>
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<td>FINAL COCKPIT PREPARATION</td>
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<td>ENGINE START</td>
<td>12</td>
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<tr>
<td>AFTER START</td>
<td>13</td>
</tr>
<tr>
<td>TAXI OUT</td>
<td>13</td>
</tr>
<tr>
<td>TAKEOFF</td>
<td>14</td>
</tr>
<tr>
<td>AFTER TAKEOFF</td>
<td>15</td>
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<tr>
<td>CLIMB</td>
<td>15</td>
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<tr>
<td>CRUISE</td>
<td>15</td>
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<td>INITIAL APPROACH</td>
<td>16</td>
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<td>FINAL APPROACH</td>
<td>16</td>
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<tr>
<td>TAXI IN</td>
<td>16</td>
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<tr>
<td>PARKING AND SHUTDOWN</td>
<td>17</td>
</tr>
<tr>
<td>LEAVING AIRCRAFT</td>
<td>17</td>
</tr>
</tbody>
</table>
THIS PAGE INTENTIONALLY BLANK
NORMAL PROCEDURES

OVERVIEW: The following sets of procedures follow step by step through the processes required to fly the PMDG 747-400. These normal procedures are divided by major flight phase and should provide a basic guideline for accomplishing the major procedures required during flight. Although these checklists do not need to be removed from the manual and followed on a step by step basis, crews are encouraged to develop a pattern of behavior which ensures that all of the following steps are accomplished in the correct order and format. Use of the in flight checklist procedures (bolded checklist steps) is required of crewmembers.

In the interest of containing operating costs, external ground power should be used during the initial cockpit preparation. This will allow the crew to delay APU start until immediately before departure. In circumstances where the quality of an external power connection is an issue, or when ground based aircraft cooling is not available, crews may elect to start the APU at their discretion in the interest of preserving an on-time departure and passenger climate comfort.

In Cold Weather Operations crews should ensure that the cockpit has not been set up for aircraft deicing operations by ground crew. If this is determined to be the case, crews are advised not to begin cockpit preparation until clearing their actions with the ground crew in order to prevent damage to the aircraft or injuries to ground personnel.

FIRST OFFICER’S FLIGHT DECK PREFLIGHT
(If aircraft is already powered, start below dashed line.)

BATTERY SWITCH .................................................................ON
STANDBY POWER SELECTOR ..............................................AUTO
HYDRAULIC DEMAND PUMP SELECTORS ..............................OFF
EXT PWR SWITCHES 1 & 2 (If Available)..................................ON
If no EXT Power Available:
   INBD CRT SELECTOR .....................................................EICAS
   ALTERNATE FLAP SELECTOR ...........................................OFF
   LANDING GEAR LEVER .....................................................DOWN
   FLAP POSITION INDICATOR AND FLAP LEVER .................AGREE
   APU BLEED SWITCH ......................................................OFF
   APU (IF NEEDED) ..............................................................START
   Rotate APU selector to START, then release to ON. After APU has spooled up and is running, APU GENERATOR 1 and or 2 AVAIL lights will illuminate. Push APU GENERATOR 1 and or 2 switches. Do not select or de-select both simultaneously. Verify ON light illuminates and AVAIL light extinguishes.
   APU GEN SWITCHES ......................................................VERIFY ON
   ELECTRONIC ENGINE CONTROL SWITCHES ........................NORM
   Verify ALTN lights extinguished and guards are closed.
   IRS SELECTORS ..............................................................OFF, then NAV, then ALIGN
   Set switches to NAV when IRS Align time counters reach 0 on Nav Display.
ELECTRICAL PANEL

EICAS ELEC PAGE ................................................................. DISPLAY
L, R UTILITY BUS SWITCHES ................................................ ON
  Verify OFF light extinguished.
BUS TIE SWITCHES ............................................................... AUTO
  Verify ISLN lights extinguished.
GEN CONT SWITCHES ............................................................ ON
  Verify OFF and DRIVE lights illuminated.
NAV LIGHTS ........................................................................... ON
  For safety, Nav lights should remain illuminated whenever aircraft has functioning electrical power
  provided by APU, ground power, or engine generators. If operating only on battery power, Nav
  Lights should be selected OFF.
BATTERY ..................................................................................... CHECK
  Rotate the Standby Power selector to BAT and verify the BAT DISCH or BAT DISCH APU
  message appears on the EICAS and the OFF light does not illuminate. Rotate the selector to
  AUTO and verify the EICAS message is cleared and the OFF light does not illuminate.

HYDRAULIC PANEL:

EICAS HYD PAGE ................................................................. DISPLAY
Hydraulic SYS FAULT and demand pump PRESS lights ................. ILLUMINATED
HYD DEMAND PUMP SELECTORS 1-4 ...................................... OFF
HYD ENG PUMP SWITCHES 1 - 4 ............................................. ON

EMERGENCY LIGHTS SWITCH .................................................. ARMED (guard closed)

FIRE CONTROL PANEL:

ENGINE FIRE SWITCHES ....................................................... IN
BTL A DISCH and BTL B DISCH lights ....................................... EXTINGUISHED
APU BTL DISCH light ............................................................... EXTINGUISHED
APU FIRE SWITCH ................................................................. IN
CARGO FIRE DISCH light ......................................................... EXTINGUISHED
CARGO FIRE ARM SWITCHES ................................................. OFF
  Verify FWD and AFT lights extinguished

ENGINE START PANEL:

ENGINE START SELECTORS 1 - 4 .......................................... IN, LIGHTS EXTINGUISHED
STANDBY IGNITION SELECTOR ............................................. NORM
CONTINUOUS IGNITION SWITCH ............................................. OFF
AUTO IGNITION SWITCH ....................................................... SINGLE
AUTOSTART SWITCH ............................................................. ON

FUEL JETTISON PANEL

EICAS FUEL PAGE ............................................................... DISPLAY
FUEL JETTISON SELECTOR ..................................................... OFF
L, R, JETTISON NOZZLE SWITCHES ...........................................OFF, NOT ILLUMINATED
FUEL PANEL:
FUEL DISTRIBUTION AND TOTAL FUEL QUANTITY ................................................CHECK
All XFEED Switches ..............................................................................................ON
Verify VALVE lights extinguish
FUEL PUMP SWITCHES .........................................................................................ALL OFF
Verify PRESS lights illuminate on all eight MAIN pump switches.
If APU is running, MAIN 2 AFT pump PRESS light will extinguish
Verify PRESS lights are extinguished on:
MAIN2/3 OVRD Pumps
CENTER L/R Pumps
HORIZONTAL STAB L/R Pumps

ANTI ICE PANEL:
EICAS ECS PAGE ..................................................................................................DISPLAY
NACELLE ANTI-ICE SWITCHES ..............................................................................OFF
Verify VALVE lights extinguish.
WING ANTI-ICE SWITCH ......................................................................................OFF
Verify VALVE lights extinguish.
WINDOW HEAT SWITCHES ..................................................................................ON
Verify INOP lights extinguished.
WINDSHIELD WIPER SELECTORS .........................................................................OFF

PAX OXYGEN SWITCH .........................................................................................NORM (guard closed)
YAW DAMPER SWITCHES .....................................................................................ON

CABIN ALTITUDE PANEL:
OUTFLOW VALVES .................................................................................................VERIFY OPEN
LANDING ALTITUDE SWITCH .................................................................................AUTO
OUTFLOW VALVE MANUAL SWITCHES ..................................................................OFF
CABIN ALTITUDE AUTO SELECTOR .........................................................................NORM

ECS Panel:
PASSENGER TEMPERATURE SELECTOR ..............................................................AUTO
FLIGHT DECK TEMPERATURE SELECTOR ............................................................AUTO
ZONE SYS FAULT light .........................................................................................EXTINGUISHED
TRIM AIR SWITCH .................................................................................................ON
UPR, LWR RECIRC FAN SWITCHES ......................................................................ON
If ground based cooling is being used during temperatures exceeding 85°F, LWR RECIRC FAN
should be switched on at least 20 minutes prior to passenger boarding in order to evacuate
warmer air from lower deck E&E spaces.
AFT CARGO HEAT SWITCH ..................................................................................OFF
EQUIPMENT COOLING SELECTOR .........................................................................NORM
If OAT is less than 70°F, set to NORM. If above 70°F, set to OVRD.
HIGH FLOW SWITCH .............................................................................................OFF
GASPER SWITCH .................................................................................................ON
PNEUMATICS PANEL
Pack SYS FAULT Light .............................................................. EXTINGUISHED
PACK SELECTORS 1, 2, AND 3 ...................................................... NORM
L, R ISLN SWITCHES ................................................................. OPEN
   Verify VALVE lights extinguished.
Engine Bleed air SYS FAULT lights ........................................ EXTINGUISHED
APU BLEED SWITCH ................................................................. ON
   Allow the APU to operate for at least one full minute before activating APU bleed switch.
ENG BLEED SWITCHES ............................................................. VERIFY ON

LIGHTING PANEL:
COCKPIT LIGHTING ................................................................. AS DESIRED
EXTERIOR LIGHTING
   LANDING LIGHTS INBD/OUTBD ............................................. OFF
   RUNWAY TURN-OFF LIGHTS ................................................ OFF
   TAXI LIGHTS ............................................................................. OFF
   BEACON ................................................................................. OFF
   NAV LIGHTS ............................................................................ VERIFY ON
   STROBE ................................................................................ OFF
   WING LIGHTS .......................................................................... OFF
   LOGO LIGHTS .......................................................................... ON

SECONDARY EICAS STAT PAGE.................................................... DISPLAY
EICAS ADVISORY/CAUTION/WARNING MESSAGES.......................... CHECK/ERASE

FMC-CDU:
See FMC Guide (Chapter 12) for detailed FMC instructions.
IDENT PAGE ................................................................................. SELECT
   Verify airplane model number and engine model number.
   Verify NAVDATA is current. (Download updates from www.navdata.at)
POS INIT PAGE ............................................................................. SELECT
   REFerence AIRPORT ENTER ICAO
   Set IRS Position ENTER
   UTC VERIFY
ROUTE PAGE
   ORIGIN/DESTINATION ENTER
   ROUTE ENTER
   ACTIVATE PUSH
   EXEC key PUSH
DEP/ARR PAGE
   Runway and SID for departure SELECT
ROUTE PAGE
   SID and route VERIFY
   EXEC key PUSH
NAV/RAD PAGE
   DISPLAY
Navigation Radios

INIT REF PAGE

CENTER CONSOLE RADIOS:

WEATHER RADAR
Note: Wx Radar Functionality not modeled.

RADIO TUNING PANEL

AUDIO PANEL

AILERON AND RUDDER TRIM

TRANSPONDER:

TRANSPONDER MODE SELECTOR

ATC SWITCH
Verify TCAS System Test Passes.

AUTOBRAKES SELECTOR

CLOCK

CRT SELECTORS:

LOWER CRT SELECTOR

INBOARD CRT SELECTOR

GROUND PROXIMITY:

Ground PROX light

Ground proximity FLAP OVERRIDE SWITCH

Ground proximity CONFIG/GEAR OVERRIDE SWITCH

Ground Proximity TERRAIN OVERRIDE SWITCH

ALTERNATE FLAPS/GEAR:

LANDING GEAR LEVER

ALTERNATE FLAPS SELECTOR

ALTERNATE FLAPS ARM SWITCH

ALTERNATE GEAR EXTEND SWITCHES

HEADING REFERENCE SELECTOR

SECONDARY EICAS ‘STAT’ PAGE

Hydraulic Quantity

Oxygen Pressure

EICAS CONTROL PANEL:

CAUTION MESSAGES
CAPTAIN'S FLIGHT DECK PREFLIGHT

CAPTAIN'S EFIS CONTROL PANEL

SET AS DESIRED

AUTOPILOT MODE CONTROL PANEL:

FLIGHT DIRECTOR SWITCHES .............................................................. ON
AUTO THRUST ARM SWITCH ......................................................... OFF
BANK LIMIT SELECTOR ..................................................................... AS DESIRED
AUTOPILOT DISENGAGE BAR .......................................................... UP
HDG INDICATOR ............................................................................ SET RUNWAY HEADING
ALT INDICATOR ............................................................................... SET INITIAL CLEARED ALTITUDE

FMC-CDU:

ACTIVE NAVIGATION DATA CHECK
POS INIT Key PUSH
Present Position CHECK
UTC CHECK
ROUTE Line Select Key PUSH
Route of Flight VERIFY
INIT REF Key PUSH
INDEX Line Select Key PUSH
APPROACH Line Select Key PUSH
FLAP/SPEED Line VERIFY BLANK
INIT REF Key PUSH

CENTER CONSOLE:

PARKING BRAKE SET
SPEED BRAKE LEVER DOWN
REVERSE THRUST LEVERS DOWN
FLAP LEVER SET
Position Lever to Agree with Flap Position.

FUEL CONTROL SWITCHES CUTOFF
STABILIZER TRIM CUTOUT SWITCHES AUTO (Guards Closed)
Stab Trim Cutout Function not modeled in this version.

RADIO TUNING PANEL AS DESIRED
AUDIO PANEL AS DESIRED

PASSENGER SIGNS:

NO SMOKING SELECTOR AUTO or ON
SEATBELTS SELECTOR AUTO or ON
CLOCK VERIFY/SET AS DESIRED

CRT SELECTORS:

LOWER CRT SELECTOR NORM
INBOARD CRT SELECTOR NORM

PMDG 747-400 AOM DO NOT DUPLICATE Revision – 26JUL05
PRIMARY FLIGHT DISPLAY (Both Capt and FO):

FLIGHT MODE ANNUNCIATION
- Autothrottle Mode: BLANK
- Roll Mode: TO/GA
- Pitch Mode: TO/GA
- Autopilot Flight Director Status: FD

DISPLAYS
- Verify no flags displayed.
- Verify no V SPD flag displayed until V-Speeds selected.

HEADING BUG
- Verify matches AFDS MCP Window

ALTIMETER

NAVIGATION DISPLAY (Both Captain and FO):

HEADING/TRACK
- CHECK

ROUTE
- DISPLAYED

DISPLAY
- CHECK

FINAL COCKPIT PREPARATION

FUEL
- CHECK

Verify Fuel Quantity in FMC-CDU, EICAS and your flight plan match.

FMC

ROUTE OF FLIGHT
- ENTER

RUNWAY, SID
- ENTER

On DEPARTURES pages select the runway and SID if applicable.

FMC PERF INIT PAGE

ZFW
- ENTER

RESERVES
- ENTER

COST INDEX
- ENTER

CRZ ALT
- ENTER

FMC THRUST LIM PAGE

OAT
- ENTER

THRUSTRATING
- SELECT, CHECK

Verify thrust rating N1% performance numbers are reflected on upper EICAS display.

FMC TAKEOFF PAGE

TAKEOFF FLAP SETTING
- SELECT, VERIFY

RUNWAY CONDITION
- ENTER WET/DRY

TAKEOFF SPEEDS
- CONFIRM, VERIFY

FMC VNAV CLB PAGE

SPEED/TRANSITION ALT
- ENTER

SPD/RESTR
- ENTER

Enter clean maneuvering speed in the SPD/RESTR line for VNAV use below 3000 feet AGL.
MCP IAS/MACH INDICATOR ...........................................................SET TO V2+10

APU (IF NOT RUNNING) .................................................................START
   Rotate APU selector to START, then release to ON. After APU has spooled up and is running,
   APU GENERATOR 1 and or 2 AVAIL lights will illuminate. Push APU GENERATOR 1 and or 2
   switches. Do not select or de-select both simultaneously. Verify ON light illuminates and AVAIL
   light extinguishes.

FUEL PUMPS AND OVERRIDE FUEL PUMPS...........................................ON
   Select Pumps ON only for tanks containing fuel.

FUEL CROSSFEEDS.................................................................SET
   If tank quantity 2 is more than 1 and tank 3 is more than 4: All crossfeeds ON.
   If tank quantity 2 is less\equal to 1 and tank 3 is less\equal to 4: Crossfeeds 1 & 4 OFF, Override
   pumps 2 & 3 OFF

STAB TRIM .................................................................CHECK SET IN GREEN

SECONDARY EICAS DOORS PAGE ..................................................DISPLAY
   Verify all doors secured.

BEFORE START CHECKLIST ......................................................PERFORM

PUSHBACK AND START

DOORS CLOSED ..............................................................VERIFY

PUSHBACK/START CLEARANCE ...............................................OBTAIN

BEFORE PUSHBACK CHECKLIST ...............................................PERFORM

PUSHBACK COMMUNICATIONS/GND SVC INTERCOM .........................COMPLY

HYDRAULIC DEMAND PUMP SELECTOR 4 .....................................AUX

HYDRAULIC DEMAND PUMP SELECTORS 1-3 ..................................AUTO

RED ANTI-COLLISION BEACON .............................................BOTH

PACK SELECTORS..........................................................ONE ON or ALL OFF

RECALL SWITCH ..................................................PUSH
   Verify only appropriate alert messages displayed.

SECONDARY EICAS ‘ENG’ DISPLAY ...........................................DISPLAY

EICAS CANCEL ..........................................................PUSH
ENGINE START

DUCT PRESSURE .............................................................................................................MONITOR

Verify that sufficient duct pressure exists for a normal engine start. Duct pressure should exceed 30 psi immediately after ENGINE START SELECTOR is pulled. Duct pressures below this level increases the probability of an abnormal or hot start. If duct pressure is low, close opposite side cross bleed valve

START ENGINE NUMBER ____ .........................................................................................ANNOUCE

   Engines 1 & 4 and engines 2 & 3 may be started simultaneously.

AUTOSTART IN USE:

FUEL CONTROL SWITCH ____ ............................................................................................RUN

ENGINE START SELECTOR..............................................................................................PULL, VERIFY ILLUMINATION

ENGINE INDICATIONS .......................................................................................................MONITOR

   Monitor N2 indication for engine rotation and observe oil pressure indication. Maximum motoring is reached when N2 stops increasing for five seconds. At 25% N2 or maximum motoring, whichever is less, but not less than the N2 start bar:

EICAS ENGINE INDICATIONS ..........................................................................................MONITOR

   At approximately 50% N2:

ENG START SELECTOR .........................................................VERIFY ILLUMINATION EXTINGUIshed

After starter cutout and RPM stabilization of engine:

START ENGINE NUMBER ____ .................................................................................REPEAT FOR ALL ENGINES

   Engines 1 & 4 and engines 2 & 3 may be started simultaneously.

MANUAL START:

ENGINE START SELECTOR..............................................................................................PULL, VERIFY ILLUMINATION

FUEL CONTROL SWITCH ____ ............................................................................................RUN

   Verify N2% RPM has reached magenta start line before introducing fuel.

ENGINE INDICATIONS .......................................................................................................MONITOR

   Monitor N2 indication for engine rotation and observe oil pressure indication. Maximum motoring is reached when N2 stops increasing for five seconds. At 25% N2 or maximum motoring, whichever is less, but not less than the N2 start bar:

EICAS ENGINE INDICATIONS ..........................................................................................MONITOR

   At approximately 50% N2:

ENG START SELECTOR .........................................................VERIFY ILLUMINATION EXTINGUIshed

After starter cutout and RPM stabilization of engine:

START ENGINE NUMBER ____ .................................................................................REPEAT FOR ALL ENGINES

   Engines 1 & 4 and engines 2 & 3 may be started simultaneously.
AFTER START

APU SELECTOR ..............................................................................................................OFF
  If extended delays are anticipated which may require engine shutdown, leave APU running.
HYDRAULIC DEMAND PUMP SELECTOR 4 ....................................................................AUTO
ENG ANTI-ICE SWITCHES ..........................................................................................AS REQUIRED
  If <10C with visible moisture, turn Engine Anti-Ice ON.
AFT CARGO HEAT ........................................................................................................AS REQUIRED

PNEUMATICS
L/R ISOLATION SWITCHES ..........................................................................................OPEN
PACK SELECTORS 1, 2, AND 3 ..................................................................................AUTO
  Ensure engines have stabilized at idle for at least 2Min prior to engaging packs.
EICAS RCL SWITCH ..................................................................................................CHECK
RELEASE FROM PUSHBACK/GND SVC ....................................................................VERIFY
FLAPS ..........................................................................................................................SET
AFTER START/TAXI CHECKLIST ................................................................................PERFORM

TAXI OUT
SECONDARY EICAS STAT DISPLAY ..............................................................................DISPLAY
FLIGHT CONTROLS .......................................................................................................CHECK
  Move rudder and control column through full range of motion, verify flight control range of motion by
  watching the flight control indicators on the display.
SECONDARY EICAS ENG MODE ..................................................................................SELECT
TAKEOFF PERFORMANCE ..........................................................................................CONFIRM
  Verify takeoff performance speeds to determine if still acceptable. If aircraft weight changed during
  boarding/departure period, ensure that PERF INIT page has been updated and is accurate.
VNAV CLB PAGE ........................................................................................................DISPLAY
CABIN CREW TAKEOFF NOTIFICATION ..................................................................PROVIDE
  When cleared onto active runway
EICAS CAUTION/ADVISORY AND STATUS MESSAGES ........................................RECALL/CANCEL/CHECK
  Ensure all cautionary messages have been addressed prior to takeoff.
PACKS .........................................................................................................................AS DESIRED/REQUIRED
BEFORE TAKEOFF CHECKLIST ................................................................................PERFORM
TAKEOFF

LANDING LIGHTS .................................................................ON FOR INCREASED VISIBILITY
STROBE LIGHTS ...............................................................ON
HDG INDICATOR .................................................................SET

Set assigned departure heading or runway heading.

CONTINUOUS IGNITION ..................................................ON
PARKING BRAKE ..........................................................VERIFY RELEASED
TAKEOFF THRUST ..........................................................SET

Takeoff thrust can be set manually, or by advancing throttles beyond 70% N1 and pressing the TO/GA button. If the EICAS warning CONFIG is received early in the takeoff roll, discontinue the takeoff and correct the problem, which will be displayed on the upper EICAS.

ENGINE INDICATIONS ..................................................MONITOR
AIRSPEED 80 KNOTS .......................................................ANNOUNCE
AIRSPEED V1 ...............................................................ANNOUNCE
AIRSPEED Vr ...............................................................ANNOUNCE
INITIAL CLimb .............................................................ESTABLISH
POSITIVE RATE OF CLimb ............................................VERIFY

Vertical speed indicator and radio altimeter will register a positive rate of climb prior to the main gear leaving the runway. As such, crews are advised to refrain from retracting the landing gear until at least a 500 feet per minute rate of climb is registered on the vertical speed indicator.

GEAR .................................................................UP
**AFTER TAKEOFF**

HDG MODE/L NAV MODE ...........................................................................................................SELECT
Turn the HDG select knob to the desired heading or reset the heading and press to activate.
Alternately, push the L NAV switch and verify that L NAV is annunciated on the PFD.

AUTOPILOT ......................................................................................................................ENGAGE AS DESIRED ONCE ABOVE 250 FEET

FLAPS ......................................................................................................................RETRACT ON SCHEDULE

V NAV MODE .............................................................................................................SELECT
Verify CLB is displayed as the thrust limit on the upper EICAS display and the throttles adjust to a climb setting. Set the IAS/MACH indicator on the MCP to at least the clean maneuvering speed.

When above 1200 feet AGL:
ENG START SELECTOR ...................................................................................................AUTO
ANTI-ICE SWITCHES ........................................................................................................AUTO
CONTINUOUS IGNITION ....................................................................................................AS REQUIRED

LANDING GEAR LEVER ..................................................................................................OFF
PACK CONTROL SELECTORS 1, 2, AND 3 ........................................................................NORM

**AFTER TAKEOFF CHECKLIST** .........................................................................................PERFORM

**CLIMB**

CLEARED ALTITUDE ..............................................................................................................VERIFY SET IN MCP WINDOW
WING/ENGINE ANTI-ICE .....................................................................................................SELECT AS REQUIRED OR AUTO
L NAV (IF NOT ALREADY SELECTED) ..................................................................................SELECT
When cleared to resume own navigation, select L NAV and ensure that L NAV is displayed on the PFD.

ECON CLB .........................................................................................................................VERIFY ACTIVE
Observe ACT ECON CLB page displayed on VNAV CLB page or selected MCP speed if applicable when passing through 10,000 ft. Commanded speed should agree with displayed flight performance.

CABIN SIGNS ......................................................................................................................AS REQUIRED

When passing transition altitude

ALTIMETERS ......................................................................................................................SET AND ANNOUNCE QNE (29.92 In Hg or 1013hPa)

After passing FL180

LANDING LIGHTS ..............................................................................................................OFF

**CRUISE**

LEVEL OFF .........................................................................................................................PERFORM
FLIGHT PROGRESS, PERFORMANCE AND NAVIGATION .................................................MONITOR
FUEL SYSTEM ....................................................................................................................MONITOR
ARRIVALS PROCEDURE ....................................................................................................ENTER AS REQUIRED
On ARRIVALS page, enter as much of the expected arrival procedure as possible. Verify routing using the MAP mode on the ND.
INITIAL APPROACH

ATIS ...............................................................................................................................OBTAIN
APPROACH BRIEFING .....................................................................................................ACCOMPLISH
DH AND MDA BUGS .......................................................................................................CHECK AND SET
LANDING DATA ............................................................................................................CHECK AND SET
  Determine correct REF speed for the planned landing weight and flap setting. Verify values against FMC computed values, the adjust or accept FMC computed figures.
SEATBELT SELECTOR ..........................................................................................................ON
EICAS RECALL ................................................................................................................CHECK
AUTOBRAKES SELECTOR ................................................................................AS REQUIRED
  See landing techniques section for detailed information regarding the use of the autobrakes.

At FL180:
WING LIGHTS ..................................................................................................................AS REQUIRED
When passing through transition level:
ALTIMETERS ................................................................................................................SET AND ANNOUNCE QNH
FLAPS ..................................................................................................................................AS REQUIRED
  Expect varying speed vectors during the approach phase of the flight. When a flap level is selected, set MCP speed to the flap maneuver speed +10 knots. Do not use the flaps as air brakes to slow the aircraft; rather, slow the aircraft using appropriate throttle input and extend the flaps according to the flap deployment schedule displayed on the PFD.

APPROACH CHECKLIST ...........................................................................................PERFORM

FINAL APPROACH

AUTOFLIGHT SYSTEMS ..........................................................................................AS REQUIRED
LOCALIZER CAPTURE .......................................................................................................ANNOUNCE AS REQUIRED
LANDING GEAR ..............................................................................................................DOWN AND VERIFY
SPEED BRAKE ................................................................................................................ARM
FINAL APPROACH CHECKLIST ................................................................................PERFORM
GLIDE SLOPE CAPTURE ..........................................................................................ANNOUNCE AS REQUIRED
MCP MISSED APPROACH ALTITUDE .................................................................................SET
AUTOFLIGHT SYSTEM (AS REQUIRED) ........................................................................MONITOR
AUTOLAND OPERATION (IF USED) ..................................................................................MONITOR

TAXI IN

SPOILERS ...............................................................................................................VERIFY RETRACTED
AUTO BRAKES SELECTOR .............................................................................................OFF
When clear of the active runway:
LANDING LIGHTS ..........................................................................................................OFF
WHITE ANTI-COLLISION LIGHTS ..................................................................................OFF
AUTOTHROTTLE ARM SWITCH ................................................................................OFF
FLIGHT DIRECTOR SWITCH ..........................................................................................OFF
FLAPS ........................................................................................................................................RETRACT
STABILIZER TRIM ....................................................................................................................4 UNITS
WEATHER RADAR ....................................................................................................................OFF
APU ...........................................................................................................................................AS REQUIRED
ENGINE AND WING ANTI-ICE SWITCHES ............................................................................OFF

PARKING AND SHUTDOWN

PARKING BRAKE .....................................................................................................................SET
SEATBELT SELECTOR ...............................................................................................................OFF
ENGINE BLEED SWITCHES ....................................................................................................OFF
Observe VALVE lights illuminate
If APU OFF Perform Next Line:
GROUND/EXTERNAL POWER GEN ..................................................................................WHEN AVAIL, SELECT ON
If APU ON Perform Next Line:
APU GEN CTRL SWITCHES 1 AND 2 ..................................................................................SELECT ON
After completing APU ON/APU OFF sections from above:
FUEL CONTROL SWITCHES 1, 2, 3, 4 (IN ORDER) ..............................................................CUTOFF
HYDRAULIC PUMPS ...............................................................................................................OFF
FUEL PUMP SWITCHES ..........................................................................................................OFF
RED ANTI-COLLISION LIGHT SWITCH ..............................................................................OFF
EXTERIOR LIGHTS ..................................................................................................................AS REQUIRED
SECONDARY EICAS STATUS DISPLAY ..................................................................................SELECT
EQUIPMENT COOLING SELECTOR ......................................................................................SET

If OAT is less than 70°F, set to NORM. If above 70°F, set to OVRD.

PNEUMATICS PANEL

APU BLEED SWITCH ............................................................................................................ON
L AND R ISLN SWITCHES ....................................................................................................OPEN
PARKING CHECKLIST ..............................................................................................................PERFORM

LEAVING AIRCRAFT

PNEUMATIC PANEL

PACK SELECTORS ..................................................................................................................OFF
UPR AND LWR RECIRC FANS ............................................................................................OFF
APU BLEED SWITCH ............................................................................................................OFF
APU SELECTOR ......................................................................................................................OFF
Allow APU to run without bleed or generator load for at least 1 minute before shutting down.
STBY POWER SELECTOR ....................................................................................................OFF
BAT SWITCH ..........................................................................................................................OFF
ABNORMAL PROCEDURES

BY EICAS MESSAGE   BY EICAS MESSAGE

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## ABNORMAL PROCEDURES

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**ENG 1,2,3,4 AUTOSTART**

**Condition:** Autostart system has failed to start the engine, or fault detected in autostart system, or start parameters exceeded, or EGT rising rapidly approaching limit during manual start.

**CREW ACTION:**

- **FUEL CONTROL SWITCH** .................................................................CUTOFF

  If on the ground:
  - If Engine Start Light extinguished:
    - Allow N2 to decrease below 20%
    - **AUTOSTART SWITCH** ..............................................................OFF
    - (Allows Engine Motoring)
    - **ENGINE START SWITCH** .......................................................PULL
      - Motor Engine for 30 seconds.
    - **ENGINE START SWITCH** ......................................................IN

  **Do not accomplish the following checklists:**
  - AUTOSTART OFF
  - ENGINE SHUTDOWN

**>ENGINE 1, 2, 3, 4 CONTROL**

**Condition:** Electronic Engine Control (EEC) system fault present.

**CREW ACTION:**

Monitor engine performance.

**>ENG CONTROLS**

**Condition:** Three or four Electronic Engine Control (EEC) systems operating in a degraded condition and lack complete redundancy.

**CREW ACTION:**

Monitor engine performance.
**ENG 1, 2, 3, 4 EEC MODE**

Condition: Engine EEC in alternate control mode.

Light: ALTN (in switch)

**CREW ACTION:**
THRUSS LEVER (Each Engine, Individually) …………………………….RETARD TO MID POSITION
EEC MODE SWITCH (Associated engine) ……………………………………ALTN

One switch at a time, methodically push all switches to ALTN

Maximum thrust limiting not available.
Autothrottle is available.

**ENG 1, 2, 3, 4 FAIL (ENGINE FAILURE/SHUTDOWN)**

Condition: Engine failure or flameout.

**CREW ACTION:**
THRUSS LEVER …………………………………………………………………CLOSE

Engine Conditions permitting, operate at idle for two minutes to allow engine to cool and stabilize.

FUEL CONTROL SWITCH ………………………………………………….CUTOFF

TRANSPONDER MODE SELECTOR ……………………………………….TA ONLY

**DO NOT ACCOMPLISH THE FOLLOWING CHECKLIST:**
ENGINE SHUTDOWN

**ENG 1, 2, 3, 4 FAIL (MULTIPLE ENGINE FLAMEOUT / STALL)**

Condition: Engines have flamed out, or engines have abnormal indications or exceeded limits or engines make abnormal noises, or engines respond abnormally to thrust lever movement.

**CREW ACTION:**
FUEL CONTROL SWITCH (Affected Engines) ………………….CUTOFF, THEN RUN

If EGT rises rapidly approaching EGT takeoff limit:

FUEL CONTROL SWITCH (affected engines) ………………….CUTOFF, THEN RUN

The multi-engine in-flight start limit is the takeoff limit. EGT turns red at the ground/single engine in-flight start limit. Autostart protects the maximum takeoff limit.

If airspeed less than 220 KIAS:

PACK CONTROL SELECTORS ……………………………………….SET

Set a maximum of one pack on.

ENGINE START SWITCH (affected engines) ……………………………..PULL

If autostart switch OFF:
Monitor EGT during engine start.

### ENGINE 1, 2, 3, 4 FUEL FILTER

**Condition:** An impending fuel filter bypass exists on the affected engine.

**CREW ACTION:**
Monitor engine closely, as erratic engine operation and flameout may occur due to fuel contamination as a result of filtering bypass.

### ENGINE 1, 2, 3, 4 FUEL VALVE

**Condition:** Engine fuel valve or fuel spar valve position disagrees with the commanded position.

**CREW ACTION:**
If on ground, do not attempt an engine start.

### ENG IGNITION

**Condition:** Ignition system fails to provide ignition when continuous ignition switch is ON.

**CREW ACTION:**
STANDBY IGNITION SELECTOR ………………………………………………………………………1 OR 2

### >ENG 1, 2, 3, 4 LIM PROT

**Condition:** Electronic Engine Control in alternate control mode and command N1 exceeds maximum rating

**CREW ACTION:**
Monitor engine performance closely, and prevent engine RPM exceedance.

### ENG 1, 2, 3, 4 LOW IDLE

**Condition:** Engine idle not in approach setting when commanded.

**CREW ACTION:**
THRUST LEVER (affected engine) ……………………………………………………………..ADVANCE (Advance thrust lever until message is no longer displayed)
ENG 1, 2, 3, 4 OIL FILT

Condition: Engine oil filter contamination approaching bypass condition.

CREW ACTION:
THRUST LEVER ............................................................RETARD
Retard thrust lever slowly until message no longer displayed.

If ENG OIL FILT message remains displayed with thrust lever closed:
FUEL CONTROL SWITCH ..............................................CUTOFF
TRANSPONDER MODE SELECTOR ...............................TA ONLY

DO NOT ACCOMPLISH THE FOLLOWING CHECKLIST:
ENGINE SHUTDOWN

ENG 1, 2, 3, 4 OIL PRESS

Condition: Oil pressure reaches red line limit.

CREW ACTION:
OIL PRESSURE INDICATION ...........................................CHECK
If oil pressure at or below red line limit:
THRUST LEVER ..........................................................CLOSE
FUEL CONTROL SWITCH ..............................................CUTOFF
TRANSPONDER MODE SELECTOR ...............................TA ONLY

DO NOT ACCOMPLISH THE FOLLOW CHECKLIST:
ENGINE SHUTDOWN

ENG 1, 2, 3, 4 OIL TEMP

Condition: Oil temperature reaches amber band.

CREW ACTION:
THRUST LEVER (Affected engine) ..................................RETARD
Retard thrust lever slowly until temperature decreases.

If temperature does not decrease below red line limit or remains in amber band for longer than 15 minutes:
THRUST LEVER ..........................................................CLOSE
FUEL CONTROL SWITCH ..............................................CUTOFF
TRANSPONDER MODE SELECTOR ...............................TA ONLY

DO NOT ACCOMPLISH THE FOLLOWING CHECKLIST:
ENGINE SHUTDOWN
**ENG 1, 2, 3, 4 REVERSER**

Condition: Fault detected in reverser system.

**CREW ACTION:**
Additional system failures may cause in flight deployment.

If indication is accompanied by vibration, yaw or other indication of reverser sleeve insecurity:

- THRUST LEVERL .................................RETARD
- FUEL CONTROL SWITCH (Affected engine) ..................................CUTOFF
- TRANSPONDER MODE SELECTOR ........................................TA ONLY

**DO NOT ACCOMPLISH THE FOLLOWING CHECKLIST:**
ENGINE SHUTDOWN

---

**>ENG 1, 2, 3, 4 RPM LIM**

Condition: Engine thrust is limited by N2 red line limit.

---

**>ENG 1, 2, 3, 4 SHUTDOWN**

Condition: Engine Fire switch pulled, or engine Fuel Control Switch in CUTOFF

---

**ENG 1, 2, 3, 4 START VLV**

Condition: Start valve position disagrees with commanded position.

**CREW ACTION:**
In-flight or ground start using bleed air source may be unsuccessful.

In flight:

- Increase airspeed until X-BLD no longer displayed before attempting start.
ENGINE IN-FLIGHT START

Condition: Following a flameout or precautionary shutdown, when no fire or apparent damage has occurred.

CREW ACTION:
Monitor EGT during start.
If X-BLD not displayed:
FUEL CONTROL SWITCH ………………………………………………………….RUN
If X-BLD displayed:
ENGINE START SWITCH ……………………………………………………….PULL
   If Autostart switch ON:
      FUEL CONTROL SWITCH ………………………………………………….RUN
   If Autostart switch OFF:
      FUEL CONTROL SWITCH ………………………………………………….RUN
   Position to RUN when N2 exceeds fuel-on indicator

ENGINE LIMIT / SURGE / STALL

Condition: Engine indications abnormal, or approaching or exceeding limits, or abnormal engine noises heard, or abnormal engine response to thrust lever movement occurs.

CREW ACTION:
THRUST LEVER (affected engine) …………………………………………………..RETARD
   Retard until indications remain within normal limits or return to normal.
If EGT continues to increase toward the limit or abnormal condition continues:
ENGINE BLEED AIR SWITCH (affected engine) ………………………….OFF
If EGT continues to increase toward the limit or abnormal condition continues:
FUEL CONTROL SWITCH (affected engine) ……………………………...CUTOFF
TRANSPONDER MODE SELECTOR ………………………………………..TA ONLY
Do not accomplish the following checklists:
   ENGINE SHUTDOWN
If EGT stabilized or decreasing and other engine indications are normal:
THRUST LEVER (affected engine) …………………………………………………..ADVANCE
   Ensure engine indications and performance remain within limits.

>IDLE DISAGREE

Condition: On or more engine idle settings disagrees with the idle commanded.
REVERSER UNLOCKED

Condition: REV annunciation displayed with reverse thrust not intentionally selected.

CREW ACTION:
With no yaw, loss of airspeed or buffet:
Operate engine normally.

With yaw, loss of airspeed or buffet:
- FUEL CONTROL SWITCH (affected engine) ..................................................CUTOFF
- TRANSPONDER MODE SELECTOR .........................................................TA ONLY

Do not accomplish the following checklist:
- ENGINE SHUTDOWN

Buffet may be reduced by decreasing airspeed.
Landing preparation:
- Use flaps 25 and VREF30+20 knots for landing.

STARTER CUTOUT 1, 2, 3, 4

Condition: Start valve fails to close.

CREW ACTION:
ENGINE START SWITCH .................................................................IN
If STARTER CUTOUT message remains displayed:
- ENGINE BLEED AIR SWITCH (Affected engine) ....................................OFF
Nacelle anti-ice for affected engine is not available.
Reverser thrust for affected engine is not available.

TWO ENGINES INOPERATIVE

Condition: Two engine landing required.

CREW ACTION:
Autothrottle is inoperative.
LANDING PREPARATION:
- Use flaps 25 and Vref25 for landing.
- PACK CONTROL SELECTORS .........................................................TWO PACKS OFF
- GROUND PROXIMITY FLAP OVERRIDE SWITCH ..........................OVRD

User Flaps 1 for go-around. Commit point is gear down.
Plan to fly final approach with gear down and flaps 10.
Plan to extend flaps to 20 at 500 feet and flaps to 25 when touchdown target is assured.
FIRE ENG 1,2,3,4
SEVERE ENGINE DAMAGE OR SEPARATION

Condition: Fire detected in the engine, or airframe vibrations detected with abnormal engine indications.

Light: Respective Fire switch and Fuel Control switch is illuminated.

CREW ACTION:
THRUST LEVER .................................................................CLOSE
FUEL CONTROL SWITCH .................................................CUTOFF
ENGINE FIRE SWITCH ......................................................PULL
If FIRE ENG message remains displayed:
    ENGINE FIRE SWITCH .................................................ROTATE
If after 30 seconds FIRE ENG message remains displayed:
    ENGINE FIRE SWITCH .............................................ROTATE TO OTHER BOTTLE
TRANSPONDER MODE SELECTOR .....................................TA ONLY

DO NOT ACCOMPLISH THE FOLLOWING CHECKLIST:
ENGINE SHUTDOWN
FIRE PROTECTION
NON-NORMAL CHECKLISTS

>BOTTLE LOW APU
Condition: APU fire extinguisher bottle pressure low.

>BTL LOW L ENG A, B
Condition: Left wing fire extinguisher bottle A or bottle B pressure low.

>BTL LOW R ENG A, B
Condition: Right wing fire extinguisher bottle A or bottle B pressure low.

>CARGO DET AIR
Condition: Cargo smoke detection airflow insufficient.

>CGO BTL DISCH
Condition: On the ground, a cargo fire extinguisher bottle pressure is low. In flight, bottles A and B are discharged.

>DET FIRE APU
Condition: APU fire detection loops A and B failed.

>DET FIRE /OHT 1, 2, 3, 4
Condition: Engine fire/overheat detection loops A and B have failed.
FIRE APU

Condition: Fire detected in the APU.

Light: APU (in switch)

**CREW ACTION:**
APU FIRE SWITCH ..........................................................PULL AND ROTATE
Rotate to discharge fire bottle into APU.

**DO NOT ACCOMPLISH THE FOLLOWING CHECKLIST:**
APU

FIRE CARGO AFT

Condition: Smoke detected in lower aft cargo compartment

Light: AFT (in switch)

**CREW ACTION:**
AFT CARGO FIRE ARM SWITCH ..................................................ARMED
Pack 3 shuts down.
PACK 3 CONTROL SELECTOR ..................................................OFF
PACK 1 or PACK 2 CONTROL SELECTOR ..................................OFF
Maximum of 1 pack should be left on.
CARGO FIRE DISCHARGE SWITCH ..............................................PUSH
215 minutes of fire suppression is available.

If airplane above 8,000ft:
LANDING ALTITUDE SWITCH .................................................MAN
LANDING ALTITUDE CONTROL ..................................SET 8,000-8,500 FEET
Set landing altitude between 8,000 and 8,500 to command cabin altitude to 8,000 feet.
Prior to descent:
LANDING ALTITUDE SWITCH .................................................AUTO

Plan to land at the nearest suitable airport, even if indication is cleared.
**DO NOT ACCOMPLISH THE FOLLOWING CHECKLIST:**
LANDING ALT
## FIRE CARGO FWD

**Condition:** Smoke detected in lower aft cargo compartment

**Light:** FWD (in switch)

**CREW ACTION:**
- FWD CARGO FIRE ARM SWITCH .................................................ARMED
  - Pack 3 shuts down.
- PACK 3 CONTROL SELECTOR ..................................................OFF
- PACK 1 or PACK 2 CONTROL SELECTOR ......................................OFF
  - Maximum of 1 pack should be left on.
- CARGO FIRE DISCHARGE SWITCH .............................................PUSH
  - 215 minutes of fire suppression is available.

If airplane above 8,000ft:
- LANDING ALTITUDE SWITCH ..................................................MAN
- LANDING ALTITUDE CONTROL .................................................SET 8,000-8,500 FEET
  - Set landing altitude between 8,000 and 8,500 to command cabin altitude to 8,000 feet.
- Prior to descent:
  - LANDING ALTITUDE SWITCH ..................................................AUTO

Plan to land at the nearest suitable airport, even if indication is cleared.

**DO NOT ACCOMPLISH THE FOLLOWING CHECKLIST:**
- LANDING ALT

## FIRE ENG 1,2,3,4

SEVERE ENGINE DAMAGE OR SEPARATION

**Condition:** Fire detected in the engine, or airframe vibrations detected with abnormal engine indications.

**Light:** Respective Fire switch and Fuel Control switch is illuminated.

**CREW ACTION:**
- THRUST LEVER .......... CLOSE
- FUEL CONTROL SWITCH .......... CUTOFF
- ENGINE FIRE SWITCH .......... PULL

If FIRE ENG message remains displayed:
- ENGINE FIRE SWITCH .......... ROTATE

If after 30 seconds FIRE ENG message remains displayed:
- ENGINE FIRE SWITCH .......... ROTATE TO OTHER BOTTLE

If indication of fire is not extinguished, plan to land at nearest suitable airport.

**DO NOT ACCOMPLISH THE FOLLOWING CHECKLIST:**
- ENGINE SHUT DOWN
**FIRE WHEEL WELL**

Condition: Fire detected in a main wheel well.

**CREW ACTION:**
Observe gear EXTEND limit speed (270K/0.82M)
LANDING GEAR LEVER  ................................................................. DOWN

Do not use FMC fuel predictions with gear extended.
If landing gear must be retracted for airplane performance:
   When FIRE WHEEL WELL message no longer displayed:
   Wait 20 minutes.
   (Ensures fire is extinguished.)
   LANDING GEAR LEVER  ................................................................. UP

Plan to land at nearest suitable airport.

**OVHT ENG 1, 2, 3, 4 NAC**

Condition: Overheat detected in an engine nacelle.
ENGINE BLEED AIR SWITCH  ................................................................. OFF
(Stops flow of bleed air through the leak)
THRUST LEVER  ................................................................. RETARD
   Retard slowly until OVHT ENG NAC message no longer displayed.

If OVHT ENG NAC message remains displayed:
   THRUST LEVER  ................................................................. CLOSE
   FUEL CONTROL SWITCH  ................................................................. CUTOFF
   TRANSPONDER MODE SELECTOR  ................................................................. TA ONLY

**DO NOT ACCOMPLISH THE FOLLOWING CHECKLIST:**
BLEED OFF
ENGINE SHUTDOWN
SMOKE / FUMES AIR CONDITIONING

Condition: A concentration of air conditioning smoke/fumes is identified.

**CREW ACTIONS:**

- **OXYGEN MASKS AND SMOKE GOGGLES**
  - **ON**

- **CREW COMMUNICATIONS**
  - **ESTABLISH**

- **RECIRCULATION FAN SWITCHES (both)**
  - **OFF**
  
  Removing fans as a possible source of smoke/fumes. Stops recirculation of smoke/fumes and increases fresh air flow.

- **APU SELECTOR**
  - **OFF**

If smoke/fumes continue:

- **ISOLATION VALVE SWITCHES**
  - **OFF**

  Isolates left and right sides of the bleed air system.

- **PACK 2 CONTROL SELECTOR**
  - **OFF**

**Do not accomplish the following checklists:**

- **CARGO DET AIR**
- **TEMP ZONE**
- **TRIM AIR OFF**

If smoke/fumes continue:

- **PACK 3 CONTROL SELECTOR**
  - **OFF**

If smoke/fumes continue:

- **PACK 3 CONTROL SELECTOR**
  - **NORM**

- **PACK 1 CONTROL SELECTOR**
  - **OFF**

- **ISOLATION VALVE SWITCH (unaffected side)**
  - **ON**

- **PACK 2 CONTROL SELECTOR**
  - **ON**

If smoke/fumes persist:

Plan to land at the nearest suitable airport.

SMOKE/FUMES/FIRE ELECTRICAL

Condition: Electrical smoke/fumes/fire is identified.

**CREW ACTION:**

- **OXYGEN MASKS AND SMOKE GOGGLES**
  - **ON**

- **CREW COMMUNICATIONS**
  - **ESTABLISH**

- **RECIRCULATION FAN SWITCHES (both)**
  - **OFF**

  Removing fans as a possible source of smoke/fumes. Stops recirculation of smoke/fumes and increases fresh air flow.

If smoke/fumes/fire source is known:

- **ELECTRICAL POWER (affected equipment)**
  - **REMOVE**

  If practical, remove power from the affected equipment by switch or circuit breaker in the flight deck or cabin.
PASSENGER EVACUATION

Condition: Evacuation of passengers and crew is required.

**CREW ACTION:**
- **PARKING BRAKE:** SET
- **FUEL CONTROL SWITCHES (ALL):** CUTOFF
- **OUTFLOW VALVE MANUAL SWITCHES:** ON
- **OUTFLOW VALVES MANUAL CONTROL:** OPEN
- **PASSENGER EVACUATION:** INITIATE
- **ENGINE FIRE SWITCHES:** PULL AND ROTATE
  - Rotate all engine fire switches in the same direction.
- **APU FIRE SWITCH:** UNLOCK, PULL AND ROTATE.

RAPID DEPRESSURIZATION
*(CABIN ALTITUDE)*

Condition: Cabin Altitude Excessive

**CREW ACTION:**
- **OXYGEN MASES:** ON
- **CREW COMMUNICATIONS:** ESTABLISH
- **CABIN ALTITUDE AND RATE:** CHECK
- If cabin altitude uncontrollable:
  - **PASSENGER OXYGEN SWITCH:** ON
- **DESCENT:** ACCOMPLISH

> EMER LIGHTS

Condition: Emergency lights switch not ARMED, or emergency lights switch ARMED and emergency lights activated.

PASS OXYGEN ON

Condition: Passenger oxygen system activated.

When passenger oxygen no longer required:
- **PASSENGER OXYGEN SWITCH:** RESET, RELEASE TO NORM
DOOR FWD/AFT CARGO

Condition:  Aft cargo door not closed and latched and locked condition sensed.

LANDING ALTITUDE SWITCH  MANUAL

LANDING ALTITUDE CONTROL  SET 8,000 FEET
Set landing altitude to 8,000 feet to command cabin altitude to 8,000 feet.
Reduces cabin differential pressure to reduce risk of door separation.

If airplane altitude at or below 8,000 feet:
  LEVEL OFF  INITIATE

If airplane altitude above 8,000 feet:
  DESCENT  INITIATE
Descend to lowest safe altitude or 8,000 feet, whichever is higher.

After level off, allow sufficient time for cabin altitude to stabilize.

OUTFLOW VALVE MANUAL SWITCHES (both)  ON
OUTFLOW VALVES MANUAL CONTROL  OPEN
Position outflow valves fully open to depressurize airplane. Once depressurized, the crew
may change altitude as necessary.

Do not accomplish the following checklists:
  CABIN ALT AUTO
  LANDING ALT
  OUTFLOW VLV L, R

DOOR ENTRY L, R 1,2,3,4,5
DOOR L, R UPPER DK

Condition:  Main deck entry door not closed and latched condition sensed.

PRESSURIZATION  CHECK
Check pressurization system for normal operation. Instruct flight attendant to check door
handle. If not closed, position to closed. If pressurization system indicates
normal operation, continue flight using normal procedures.
Bleed 1, 2, 3, 4

Condition: Engine bleed overpressure, or High Pressure bleed valve or Pressure regulating valve failed to close when commanded.

Lights: SYS FAULT

Crew Action:
ENGINE BLEED AIR SWITCH (Affected Engine) OFF
NACELLE ANTI-ICE SWITCH (Affected Engine) ON

If NAI VALVE message for affected engine displayed:
NACELLE ANTI-ICE SWITCH (Affected engine) OFF

If NAI VALVE message for affected engine not displayed:
Operate nacelle anti-ice normally.

Do not accomplish the following checklist:
BLEED OFF
BLEED DUCT LEAK L, C, R

Condition: Bleed air leak or overheat along left, center or right duct section.

CREW ACTION:
If BLD DUCT LEAK C message displayed:
- ISOLATION VALVE SWITCHES (both) OFF
- PACK 2 CONTROL SELECTOR OFF
- APU SELECTOR OFF
- AFT CARGO HEAT SWITCH OFF
- TRIM AIR SWITCH OFF
- PASSENGER TEMPERATURE SELECTOR AS DESIRED

Cargo smoke detection no longer available.
Do not use ground pneumatic air.
Do not accomplish the following checklists:
- CARGO DET AIR
- TEMP ZONE
- TRIM AIR OFF

If BLED DUCT LEAK L or R message displayed:
- ISOLATION VALVE SWITCH (affected side) OFF
- ISOLATION VALVE SWITCH (unaffected side) ON
- ENGINE BLEED AIR SWITCHES (Affected side) OFF
  Isolates the air source and maintains pressure on the unaffected side.
- PACK CONTROL SELECTOR (affected side) OFF
- HYDRAULIC DEMAND PUMP 1 or 4 (affected side) OFF
- WING ANTI-ICE SWITCH OFF
  Do not use wing anti-ice.

Do not accomplish the following checklists:
- BLEED OFF
- HYD PRESS DEMAND 1 OR 4 (affected side)

LANDING PREPARATION:
Leading Edge flaps operate in secondary mode. Allow additional time during approach for flap extension. (not modeled in this version.)
- PACK CONTROL SELECTORS SET
  Maximum one pack on.

Do not accomplish the following checklists:
- FLAPS PRIMARY
**BLEED HP ENG 1, 2, 3, 4**

Condition: HP (high pressure) bleed valve failed closed.

**CREW ACTION:**
None.

Sufficient bleed air may not be available for nacelle anti-ice if N1 less than 70% at or above 10,000 feet or less than 55% below 10,000 feet.

**BLEED ISLN L, R**

Condition: Isolation Valve switch position and valve position disagree.

Light: VALVE (on ISLN switch)

**CREW ACTION:**
If attempting duct isolation and isolation valve will not close:
- ISOLATION VALVE SWITCH (unaffected side) OFF
- PACK 2 CONTROL SELECTOR OFF

**> BLEED ISLN APU**

Condition: APU bleed air isolation valve position disagrees with commanded position.

Light: VALVE (on APU Bleed switch)

**CREW ACTION:**
None.

**> BLEED 1, 2, 3, 4 OFF**

Condition: Engine Bleed Air switch OFF, engine operating, and engine bleed air valve closed.

Light: OFF (on BLEED switch)

**CREW ACTION:**
Correct switch position as required.
**BLEED 1, 2, 3, 4 OVHT/PRV**

Condition: Engine bleed air overheat or PRV failed closed.

**CREW ACTION:**
None.

Nacelle anti-ice not available for affected engine.
Reverse thrust not available for affected engine.

**>E/E CLNG CARD**

Condition: Fault in equipment cooling system and system no fully functional.

**CREW ACTION:**
None.

**EQUIP COOLING**

Condition: With Equipment Cooling selector in NORM or STBY, airflow inadequate or overheat or smoke detected; or with selector in OVRD, differential pressure for reverse flow inadequate; or ground exhaust valve not in commanded position.

**CREW ACTION:**
Avionics/electronic equipment and displays may become unreliable or fail.

**ON GROUND:**

- EQUIPMENT COOLING SELECTOR STBY

**IN FLIGHT:**

- EQUIPMENT COOLING SELECTOR OVERRIDE
  
  If EQUIP COOLING message remains displayed, or redisplays:
  Plan to land at nearest suitable airport.

**LANDING ALT**

Condition: Disagreement between controller landing altitude and FMC landing altitude.

**CREW ACTION:**

- LANDING ALTITUDE SWITCH MAN
- LANDING ALTITUDE CONTROL SET
  Manually set landing altitude.
OUTFLOW VALVE L, R

Condition: Automatic control of outflow valve inoperative, or respective Outflow Valve Manual switch ON.

CREW ACTION:
OUTFLOW VALVE MANUAL SWITCH (affected valve) ON
PACK CONTROL SELECTOR ON PACK OFF
OUTFLOW VALVES MANUAL CONTROL CLOSE
Position affected outflow valve closed.

PACK 1, 2, 3

Condition: Pack controller fault, or pack operation fault, or pack overheat, or pack 2 shutdown with either cabin pressure relief valve open, or a shutoff of all engine bleed air.

Light: SYS FAULT (pack operation fault or overheat only)

CREW ACTION:
If one or two PACK messages displayed:
TRIM AIR SWITCH ON
PACK CONTROL SELECTOR (affected packs) "A"
PACK RESET SWITCH PUSH
If PACK messages remain displayed or are displayed again:
PACK CONTROL SELECTOR (affected packs) "B"
PACK RESET SWITCH PUSH
If PACK messages remain displayed or are displayed again:
PACK CONTROL SELECTOR (Affected packs) OFF

If PACK1, PACK 2, PACK 3 messages displayed:
Pressurization is lost.

If CABIN ALTITUDE message displays:
PASSENGER OXYGEN SWITCH ON
DESCENT ACCOMPLISH
Without delay, close thrust levers, extend speedbrakes and descent and VMO/MMO. Level off at lowest safe altitude or 10,000 feet whichever is higher.

Avoid icing conditions. Nacelle and wing anti-ice may be inoperative.
### PACK CONTROL

**Condition:** Automatic control of outlet temperature of all packs has failed.

**CREW ACTION:**
- **PACK RESET SWITCH** _PUSH_
- **Note:** If PACK CONTROL message remains displayed or is displayed again, packs continue to operate but air outlet temperature is not controlled.

If PACK CONTROL message remains displayed or is displayed again:
- **TRIM AIR SWITCH** _ON_
  - Packs may overheat and shutdown at lower altitudes during descent.
- **If TEMP ZONE messages is displayed:**
  - Cabin temperature cannot be controlled.
- **If TEMP ZONE message is not displayed:**
  - Pack outlet temperature cannot be reduced to decrease cabin temperature.
  - **Note:** Passenger cabin temperatures may be controlled with passenger temperature selector and cabin temperature panel.

### TEMP CARGO HEAT

**Condition:** Overheat detected in aft cargo compartment when aft cargo heat system is operating.

**CREW ACTION:**
- **AFT CARGO HEAT SWITCH** _OFF_
  - On extended flights, aft cargo compartment temperature may decrease to below freezing.
  - **Note:** If aft cargo heat is left on, the system cycles at a higher temperature and alternately displays TEMP CARGO HEAT message.

### TEMP ZONE

**Condition:** Zone duct overheat, or master trim air valve failed closed, or zone temperature controller failed.

**Light:** SYS FAULT

**CREW ACTION:**
- **ZONE RESET SWITCH** _PUSH_
  - If TEMP ZONE message remains displayed or is displayed again within five minutes:
    - **TRIM AIR SWITCH** _OFF_
    - **PASSENGER TEMPERATURE SELECTOR** _SET_
    - If zone temperature controller failed, all cabin zones are maintained at a moderate temperature.

**Do not accomplish the following checklist:**
- **TRIM AIR OFF**
>TRIM AIR OFF

Condition: Master trim air valve closed. Flight deck and passenger cabin temperature controlled in backup mode.

CREW ACTION: None.
ICE-RAIN PROTECTION

NON-NORMAL CHECKLISTS

>ANTI-ICE NAC

Condition: Any nacelle anti-ice system on, TAT greater than 12C and ice detector does not detect ice.

CREW ACTION:
NAI SWITCHES OFF

>ANTI-ICE WING

Condition: Either Wing Anti-Ice system on, TAT greater than 12C and ice detector does not detect ice.

CREW ACTION:
WAI SWITCH OFF

HEAT L, R AOA
HEAT L, R TAT
HEAT P/S CAPT, F/O
HEAT P/S L, R AUX

Condition: Heat failure on respective probe.

CREW ACTION:
None.

Flight in icing conditions may result in erroneous flight instrument indications.

HEAT WINDOW L, R

Condition: Window heat of respective windshield not powered.

Light: INOP

CREW ACTION:
WINDOW HEAT SWITCH (affected window) OFF 10 SEC, THEN ON
If HEAT WINDOW message remains displayed:
WINDOW HEAT SWITCH OFF
NAI VALVE 1, 2, 3, 4

Condition: Respective nacelle anti-ice valve not in commanded position.

CREW ACTION:
If nacelle anti-ice switch ON:
   Nacelle anti-ice not available for affected engine.
   (Valve has failed closed)

If nacelle anti-ice switch OFF, while TAT above 10C:
   Flight conditions permitting, avoid high thrust settings.
   (Valve has failed open)

WAI VALVE LEFT RIGHT

Condition: Respective wing anti-ice valve not in commanded position.

CREW ACTION:
If wing anti-ice switch ON:
   WING ANTI-ICE SWITCH OFF
   (Valve has failed closed.)

If wing anti-ice switch OFF:
   WING ANTI-ICE SWITCH ON
   (Valve has failed open)

After landing:
   ENGINE BLEED AIR SWITCHES (affected side) OFF
   ISOLATION VALVE SWITCH (affected side) OFF
AUTOMATIC FLIGHT
NON-NORMAL CHECKLISTS

> AUTOPILOT

Condition: Selected autopilot operating in a degraded mode. Engaged roll and/or pitch mode may have failed.

CREW ACTION:
Select different autopilot.

> AUTOPILOT DISC

Condition: All engaged autopilots have disengaged.

CREW ACTION:
Determine cause. Correct as desired.

> AUTOTHROT DISC

Condition: Autothrottle has disconnected.

CREW ACTION:
Determine cause. Correct as desired.

> NO AUTOLAND

Condition: Autoland not available.

CREW ACTION:
Determine cause. Correct as desired.

> NO LAND 3

Condition: Autoland system does not have redundancy for triple channel Autoland.

CREW ACTION:
Determine cause. Correct as desired.
ELECTRICAL SYSTEM
NON-NORMAL CHECKLISTS

> BAT DISCH APU

Condition: APU Battery discharging.

CREW ACTION:
Correct as necessary.

> BAT DISCH MAIN

Condition: Main Battery discharging.

CREW ACTION:
Correct as necessary.

> BATTERY OFF

Condition: Battery Switch OFF
Light: OFF (in battery switch)

CREW ACTION:
Ensure/Correct battery switch position as required.

> DRIVE DISC 1, 2, 3, 4

Condition: Generator Drive Disconnect switch pushed, IDG has disconnected.

CREW ACTION:
None.
Drive must be reset by maintenance when aircraft is landed.
ELEC AC BUS 1, 2, 3, 4

Condition: AC bus unpowered.

Light: OFF, ISLN

CREW ACTION:
GENERATOR CONTROL SWITCH OFF, THEN ON

Attempt only one reset of generator control breaker.

If ELEC AC BUS message remains displayed:

Do not attempt to close bus tie breaker.

If ELEC AC BUS 1 or 4 message remains displayed:

Avoid icing conditions.
For AC bus 1 failure, flight in icing conditions may result in unreliable Captain’s and standby flight instrument indications.
For AC bus 4 failure, flight in icing conditions may result in unreliable First Officer’s flight instrument indications.
Autothrottle is inoperative.
LNAV/VNAV modes inoperative.
Reference N1 blank.
Do not accomplish the following checklists:
HEAT P/S CAPT, F/O
HEAT P/S L, R AUX

If ELEC AC BUS message no longer displayed but, ELEC BUS ISLN message is displayed:
BUS TIE SWITCH OFF, THEN AUTO

Attempt only one reset of bus tie breaker.

ELEC BUS ISLN 1, 2, 3, 4

Condition: Bus tie breaker open.

Light: ISLN (on bus tie switch)

CREW ACTION:
BUS TIE SWITCH OFF, THEN AUTO

Attempt only one reset of bus tie breaker.
ELEC DRIVE 1, 2, 3, 4

Condition: IDG oil pressure low or IDG oil temperature high.

Light: DRIVE (on Generator Disconnect switch)

**CREW ACTION:**
GENERATOR DRIVE DISCONNECT SWITCH (Affected generator) PUSH
(prevents damage to IDG)

Do not accomplish the following checklists:
DRIVE DISC
ELEC GEN OFF

ELEC GEN OFF 1, 2, 3, 4

Condition: Generator control breaker open.

Light: OFF

**CREW ACTION:**
GENERATOR CONTROL SWITCH OFF, THEN ON

Attempt only one reset of generator control breaker.

> ELEC SSB OPEN

Condition: Split System Breaker open when commanded closed.

**CREW ACTION:**
None.

ELEC UTIL BUS L, R

Condition: One or more galley or utility bus unpowered, or galley emergency power switch off.

Light: OFF

**CREW ACTION:**
UTILITY POWER SWITCH OFF, THEN ON

Attempt only one reset of Utility Power switch. Leave Utility Power switch ON.
(Allows unaffected Utility Bus to maintain power.)
**STBY BUS APU**

Condition: APU standby bus unpowered.

**CREW ACTION:**
Correct as necessary.

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**STBY BUS MAIN**

Condition: Main standby bus unpowered.

**CREW ACTION:**
Correct as necessary.
AILERON LOCKOUT

Condition: Aileron lockout actuator position disagrees with commanded position.
Outboard ailerons may be locked out in low speed envelope, or active during high speed envelope.

CREW ACTION:
At high airspeed, avoid large or abrupt control wheel inputs. Crosswind limit for landing is 20 knots.

FLAPS CONTROL

Condition: Flap control units inoperative.

CREW ACTION:
Limit airspeed to the flaps 5 placard speed while flaps are between UP and 5.

Plan additional time for flap operation.
ALTERNATE FLAPS ARM SWITCH ........................................... ALTN ALTERNATE FLAPS SELECTOR ........................................................ AS REQUIRED
Position alternate flap selector to EXT or RET to extend or retract flaps on schedule.

If expanded flap position indication inoperative:
• autopilots are inoperative
• outboard ailerons are unlocked

During flap extension, maintain flaps UP maneuvering speed. Slow to flaps 5 maneuvering speed after 3 minutes and 45 seconds with Alternate Flap selector in EXT. Slow to flaps 25 approach speed after 5 minutes total. Do not fly in stick shaker. Extend gear after flaps extended.

GROUND PROXIMITY FLAP OVERRIDE SWITCH ......................... OVRD During flap retraction, do not exceed 20,000 feet until flaps are up. At gross weights above 308,443 kilograms, limit angle of bank to 15 degrees until flaps are up.

If flap retraction required, accelerate to flaps 5 maneuvering speed. After 90 seconds, accelerate to flaps 5 placard. After 5 minutes total with Alternate Flap selector in RET, accelerate to climb speed. Do not fly in stick shaker.

Use flaps 25 and VREF25 for landing.

Note: Due to limitations of the simulator, the extension times for standard and alternate flaps systems are not currently modeled in the PMDG 747-400.
**FLAPS PRIMARY**

Condition: One or more flap groups are operating in secondary control mode.

**CREW ACTION:**
Plan additional time for flap operation.

Note: Due to limitations of the simulator, the extension times for standard and alternate flaps systems are not currently modeled in the PMDG 747-400.

**SPEED BRAKE AUTO**

Condition: A fault is detected in the automatic ground spoiler system.

**CREW ACTION:**
DO NOT ARM SPEEDBRAKE LEVER.
Extend spoilers manually after landing.

**>SPEEDBRAKES EXT**

Condition: Speedbrakes extended at an inappropriate flight condition.

**CREW ACTION:**
Check Speedbrake position.
Retract Speedbrakes if not desired or reduce thrust lever position to idle if speedbrakes desired.

**>YAW DAMPER LWR, UPR**

Condition: Yaw damper failure or power failure to the yaw damper control unit.

Light: INOP (on switch)

**CREW ACTION:**
Ensure power to Yaw Damper and/or that Yaw Damper switch is engaged.
INSTRUMENTS

NON-NORMAL CHECKLISTS

ALT DISAGREE

Condition: Captain and First Officer uncorrected altitude indications disagree by more than 200 feet.

CREW ACTION:

LANDING PREPARATION:
- Maintain visual conditions if possible.
- Establish landing configuration as early as practical.
- Use Radio altitude for terrain clearance reference (available below 2,500 feet.)
- Use electronic and visual glide slope indicators, where available.

NOTE: Flight not permitted in RVSM airspace.
- Transponder altitude received by ATC may not be reliable.

>ATTITUDE

Condition: Instrument comparator senses disagreement between Captain’s and First Officers’ selected IRS attitude output.

>BARO DISAGREE

Condition: Captain’s and First Officer’s barometric reference settings differ for more than one minute.

CREW ACTION:
- Determine correct barometric setting for both units.
>FMC MESSAGE

Condition: A high priority FMC message exists.

>GPS

Condition: Dual GPS failure.

CREW ACTION:
Do not rely upon GPS information for navigation purposes.

IRS CENTER, LEFT, RIGHT

Condition: Inertial Reference Unit fault detected.

CREW ACTION:
IRS SOURCE SELECTORS
(Operable IRU) ..................................................L, C or R
IRS MODE SELECTOR
(Affected IRU) ..........................................................ATT
Alignment takes 30 seconds.

If IRS message not displayed:
IRS HEADING ..........................................................ENTER
Enter heading on the SET IRS HEADING line of the CDU POS INIT page.
IRS heading may have to be updated periodically.

If IRS message is still displayed:
IRS MODE SELECTOR
(Affected IRU) ..........................................................OFF

>IRS AC CENTER, LEFT, RIGHT

Condition: AC Power interrupted to respective IRS.

>IRS DC CENTER, LEFT, RIGHT

Condition: DC Backup Power respective IRS has failed.
>IRS MOTION

Condition: Excessive airplane motion detected during alignment.

CREW ACTION:
Stop airplane motion until IRS alignment complete.
Verify position correct and reenter if necessary.

TRANSPONDER L, R

Condition: Affected ATC transponder has failed.
## FUEL SYSTEM

### NON-NORMAL CHECKLISTS

### FUEL IMBAL 1-4

**Condition:** Fuel difference of 3,000lbs between main tanks 1 and 4.

**CREW ACTION:**
Consider the possibility of an engine fuel leak. If fuel imbalance has occurred without indications of a leak, configure fuel pumps and crossfeed valves as required to balance fuel. When fuel balanced, return to normal fuel system configuration.

### FUEL IMBAL 2-3

**Condition:** Fuel difference of 6,000lbs between main tanks 2 and 3.

**CREW ACTION:**
Consider the possibility of an engine fuel leak. If fuel imbalance has occurred without indications of a leak, configure fuel pumps and crossfeed valves as required to balance fuel. When fuel balanced, return to normal fuel system configuration.

### FUEL IMBALANCE

**Condition:** Fuel difference of 6,000lbs between inboard main tanks (2 and 3) and outboard main tanks (1 and 4) after reaching FUEL TANK/ENG condition.

**CREW ACTION:**
Consider the possibility of an engine fuel leak. If fuel imbalance has occurred without indications of a leak, configure fuel pumps and crossfeed valves as required to balance fuel. When fuel balanced, return to normal fuel system configuration.

### >FUEL JETT A, B

**Condition:** Selected fuel jettison system has failed.
FUEL JETT SYS

Condition: Fuel total les that fuel to remain and one fuel nozzle valve open or both jettison cards failed.

CREW ACTION:
FUEL JETTISON NOZZLE VALVE SWITCHES (both) ……………………………………….OFF
FUEL JETTISON SELECTOR …………………………………………………………….OFF

FUEL LEAK ENGINE

Condition: An in-flight engine fuel leak suspected or confirmed.

CREW ACTION:
One or more of the following may be evidence of a fuel leak:
- Visual observation of fuel spray from strut/engine.
- Excessive engine fuel flow.
- Total fuel quantity decreasing at an abnormal rate.
- FUEL DISAGREE message on CDU scratchpad.
- INSUFFICIENT FUEL message on CDU scratchpad.
- FUEL QTY LOW EICAS message.
- FUEL IMBAL 1-4 EICAS message.
- FUEL IMBAL 2-3 EICAS message.
- FUEL IMBALANCE EICAS message.

If engine fuel leak suspected:
STABILIZER TANK PUMP SWITCHES ………………………………………………..OFF
CENTER WING TANK PUMP SWITCHES ………………………………………………OFF
CROSSFEED VALVE SWITCHES (ALL) ……………………………………………….OFF
OVERRIDE PUMP 2 AND 3 SWITCHES ………………………………………………..OFF

Identify affected engine system by observing one main fuel tank quantity decreasing faster than other main tank fuel quantities.

An increase in fuel imbalance of approximately 1100lbs or more in 30 minutes should be considered an engine fuel leak.

Conditions permitting, have a crew member visually check for engine fuel leak.

DO NOT ACCOMPLISH THE FOLLOWING CHECKLISTS:
FUEL IMBAL 1-4
FUEL IMBAL 2-3
FUEL IMBALANCE
X FEED CONFIG

If no engine fuel leak:
Resume normal fuel management.

If FUEL DISAGREE – PROG 2 displayed:
TOTALIZER or CALCULATED ……………………………………………………SELECT USE
Select most accurate indication.
If engine fuel leak confirmed:

**THRUST LEVER (affected engine)............................CLOSE**

Conditions permitting, operate at idle for two minutes to allow engine to cool and stabilize.

**FUEL CONTROL SWITCH (Affected engine) CUTOFF**
**TRANSponder MODE SELECTOR TA ONLY**

**DO NOT ACCOMPLISH THE FOLLOWING CHECKLISTS:**

**ENGINE SHUTDOWN**

Use TOTALIZER to determine fuel remaining.

After engine shutdown, all remaining fuel can be used for operating engines.

Resume normal fuel management procedures.

If FUEL QTY LOW message displayed:

**CROSSFEED VALVE SWITCHES (ALL)...........................................ON**

**MAIN PUMP SWITCHES (ALL)..........................................................ON**

Avoid high nose up attitude and excessive acceleration and deceleration.

---

**FUEL OVRD 2, 3 AFT, FWD**

**Condition:** Low pump pressure detected when pump activated.

**Light:** PRESS (on switch)

**CREW ACTION:**

If single fuel pump inoperative:

Continue normal operations.

If both override pumps in tank 2 or 3 inoperative:

**OVERRide PUMP 2 AND 3 SWITCHES ............................................OFF**

**MAIN PUMP 1 AND 4 SWITCHES ...................................................OFF**

When FUEL TANK/ENG message displayed:

**MAIN PUMP 1 AND 4 SWITCHES ...................................................ON**

**CROSSFEED VALVE 1 AND 4 SWITCHES .....................................OFF**

---

**FUEL OVRD CTR L, R**

**Condition:** Low pump pressure detected when pump activated.

**Light:** PRESS (on switch)

**CREW ACTION:**

If single center wing tank override pump inoperative and center wing tank quantity greater than 1800lbs:

**CENTER WING TANK PUMP SWITCH ............................................OFF**

**MAIN PUMP 1 AND 3 SWITCHES ................................................OFF**
When the other center wing tank pump message is displayed:
MAIN PUMP 1 AND 4 SWITCHES  ON
Resume normal fuel management.

FUEL PUMP STAB L, R

Condition: Low Pump pressure detected when pump activated.
Light: PRESS

CREW ACTION:
If single pump inoperative: Continue normal operations.

FUEL PRESS ENG 1, 2, 3, 4

Condition: Engine on suction feed.

CREW ACTION:
CROSSFEED VALVE SWITCHES (ALL) ON
MAIN PUMP SWITCHES (Related tank) ON
If both main pumps in tank 1 or 4 inoperative:
The last 7,000lbs of fuel in the affected tank available only by suction feed.
OVERRIDE PUMP 2 AND 3 SWITCHES ON
When FUEL OVRD 2 and 3, AFT and FWD messages displayed:
Fuel in main tanks 2 and 3 is standpipe level 7,000lbs.
OVERRIDE PUMP 2 AND 3 SWITCHES OFF
CROSSFEED VALVE 1 AND 4 SWITCHES OFF

DO NOT ACCOMPLISH THE FOLLOWING CHECKLIST:
FUEL PRESS ENG
**FUEL PUMP 1, 4 AFT, FWD**

Condition: Low pump pressure detected when pump activated.

Light: PRESS (in switch)

**CREW ACTION:**
If single fuel pump inoperative:
Continue normal operations.

If Both main pumps in tank 1 or 4 inoperative:
The last 7,000 lbs of fuel in the affected tank available only by suction feed.
When FUEL TANK/ENG message displayed:
When the FUEL OVRD 2 and 3, AFT and FWD messages displayed:
The last 7,000 lbs of fuel in the affected tank must be suction fed.
OVERRIDE PUMP 2 AND 3 SWITCHES OFF
CROSSFEED VALVE 1 AND 4 SWITCHES OFF

DO NOT ACCOMPLISH THE FOLLOWING CHECKLISTS:
FUEL PRESS ENG
FUEL XFER 1+4

**FUEL PUMP 2, 3 AFT, FWD**

Condition: Low pump pressure detected when pump activated.

Light: PRESS (in switch)

**CREW ACTION:**
If single fuel pump inoperative:
Continue normal operations.

If Both main pumps in tank 2 or 3 inoperative:
The last 7,000 lbs of fuel in the affected tank available only by suction feed.
OVERRIDE PUMP 2 AND 3 SWITCHES OFF
When FUEL TANK/ENG message is displayed:
CROSSFEED VALVE 1 AND 4 SWITCHES OFF
When the FUEL OVRD 2 and 3, AFT and FWD messages displayed:
The last 7,000 lbs of fuel in the affected tank must be suction fed.
OVERRIDE PUMP 2 AND 3 SWITCHES OFF
CROSSFEED VALVE SWITCH (affected tank) OFF

DO NOT ACCOMPLISH THE FOLLOWING CHECKLISTS:
FUEL PRESS ENG
**FUEL QTY LOW**

Condition: Fuel quantity 2,000lbs or less in one or more main tanks.

**CREW ACTION:**
Consider the possibility of an engine fuel leak. If a fuel leak is suspected or confirmed, do not accomplish this procedure until the FUEL LEAK ENGINE checklist is completed.

CROSSFEED VALVE SWITCHES (ALL)  .................................................................ON  
MAIN PUMP SWITCHES (ALL)  .................................................................ON

Plan to land at the nearest suitable airport.  
Avoid high nose up attitude and excessive acceleration and deceleration.

**FUEL RES XFR 2, 3**

Condition: Reserve transfer valves not in commanded position. Fuel in affected tank not available if the quantity does not decrease.

**CREW ACTION:**
If reserve tank fuel remains trapped, reduce maximum operating speed:
Vmo/Mmo  ........................................325 KIAS/0.92 Mach

**FUEL STAB XFR**

Condition: Horizontal stabilizer fuel fails to transfer.

**CREW ACTION:**
STABILIZER TANK PUMP SWITCHES  ON  
If FUEL STAB XFR message remains displayed:  
CENTER WING TANK PUMP SWITCHES  OFF  
CROSSFEED VALVE 1 AND 4 SWITCHES  OFF  
OVERRIDE PUMP 2 AND 3 SWITCHES  OFF  
STABILIZER TANK PUMP SWITCHES  OFF

Stabilizer and center wing fuel tanks not available.

**WARNING: DO NOT JETTISON FUEL.**

If gross weight when FUEL STAB XFR first displayed was less than 832,000lbs:  
Usable fuel is all fuel in tanks 1 and 4 plus the fuel in tanks 2 and 3 down to 17,000lbs to maintain CG within limits.

If gross weight when FUEL STAB XFR first displayed was greater than or equal to 832,000lbs:  
Usable fuel is all fuel in the main fuel tanks (1, 2, 3, 4). Land before main tank 2 or 3 empty to maintain CG within limits.
>FUEL TANK/ENG

Condition: Main tank 2 quantity equal to or less than Main Tank 1 quantity, or Main Tank 3 quantity equal to or less than main Tank 4 quantity and crossfeed valve 1 or 4 open.

OR

On the ground after refueling or initial electrical power established with main tank 2 quantity less than or equal to tank 1 plus 1,100lbs and tank 3 less than or equal to main tank 4 plus 1,100lbs and crossfeed valve 1 or 4 is open.

> FUEL TEMP LOW

Condition: Fuel temperature -37C or less.

CREW ACTION:
Increase TAS or find warmer flight levels.

FUEL TEMP SYS

Condition: Fuel temperature sensing inoperative.

CREW ACTION:
Use total air temperature (TAT) as indication of fuel temperature.

FUEL X FEED 1, 4

Condition: Fuel crossfeed valve position disagrees with commanded position.

CREW ACTION:
If FUEL TANK/ENG message is displayed:
CROSSFEED VALVE 2 AND 3 SWITCHES OFF
Note: A closed crossfeed valve prevents related engine from being provided fuel from any tank other than related main tank.

FUEL X FEED 1,4 and FUEL TANK/ENG message remain displayed.

DO NOT ACCOMPLISH THE FOLLOWING CHECKLIST:
X FEED CONFIG
**FUEL X FEED 2, 3**

Condition: Fuel crossfeed valve position disagrees with commanded position.

**CREW ACTION:**
CROSSFEED VALVE 2 AND 3 SWITCHES OFF
(Prevents lateral imbalance. Fuel in the center wing tank is provided to engines 1 and 4 only)

NOTE: A closed crossfeed valve prevents related engine from being provided fuel from any tank other than related main tank.

With center wing tank fuel when the FUEL TANK/ENG message displayed, delay tank-to-engine procedure until FUEL OVRD CTR L or R message displays and center wing tank quantity less than 2,000lvs.

**DO NOT ACCOMPLISH THE FOLLOWING CHECKLIST:**
X FEED CONFIG

---

**>JETT NOZ ON**
Condition: Both fuel jettison nozzle valves open.

---

**>JETT NOZ ON L, R**
Condition: Fuel jettison nozzle valve open.

---

**>JETT NOZZLE L, R**
Condition: Fuel jettison nozzle valve position disagrees with commanded valve position.
Light: VALVE (on switch)

---

**>SCAV PUMP ON**
Condition: Center wing tank scavenge pump operating while airplane is on the ground.

---

**>X FEED CONFIG**
Condition: One or more fuel crossfeed valves incorrectly configured.
HYDRAULIC SYSTEM

NON-NORMAL CHECKLISTS

HYD CONTROL 1, 4

Condition: Hydraulic control system inoperative.

CREW ACTION:

DEMAND PUMP SELECTOR (affected system) ON
(Ensures system hydraulic pressure during periods of high demand.)

Affected system indications may be inoperative.

HYD OVHT SYS 1, 2, 3, 4

Condition: Excessive hydraulic system temperature.

Light: SYS FAULT

CREW ACTION:

If autopilot operating on affected system (as listed below), disconnect autopilot prior to depressurizing hydraulic system.

ENGINE PUMP SWITCH (affected system) OFF
DEMAND PUMP SELECTOR (affected system) OFF

When HYD OVHT SYS message no longer displayed:

DEMAND PUMP SELECTOR AUTO

Do not accomplish the following checklist:
HYD PRESS ENG

If HYD OVHT SYS message displayed again:

DEMAND PUMP SELECTOR OFF

Do not accomplish the following checklist:
HYD PRESS SYS

NOTE: Degraded or inoperative system items:

System 1:
AUTOPilot C OFF

Airplane may enter ground mode when gear extended for landing.

INOPERATIVE ITEMS:

Left Outboard elevator
Inboard trailing edge flap hydraulic operation.
Nose and body gear steering.
System 1 alternate brake source.

THE FOLLOWING CONDITIONS EXIST IF AIRPLANE ENTERS GROUND MODE IN FLIGHT:

Wing anti-ice inoperative when EICAS message WAI VALVE displayed.
Reverse thrust levers active in flight.
Approach idle minimum thrust setting inoperative.
Minimum maneuvering speed indication inoperative.
Speedbrake lever flight detent automatic stop inoperative.
Automatic ice detection system inoperative.
Transponder disabled.
Upper deck doors may be unlocked in flight.
TCAS operative in TA ONLY mode.

System 2:
AUTOPILOT R  OFF
Stabilizer trim rate reduced.
Spoiler capability reduced.

INOPERATIVE ITEMS:
System 2 alternate brake source.

System 3:
AUTOPILOT L  OFF
Stabilizer trim rate reduced.
Spoiler capability reduced.

System 4:
Spoiler capability reduced.

Airplane may enter ground mode when gear extended for landing.

INOPERATIVE ITEMS:
Right outboard elevator.
Outboard trailing edge flap hydraulic operation.
Wing gear hydraulic extension and retraction. (not modeled in sim)
System 4 primary brake source.
Autobrakes.

THE FOLLOWING CONDITIONS EXIST IF AIRPLANE ENTERS GROUND MODE:
Wing anti-ice inoperative when EICAS message WAI VALVE displayed.
Autothrottle inoperative.
Reverse thrust levers active in flight.
Approach idle minimum thrust setting inoperative.
Minimum maneuvering speed indication inoperative.
Speedbrake lever flight detent automatic stop inoperative.
Automatic ice detection system inoperative.
Transponder disabled.
Upper deck doors may be unlocked in flight.
TCAS operative in TA ONLY mode.

LANDING PREPARATION:

If system 1 or 4 is inoperative:
Trailing edge flaps operate in secondary mode. Allow additional time during approach for flap extension. (Due to sim limitations, time differences are not modeled.)

\begin{align*}
\text{ALTERNATE GEAR EXTEND SWITCH} & \quad \text{ALTN} \\
\text{LANDING GEAR LEVER} & \quad \text{DOWN}
\end{align*}

If system 4 is inoperative:

\begin{align*}
\text{AUTOBRAKE SELECTOR} & \quad \text{OFF}
\end{align*}

If more than one HYD PRESS SYS message displayed:

Use flaps 25 and VREF 30+20 for landing. Crosswind limit is 20 knots.
Plan to land at the nearest suitable airport.

If systems 1 and 4 are inoperative:
   Trailing edge flaps operate in secondary mode. Allow additional time during approach for flap extension.

**DO NOT ACCOMPLISH THE FOLLOWING CHECKLIST:**

**FLAPS PRIMARY**

<table>
<thead>
<tr>
<th>Control</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>LANDING GEAR LEVER</td>
<td>OFF</td>
</tr>
<tr>
<td>ALTERNATE GEAR EXTEND SWITCHES</td>
<td>ALTN</td>
</tr>
<tr>
<td>After all gear indicate down:</td>
<td></td>
</tr>
<tr>
<td>LANDING GEAR LEVER</td>
<td>DOWN</td>
</tr>
<tr>
<td>AUTOBRAKES SELECTOR</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Automatic ground spoilers are inoperative. Extend ground spoilers manually.

If systems 2 and 3 are inoperative:
   Stabilizer trim and elevator feel are inoperative. Avoid abrupt elevator movement.
   Autopilots are inoperative.

**HYD PRESS DEM 1, 2, 3, 4**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Demand pump output pressure low.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light:</td>
<td>PRESS</td>
</tr>
</tbody>
</table>

**CREW ACTION:**

DEMAND PUMP SELECTOR (Affected system) ON

If HYD PRESS DEM message remains displayed:
   DEMAND PUMP SELECTOR (affected system) OFF
   (Avoids system contamination and/or pump damage.)

**HYD PRESS SYS 1, 2, 3, 4**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Loss of hydraulic system pressure.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light:</td>
<td>PRESS and SYS FAULT</td>
</tr>
</tbody>
</table>

**CREW ACTION:**

DEMAND PUMP SELECTOR (Affected system) ON
ENGINE PUMP SWITCH (Affected system) OFF
   (Avoids system contamination and/or pump damage)

**DO NOT ACCOMPLISH THE FOLLOWING CHECKLIST:**

HYD PRESS ENG

If HYD PRESS SYS message remains displayed:
   DEMAND PUMP SELECTOR (affected system) OFF
Note degraded or inoperative system items below. Complete landing preparation early.

System 1:
AUTOPILOT C OFF
Airplane may enter ground mode when gear extended for landing.

INOPERATIVE ITEMS:
Left Outboard elevator
Inboard trailing edge flap hydraulic operation.
Nose and body gear steering.
System 1 alternate brake source.

THE FOLLOWING CONDITIONS EXIST IF AIRPLANE ENTERS GROUND MODE IN FLIGHT:
Wing anti-ice inoperative when EICAS message WAI VALVE displayed.
Reverse thrust levers active in flight.
Approach idle minimum thrust setting inoperative.
Minimum maneuvering speed indication inoperative.
Speedbrake lever flight detent automatic stop inoperative.
Automatic ice detection system inoperative.
Transponder disabled.
Upper deck doors may be unlocked in flight.
TCAS operative in TA ONLY mode.

System 2:
AUTOPILOT R OFF
Stabilizer trim rate reduced.
Spoiler capability reduced.

INOPERATIVE ITEMS:
System 2 alternate brake source.

System 3:
AUTOPILOT L OFF
Stabilizer trim rate reduced.
Spoiler capability reduced.

System 4:
Spoiler capability reduced.

Airplane may enter ground mode when gear extended for landing.

INOPERATIVE ITEMS:
Right outboard elevator.
Outboard trailing edge flap hydraulic operation.
Wing gear hydraulic extension and retraction. (not modeled in sim)
System 4 primary brake source.
Autobrakes.

THE FOLLOWING CONDITIONS EXIST IF AIRPLANE ENTERS GROUND MODE:
Wing anti-ice inoperative when EICAS message WAI VALVE displayed.
Autothrottle inoperative.
Reverse thrust levers active in flight.
Approach idle minimum thrust setting inoperative.
Minimum maneuvering speed indication inoperative.
Speedbrake lever flight detent automatic stop inoperative.
Automatic ice detection system inoperative.
Transponder disabled.
Upper deck doors may be unlocked in flight.
TCAS operative in TA ONLY mode.

LANDING PREPARATION:

If system 1 or 4 is inoperative:
   Trailing edge flaps operate in secondary mode. Allow additional time during approach for flap extension. (Due to sim limitations, time differences are not modeled.)

ALTERNATE GEAR EXTEND SWITCH ALTN
LANDING GEAR LEVER DOWN

If system 4 is inoperative:
   AUTOBRAKE SELECTOR OFF

If more than one HYD PRESS SYS message displayed:
   Use flaps 25 and VREF 30 + 20 for landing. Crosswind limit is 20 knots.

Plan to land at the nearest suitable airport.

If systems 1 and 4 are inoperative:
   Trailing edge flaps operate in secondary mode. Allow additional time during approach for flap extension.

DO NOT ACCOMPLISH THE FOLLOWING CHECKLIST:
FLAPS PRIMARY

<table>
<thead>
<tr>
<th>HYD PRESS ENG 1, 2, 3, 4</th>
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<tr>
<td>Condition: Associated Engine Driven Hydraulic pump has failed.</td>
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<table>
<thead>
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<th>&gt;HYD QTY LOW 1, 2, 3, 4</th>
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<td>Condition: Hydraulic Quantity Low.</td>
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LANDING GEAR/BRAKING
NON-NORMAL CHECKLISTS

AIR/GND SYSTEM

Condition: Air/Ground sensing system failed to air position.

CREW ACTION:
LANDING PREPARATION:
One symmetrical pair of thrust reversers is inoperative. Auto speedbrake deployment inoperative. When deployed manually, spoilers extend to flight position. Autobrake system inoperative.

ANTISKID

Condition: Fault detected in antiskid system

CREW ACTION:
Braking effectiveness may be reduced.
Note: Autobrake system inoperative. Use minimum braking consistent with runway conditions to reduce possibility of tire blowout.

ANTISKID OFF

Condition: Antiskid power off on all wheels, or parking brake lever released and the parking brake valve not fully open, or brake system control unit power loss.

CREW ACTION:
Use brakes with caution. Braking effectiveness reduced.
Note: Autobrake system inoperative. Use minimum braking consistent with runway conditions to reduce possibility of tire blowout.

AUTOBRAKES

Condition: Autobrakes disarmed or inoperative or autobrakes armed with autobrakes selector OFF, or RTO initiated and autobrakes have not been applied.

CREW ACTION:
AUTOBRAKES SELECTOR OFF, THEN AS DESIRED
If AUTOBRAKES message remains displayed:
AUTOBRAKES SELECTOR OFF
### BODY GEAR STRG

**Condition:** Body gear steering unlocked when commanded locked, or system pressurized when not commanded.

### BRAKE LIMITER

**Condition:** Brake torque limiter failure on more than one wheel per truck, or parking brake lever released and the parking brake valve not fully open, or brake unit control system power loss.

**CREW ACTION:**
Brake with caution.

### BRAKE SOURCE

**Condition:** Brake system pressure from hydraulic systems 1, 2, and 4 are low.

### BRAKE TEMP

**Condition:** Temperature of one or more brakes excessive. One or more brakes have reached a temperature where fuse plug melting may occur.

**CREW ACTION:**
If practicable:
- Observe gear EXTEND limit speed (270K/0.82M)
- LANDING GEAR LEVER DOWN
  (Allows cooling air to flow around brakes)
- When indication of high brake temperature is cleared:
  LANDING GEAR LEVER UP

If on the ground:
- Allow a minimum of 70 minutes brake cooling time.
>AIRSPEED LOW
Condition: Airspeed less than minimum maneuvering speed.

>ALT CALLOUTS
Condition: Altitude advisories and minimums annunciations are no longer provided.

>ALTITUDE ALERT
Condition: Airplane has deviated more than 300 feet from MCP selected altitude.

>CONFIG FLAPS
Condition: Flaps not in takeoff position when airplane on the ground, airspeed less than V1, three or more Fuel Control switches in RUN position, and engine 2 or 3 thrust in takeoff range.

>CONFIG GEAR
Condition: Any landing gear not down and locked when any thrust lever closed below 800 feet radio altitude or when flaps are in a landing position.

>CONFIG GEAR CTR
Condition: Body gear steering not centered when airplane on the ground, airspeed less than V1, three or more Fuel Control switches in RUN, and engine 2 or 3 thrust in takeoff range.
>CONFIG PARKING BRK

Condition: Parking brake set when airplane on the ground, airspeed less than V1, three or more Fuel Control switches in RUN, and engine 2 or 3 thrust in takeoff range.

>CONFIG SPOILERS

Condition: Speedbrake lever not DOWN when airplane on the ground, airspeed less than V1, three or more Fuel Control switches in RUN and engine 2 or 3 thrust in takeoff range.

>CONFIG WARN SYS

Condition: Fault detected in the configuration warning system.

GND PROX SYS

Condition: GPWS alerts may not be provided.

CREW ACTION:

NOTE: Some or all GPWS alerts are not available. GPWS alerts which occur ARE VALID AND SHOULD BE COMPLIED WITH.

>OVERSPEED

Condition: Airspeed exceeds Vmo/Mmo
# COCKPIT OVERVIEW

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COMMUNICATION SYSTEMS

Radios: The 747-400 has three Very High Frequency (VHF) communication radios for normal radio communications and two High Frequency (HF) communication radios for use while out of standard VHF radio communications range. All five radios can be tuned from any of the three radio tuning panels in the cockpit.

Microsoft Flight Simulator does not have a functional HF radio model and limits the number of VHF radios that it is possible to model. As such we have not modeled the functionality of HF radio or the third COM radio.

The radio tuning panels onboard the 747-400 are located on the control pedestal. Each radio tuning panel has a liquid crystal dual frequency display, which shows both the active and standby frequencies.

Crewmembers can select between the two frequencies by using the flip-flop key between the two frequency windows.

ACTIVE FREQUENCY INDICATOR

STANDBY FREQUENCY INDICATOR

ACARS: (Arinc Communications Addressing and Reporting System) automatically communicates information related to the disposition of the flight via a high speed digital data link to ground personnel over the ARINC proprietary VHF radio network.

Control of the ACARS system is normally through the center FMC Multi-Mode Control Display Unit (MCDU), located on the control pedestal. Any of the three MCDUs may be used, however, provided only one is used at a time.

ACARS is capable of transmitting selected company reports and information, flight data and aircraft system status via discreet compressed transmissions. The ACARS system automatically transmits the aircraft as being OUT of the gate, OFF the ground, ON the ground at destination or IN the gate. These reports are made using the landing gear Air/Ground sensing equipment, as well as parking brake disposition and cabin doors. All cabin doors except the upper deck, 3L, 3R and 4R provide status information to the ACARS system.

The OUT time reported is the time at which the parking brake is released after all the aircraft doors have been closed.

The OFF time reported is recorded at aircraft liftoff and is transmitted after a short delay to ensure accuracy.

The ON time reported is recorded at aircraft touchdown time and is transmitted after a short delay to ensure accuracy.

The IN time is reported as the last time the parking brake is set before the opening of any doors.

During the course of the flight it is possible to automatically or manually update the Estimated Time of Arrival (ETA) at the destination airport. Crews are encouraged to use this feature in order to ensure personnel at the downline station can accurately predict the arrival time of the aircraft.

ACARS functionality is to be added as part of a future update. It is intended to include weather reporting capability and OOOI times reporting and recording.
NAVIGATION SYSTEMS

Overview: The 747-400 has two VHF navigation radios, three ILS/MLS receivers, and two ADF navigation radios installed. The VHF radios (designated Left and Right) provide dedicated VOR navigation radio support and can be tuned automatically by the FMC-CDU or manually by the crew. Both ADF receivers can be tuned manually by the crew.

VOR Navigation Radios: Both VOR receivers are linked directly to the FMC, and provide VOR navigation bearing and course deviation information to the crew via the Navigation Display.

Under normal operating conditions, the crew will leave the VOR receivers to be tuned automatically by the Flight Management Computer. The FMC uses a logic process in order to choose VOR frequencies that facilitate triangulation of the current aircraft position as a backup to Inertial navigation and GPS position data. The VOR receiver antennas are located near the top of the vertical stabilizer.

The VOR receivers can be tuned manually by using the NAV RAD page on any FMC/MCDU.

VOR bearing pointers and information can be displayed on the navigation display if the crew selects the VOR L/R switches ON from the EFIS-Mode Control Panel. VOR bearing pointers are available in all navigation modes except PLN.

Instrument Landing System: The 747-400 carries triple redundant ILS receivers. The ILS system can be manually tuned by the crew, or automatically tuned by the FMC.

The localizer portion of the ILS shares the VOR antenna located in the vertical stabilizer until localizer capture. Once the localizer has been captured, reception is switched to the dedicated ILS-Localizer antennas located on the radome bulkhead. This is done to prevent ILS signal blanking or distortion that may result at higher pitch angles when the nose of the airplane protrudes into the line-of-sight path between the Localizer transmitter and the VOR antennae on the vertical stabilizer.

ILS-Glideslope acquisition antennas are also located in the radome, with tracking antennas located in the leading edge of the nose gear doors. Glideslope reception switches from the radome receivers to the nose gear door receivers when the landing gear are selected down.

When active, the tuned ILS frequency will be displayed on the Primary Flight Display (PFD) and Navigation Display (ND) if APR (approach) mode has been selected. The flight management computer will receive the appropriate frequency and display the decoded ILS station identifier for the crew as well.

ILS tuning, either manual or automatic is inhibited under all of the following circumstances:

- When localizer and Glideslope captured and autopilot engaged.
- Aircraft on the ground, within localizer coverage, heading within 45 degrees of front course and groundspeed in excess of 40 knots.
- Flight Director engaged, localizer or Glideslope captured and radio altitude less than 500 feet AGL.

Localizer and Glideslope deviation bars, as well as ILS identifier or frequency, DME information (if available) and selected approach course information will be displayed on the PFD when the ILS is properly tuned. The ND will display localizer deviation bars, Glideslope deviation bars, runway heading and the ILS frequency, course and DME information when the associated ND is selected to approach.

Automatic Direction Finding (ADF): The 747-400 carries two ADF receivers. There is one integral sense and loop antenna for each receiver. Either ADF radio can provide bearing information to a selected station.
The ADF systems can be tuned from the NAV RAD page of the FMC/MCDU.

The ADF bearing pointers for the left and right systems can be displayed on the navigation displays in all modes except PLN. The ADF pointers can be selected using the ADF/VOR selectors on the EFIS/Mode Control Panel.

**Distance Measuring Equipment (DME):**
The 747-400 carries two 5-channel DME radios to provide distance information to the FMC. This information is displayed on the ND when a DME channel is tuned. The radios are tuned automatically by the FMC.

The FMC manages use of the DME channels, and will use channels 1 and 2 for position update, 3 and 4 for navigation and channel 5 for the ILS system.

DME information derived from channels 3 through 5 is displayed on the ND if the crew has selected the appropriate navigation displays. The identifiers of stations tuned on channels 1 and 2 are displayed on the FMC POS REF page.

**ILS Marker Beacon Sensing:** The marker beacon receiver is a functioning part of the left VOR receiver and provides data to the Primary Flight Display for visual and audio interpretation of outer, middle and inner marker signals.

**Transponder:** The 747-400 carries a dual transponder system that is controlled from a single transponder control panel on the center console.

The Transponder control also has integrated controls for TCAS display formats and modes, as well as an IDENT button.

**Clock:** Two clocks located on the instrument panel provide GMT, elapsed time and chronometer functions for the crew.

The clocks also report GMT to the FMC and the flight recorders.

**Weather Radar:** Weather radar is not currently modeled.

**Air Data Computers:** The 747-400 air data computer includes two digital air data computers, two angle of attack sensors, two TAT temperature probes, four pitot-static probes and two flush mounted static air sensors.

**Inertial Reference System**
The 747-400 has three Inertial Reference Units, or IRUs. Each IRU uses laser gyro accelerometers to provide:

- Acceleration
- Attitude
- Ground speed
- Latitude and longitude information to all instruments and systems requiring inertial data
- Track
- True and magnetic heading
- Wind direction and speed

Considered together as a group, the IRU’s comprise the Inertial Reference System. It is important to note that the IRS does not navigate or provide direct navigation commands to any system on the aircraft. Instead the IRS provides continual inertial position reference, which is transmitted to the FMC, which then uses the information in the process of navigational computations.

IRS position information can only be updated with the aircraft stationary, on the ground, via pilot entry of position data through a CDU.

If the IRS loses both AC and DC power in flight, alignment will be lost and the FMC will cease using IRS information for navigation. An IRU can be restarted in flight in the attitude mode to provide attitude information.

**Radio Altimeters:** The 747-400 carries three radio altimeters which supply the flight control computers with radio altitude information below 2,500 feet. This information is displayed on the PFD for crewmember use.
The left radio altimeter supplies data to the Ground Proximity Warning System and the Aircraft Configuration Warning System.

**Ground Proximity Warning System (GPWS):** The GPWS alerts the flight crew to potential hazards associated with deviation from flight path conditions and provides visual and aural warnings or alerts when the airplane is flown into one of these conditions.

The GPWS computer uses input from the following systems, and must have access to all the below listed systems in order to generate indications appropriate to the conditions of flight.

- An operating Air Data Computer
- An operating stall warning system
- Gear lever position
- Left and center flap control units
- Left EFIS control panel
- Left FMC
- Left ILS receiver
- Left IRS
- Left Radio altimeter

There are seven basic modes with specific indications for each separate mode. In addition, some modes have multiple sub-modes, which are described below. Voice warnings are incorporated to help identify the cause of the warning or alert and to help the crew identify the flight condition threat and respond immediately.

**Mode 1 - Excessive Descent Rate:** Monitors for excessive rate of descent, regardless of aircraft configuration. Initial warning is comprised of the aural voice alert of “SINK RATE” and activation of the amber GND PROX/G/S inhibit light switch. If the excessive rate of descent is not corrected, the secondary warning of “WHOOP WHOOP PULL UP” sounds and the master caution light illuminates. A red PULL UP message is displayed on both the Captain’s and the First Officer’s PFD.

**Sub-mode 2A** (Gear and Flaps out of position.) Aural voice alert of “TERRAIN, TERRAIN” and the amber GRND PROX/G/S INHIBIT light illuminates. If the excessive closure rate is not arrested, the aural warning changes to “WHOOP WHOOP PULL UP” and the master caution light illuminates. A red PULL UP message is displayed on both the Captain’s and the First Officer’s PFD.

**Sub-mode 2B** (Flaps positioned for landing with gear retracted.) Provides a repeated aural alert of “TERRAIN TERRAIN” and the amber GND PROX/G/S INHIBIT light illuminates. If the excessive closure rate continues below 700 feet radio altitude and the landing gear are not in the down and locked position, the aural changes to “WHOOP WHOOP PULL UP” and the red master caution light is illuminated. A red PULL UP message is displayed on both the Captain’s and the First Officer’s PFD.

**Mode 2 - Excessive Terrain Closure Rate:** Monitors for excessive terrain closure rate when the landing gear and flaps are not in the landing configuration without the gear being lowered.

**Mode 3 - Altitude Loss After Takeoff or Go Around:** If the airplane begins to descend during takeoff or during a go-around, (while still below 700 feet radio altitude) an aural warning of “DON’T SINK” is heard and the amber GND PROX/G/S INHIBIT light illuminates.

**Mode 4 - Unsafe Terrain Clearance:** Monitors for unsafe terrain clearance while the gear are in the up and locked or in transit position, or the flaps are not in the landing positions.

**Sub-mode 4A** (Unsafe terrain clearance with gear up.) provides an aural alert of “TOO LOW GEAR” or “TOO LOW TERRAIN” depending upon speed and altitude.

**Sub-mode 4B** (Unsafe terrain clearance with flaps not in landing position.) provides the repeated aural alert “TOO LOW FLAPS” or “TOO LOW TERRAIN” depending upon speed and altitude.

**Mode 5 - Glideslope Deviation:** If the aircraft deviates more than 1.3 dots below the glideslope, provides the repeated aural
alert “GLIDESLOPE.” Volume of warning increases if condition is not immediately corrected.

Mode 5 can be inhibited for approaches which are expected to deviate from the intended Glideslope, such as visual approach after brake out of IFR conditions under special circumstances, or a turning IGS approach.

**Mode 6 - Altitude Advisories:** Provides voice call-outs of radio altitude at 400, 300,200,100,50,40,30,20 and 10 feet above the touch down point.

If the Captain has set the DH in the PFD, Mode 6 will announce “MINIMUMS” at the selected altitude.

**Mode 7 – Windshear:** Monitors flight conditions for excessive downdrafts or tailwinds. If such conditions are detected an aural alert of “WINDSHEAR” follows a two toned siren. A red WINDSHEAR” message is displayed on both PFDs during all windshear alerts.

The Autopilot Flight Director System (AFDS) will provide windshear guidance in both pitch and roll modes.

When active, the windshear warning inhibits all other GPWS warning modes. Modes 1-6 will remain inhibited until the windshear condition ceases or an escape maneuver (such as pressing the TO/GA switch) is initiated.

The proper windshear escape maneuver is to press either TO/GA switch twice. This will initiate an automated go-around by toggling the autothrottles to full power, (thrust levers forward and removal of any power de-rate selected in the FMC) and cause the flight directors to command a 15 degree nose up target pitch attitude, or slightly below the pitch limit indicator for a given phase of flight, whichever is lower.

If the flight director switches were off during the windshear alert, activation of the TO/GA switches will cause the command bars to become active in order to provide pitch and roll guidance.

**Altitude Alerting System:** The altitude alerting system functions as a background system in much the same manner as the GPWS and is designed to alert the flight crew when approaching and departing an MCP selected altitude.

**Approaching a selected altitude:**

At 900 feet prior to reaching the altitude selected in the MCP altitude window, a white box will be displayed around the altitude display on the Captain’s and First Officer’s PFD.

At 300 feet prior to the selected altitude, the white box is removed.

**Deviation from a selected altitude:**

If the altitude alerting system detects a variation exceeding more than 300 feet from the MCP selected altitude the following alert is provided:

- Master Caution Light illuminate
- Caution alert chime sounds
- EICAS caution message ALTITUDE ALERT is displayed.
- Current altitude box changes to amber.

If the altitude variation exceeds 900 feet, or returns to within the 300-foot envelope:

- Master Caution light extinguishes
- EICAS caution message is no longer displayed.
- Current altitude box changes to white.

Altitude alerting is inhibited when the landing gear is selected in the down and locked position and the flaps are selected in the landing position, or after Glideslope capture during the approach.
COCKPIT DISPLAY SYSTEMS

Overview: The 747-400 uses an integrated display system, which consists of six flat panel CRTs or six flat panel LCD screens. The screens are referred to by their geographic position on the panel:

- Outboard (Captain's or FO's)
- Inboard (Captain's or FO's)
- Upper
- Lower (See lettered outline, below.)

Each crewmember has two screens located directly in front of the crew member station. Each of these screen pairings is known as an Electronic Flight Instrumentation System, or EFIS.

Electronic Flight Instrument System (EFIS): The EFIS is comprised of two eight inch by eight inch square flat panel CRT displays. The outboard CRT is the Primary Flight Display (PFD) and the inboard is the Navigation Display (ND). Each pilot has both a PFD and a ND screen.

The EFIS system receives flight and aircraft performance data such as attitude, vertical speed, heading, track and location information from the Inertial Reference Systems (IRS), as well as flight background information, progress information and map background information from the Flight Management Computer (FMC). This information is presented to the Captain and First Officer in the form of a moving map display and dynamic, graphic flight instrument displays designed to reduce pilot workload.

Layout and Controls: To operate the airplane effectively, it is important the crewmembers understand that controls are generally grouped into logical positions on the panel. The EFIS/Mode Control Panel allows the crew to customize the information displayed on each EFIS (Primary Flight Display / Navigation Display) pairing for the Captain and FO. These controls are detailed below.
PRIMARY FLIGHT DISPLAY

Overview: The PFD presents graphical interpretations of traditional aircraft performance and flight control instruments. Airplane attitude indications, flight director commands, deviation from localizer or Glideslope indications, airspeed, heading and rate of climb/descent are all presented in a concise, graphical format designed to reduce pilot workload while flying the aircraft.

Information displayed on the PFD is broken down into six distinct areas:

- Autopilot Flight Mode Annunciation
- Airspeed Indication
- Attitude Indication
- Altitude Indication
- Vertical Speed Indication
- Heading Indication

This information is laid out in a format centered around the attitude indicator in order to reduce pilot information scan time.

Primary Flight Display Information: The PFD provides all of the interpretive data the pilot will need to fly the aircraft. Pitch and bank attitude, airspeed, airspeed trend, autopilot modes, altitude, vertical speed, commanded altitude and airspeed, heading precision approach information, and flight directors are all represented.

The information presented on the PFD is taken directly from a combination of Inertial Reference Computers and the Air Data Computer. Should any data become unreliable or unusable, an amber flag will be displayed in place of the associated graphic display.

Each of the information sub-groups is discussed below.
**Airspeed Indication:** Airspeed is displayed on a moving tape with dynamic speed information such as structural limits, stall speed, maneuvering speeds and trend information overlaid onto the display.

**Command Speed Display:** Displays airspeed selected via the MCP IAS/Mach Command Speed knob. Displays FMC determined speed if IAS/Mach window is blank.

**Maximum Speed Strip:** Displays maximum structural speed or gear/flap placard speed, whichever is applicable.

**Maximum Maneuvering Speed:** Displays maximum safe maneuvering speed and shows margin to high speed buffet, stick shaker and overspeed warning.

**Airspeed Trend Vector:** Shows airspeed trend in direction of arrow. Tip of arrow shows where airspeed will be in ten seconds at current trend.

**Current Airspeed Display:** Displays current airspeed.

**Command Speed Bug:** Displays airspeed selected via the MCP IAS/Mach Command Speed knob. If IAS/Mach window is blank then bug shows current speed commanded by FMC. Should always show same number as command speed display.

**Flap Setting Indicator Track:** Below 20,000 MSL, current and next flap setting will be shown. REF marking indicates currently selected landing REF speed according to FMC.

**Minimum Maneuvering Speed:** Indicates minimum safe maneuvering speed and shows margin to stall warning and stick shaker activation.

**Minimum Speed/Stall Speed:** Displays current minimum speed for aircraft configuration.

**Current Mach Number:** Displays current Mach number.
**Autopilot Flight Director System Mode Annunciation:**

The Autopilot Flight Director System controls aircraft performance across the full flight regime by managing three primary AFDS autopilot regimes. These regimes are:

- Autothrottle
- Roll
- Pitch

The AFDS will control flight in each of these regimes by selecting particular modes for each regime. The status of these modes, and the AFDS as a whole is displayed on the PFD above the attitude indicator.

The AFDS mode annunciator consists of three mode annunciators that display both current and armed modes for each of the autothrottle, roll and pitch regimes.

**Autothrottle Modes:**

- THR Thrust Mode
- THR REF Thrust Reference Mode
- IDLE Throttles Closed
- HOLD Thrust Holding Mode
- SPD Thrust Speed Mode

Each of these modes is explained in greater depth in the Flight Management Systems chapter, but are listed here for reference.

**Roll modes:**

- TO/GA Takeoff/Go Around
- LNAV Lateral Navigation
- HDG SEL Selected Heading
- HDG HOLD Hold Current Heading
- LOC Track Localizer
- ROLLOUT Track Runway
- ATT Attitude Hold

Each of these modes is explained in greater depth in the Flight Management Systems chapter, but are listed here for reference.

**Pitch modes:**

- TO/GA Takeoff/Go Around
- VNAV Vertical Navigation
- VNAV SPD VNAV Speed Mode
- VNAV PTH VNAV Path Guidance
- VNAV ALT VNAV Altitude
- FLCH SPD Flight Level Change
- V/S MCP Vertical Speed
- ALT MCP Altitude Hold
- G/S Track Glideslope
- FLARE Flare Guidance

Each of these modes is explained in greater depth in the Flight Management Systems chapter, but are listed here for reference.

**AFDS modes are:**

- FD Flight Director
- CMD Autopilot ON
- LAND 2 Degraded Autoland
- LAND 3 Full Autoland
- NO AUTOLAND Autoland Failed

Each of these modes is explained in greater depth in the Flight Management Systems chapter, but are listed here for reference.
**Attitude Indicator:** The attitude indicator provides a significant technological advance over traditional cockpit display instruments. This is due in large part to the significant amount of information that can be displayed graphically on the instrument based on the particular flight mode or maneuver being performed. The Attitude indicator is demarked in $2.5^\circ$ pitch increments, and has a fully overlaid flight director command bar mode. Dynamic pitch limit bars visually demonstrate the maximum attainable pitch angle in any given flight mode or maneuver. Localizer and glideslope markers, as well as marker beacons, radio altitude indicator and angle of bank indications round out the information spectrum displayed on this instrument.

**Flight Path Vector:** (Not shown) A circular reticle displayed on the PFD which shows instantaneous aircraft inertial direction.

**Approach Reference:** Displays selected ILS identifier (frequency only if not identified.) DME if available.

**AFDS Mode Annunciator:** Displays current AFDS mode.

**MDA/RA Indication:** Depending on mode of flight, will display MDA/DH as set on MCP. Radio Altitude displayed below 1500 feet.

**Angle of Bank/ Slip Indicator:** Upper triangle displays angle of bank. Lower box indicates slip/skid in turn.

**Marker Beacon:** Displays OM, MM, IM color coded.

**Pitch Limit Indicator:** Absolute aircraft pitch limit given current aircraft configuration/ regime of flight. Pitching up to this mark will induce a stall.

**Pitch Ladder:** Pitch ladder delimited in $2.5^\circ$ increments.

**Airplane Attitude:** Airplane attitude display (always centered.)

**Flight Director Command Bars:** Displayed when F/D selected ON.

**Glideslope Indicator:** Standard glideslope indication. Diamond not filled when fully deflected.

**Localizer Indicator:** Standard localizer indication. Diamond not filled when fully deflected.

**DH Indication:** DH displayed when selected and set on MCP.
**Vertical Speed Indication:** The vertical speed indication is derived directly from the IRS, and as such can be considered an instantaneous reading of vertical speed. The vertical speed indicator has a needle, which fluctuates vertically against a graphic display and as such is capable of showing both the rate of climb/descent, and also the vertical speed trend.

At vertical speeds in excess of 400 feet per minute, a numerical display of vertical speed will appear below the graphic display.

**Vertical Speed Bug:** Shows target vertical speed as selected in the MCP V/S command window.

**Vertical Speed Needle:** Needle indicates current vertical speed and moves to show rate of change in vertical speed.

**Vertical Speed Rate Scale Delineation:** Vertical Speed scale against which Vertical Speed Needle is read.

**Vertical Speed Display:** Number indicates vertical speed. Displayed only when vertical speed exceeds 400 feet per minute.

**Heading Indication:** The heading indicator is a composite graphic display which shows both aircraft heading and aircraft track, further simplifying wind correction angles both in cruise and on approach.

**Heading Pointer:** Indicates current heading.

**Drift Angle/Ground Track Pointer:** Shows ground track currently computed by FMC.

**Heading Bug:** Heading bug as set in MCP command heading window.

**Heading Reference:** Displays MAG for magnetic north, TRU for true north as selected by heading reference switch.

**Current MCP Selected Course:** Shows course currently selected in MCP command heading window. Should match location of heading bug, but unlike heading bug will always be visible in spite of current heading.
Altitude Indication: Displays altitude as computed by the air data computer. Information is displayed in a graphical format against a moving background display showing both current altitude and trend direction.

Default display is to standard foot indication. If desired, a crew selection of metric units can be displayed, and varies from the diagram below only in that a metric notation box is displayed directly above the numeric current altitude display. In addition a metric altitude will be displayed above the MCP selected altitude display at the top of the altitude indicator tape.
**ELECTRONIC FLIGHT INSTRUMENT SYSTEM MODE CONTROL PANEL (EFIS/MCP)**

**Overview:** The primary method for customizing the information displayed by the EFIS is through use of the EFIS-Mode Control Panel. One EFIS-MCP for each pilot is located at each end of the glareshield panel. The EFIS-MCP provides a centralized control for selecting settings, modes and ranges on the Navigation Display, as well as buttons to display navigation aids, waypoints and airport information directly onto the moving map displayed on the Navigation Display.

On this panel are also controls to set the Decision Height (DH) and Minimum Descent Altitude (MDA), as well as barometric settings in inches of Mercury (in. Hg) or hectoPascals (hPa). A pressure switch has been included which allows the crew to select between the use of feet or meters on the PFD.

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**DH/MDA Selector [Outer Ring]**

**Altitude Select [Inner]** (Twist/Push to Set)

**BARO Setting [Inner]** (Twist/Push to Set)

**Meters/Feet Select**

Two, three position toggle switches allow the pilot to activate display of the left and right VOR/ADF bearing pointers on the Navigation Display.

**Flight Path Vector ON/OFF Pressure Switch**
Setting/Displaying Minimums: There are two types of approach altitude minimums that can be set from the EFIS/MCP.

RADIO: Determines approach minimums by using radar altimeter data to compute Height Above Touchdown (Displayed as HA on approach charts). Most commonly used on precision approaches like an ILS.

BARO: Uses barometric pressure altitude to determine the Minimum Descent Altitude. (Displayed as MDA on approach charts.) Most commonly used on non-precision approaches like a VOR approach.

To select between RADIO and BARO minimums, place the mouse directly over the word MINS on the EFIS/MCP. Left-Clicking will switch the knob between the two settings.

Radio/Baro Change click area:

After selecting RADIO or BARO minimums, you can change the HA/MDA altitude by left/right clicking when you are presented with a "Left/Right" arrow icon. This will cause the minimums display on the Primary Flight Display to change in response to your clicking.

MDA display:

To reset or clear the selected HA/MDA setting, simply press the reset button in the middle of the switch (RST).

Setting Barometric Altimeter: Barometric altimeter can be selected to display inHg (inches of mercury) or HPA (hectopascals), based on pilot preference.

To change between the two, hover the mouse over the BARO test located above the switch. This will cause the mouse cursor to change to a hand. Left clicking will rotate the knob between IN/HPA.

To change the altimeter setting, move the mouse near the knob until you are presented with the “Left/Right” click arrow. You can then left/right click to adjust the barometric setting.

Pressing the Standard button (STD) will set the barometric pressure to “Standard” setting (29.92 inHG, for example.)

Pressing the MTRS button will cause the altitude information on the primary flight display to show METERS.
VOR/ADF Display Selectors: Information related to currently tuned ADF/VORs can be displayed on the Navigation display by selecting the Left/Right VOR/ADF switches to the desired position, including OFF.

Selecting either switch to VOR or ADF will cause the station information to be displayed on the lower left right corner of the Navigation display respectively. VOR stations are displayed in green, while ADF stations are displayed in blue.

Receiver information (VOR L/ VOR R), station identifier, and DME distance information are also displayed if the information is available.

On the navigation display compass rose, selecting a VOR or ADF will cause a similarly matched arrow to indicate current azimuth for the station.

Station Azimuth Arrow:

The Navigation type is done by using the Navigation Display Selector on the EFIS/MCP.

This selector can be rotated left and right using left/right mouse clicks.

To change between the Expanded Compass Rose and the Full Compass Rose format, simply press the CTR button in the middle of the switch.

Selecting Navigation Display Range: The range of the navigation display is selectable at increments between 10nm and 640nm using the range selector knob on the EFIS/MCP.

The center push button on this knob can be pressed to display TCAS traffic information, provided that TCAS information is being provided by the Transponder. (Transponder switch in TA/RA or TA ONLY position.)

Adding Information to the Nav Display: A bottom row of six buttons on the EFIS/MCP can be used to add or remove information from the navigation display in order to aid situational awareness.

Optional overlays include Weather (radar not modeled in this version), STA (VOR/Navigation Stations), WPT (navigation waypoints), ARPT (Airports), DATA (navigation data related to route of flight) and POS (positional information.)

All of these switches can be used to customize the navigation display for optimal use in any regime of flight.
NAVIGATION DISPLAY

Overview: EFIS allows each pilot to have a highly customizable Navigation Display (ND). Through the EFIS-MCP, each pilot can tailor the information displayed in order to provide the maximum benefit for the particular flight regime or maneuver.

The Navigation Display is capable of providing flight planning assistance in the form of a PLN mode, navigation and situational awareness in the form of a MAP mode, as well as general navigation and approach capabilities in the VOR and APP modes.

Navigation Display Modes: There are four operating modes for each ND, including MAP, PLN, VOR and APP mode. The mode selection directly controls how information is displayed to the flight crew, and indirectly controls the operation of other avionics equipment aboard the aircraft in order to perform the display functions required.

MAP Mode: MAP mode is the normal operating mode for most phases of flight in the 747-400, as it provides the most complete situational awareness for the flight crew while performing routine navigation and flight operations. This mode presents information against a moving map background and is oriented with the airplane track to the top of the display.

Information displayed includes:
- Heading
- Trend Vectors
- Range to Altitude Intercept
- Wind Direction, relative bearing and speed
- Ground Speed
- True Air Speed
- Distance and Time to Go
- Radio selection data
- ADF and VOR pointer indications
- ETA and selected navigational data points as provided in the FMC database.
- Weather Radar Returns

The range displayed by the MAP mode can be adjusted to suit crew needs using the EFIS-MCP Range Selector. MAP mode distance can be adjusted from 10nm to 640nm.

The MAP mode can be displayed in either the expanded mode, shown, or as a full compass rose similar to a conventional HSI. The crew can switch between these two modes by pressing CTR button in the mode selector switch on the EFIS-MCP.

A representative breakdown of MAP mode display capabilities is provided below.

(The following display graphics are provided in black and white to aid in clarity and simplicity when printing this document.)
**MAP Mode:**

**Heading Pointer**
Indicates the actual magnetic heading of the aircraft. (MAP and PLN modes.)

**Groundspeed / True Airspeed**
Displays the current groundspeed and airspeed of the aircraft. (Same in all modes.)

**Wind Direction/Speed and Relative Wind Bearing**
Displays the wind direction and speed. Vector arrow shows wind bearing relative to display. (MAP and PLN modes.)

**Heading Bug**
Indicates heading selected using the MCP heading selector. After changing or selecting a heading, a dotted line will extend from the aircraft marker to the heading bug for 10 seconds. The heading bug automatically swings to the localizer course at localizer capture during approaches.

**Left/Right VOR/ADF Information**
VOR - Displays VOR identifier and DME data. If VOR is not yet identified, displays VOR frequency. If only DME signal is identified, VOR identifier is small font.

ADF - Displays ADF frequency and identifier. Frequency only is shown until ADF is identified.

**Route Line**
(Magenta) Shows active flight plan in FMC. (Dashed White) Unconfirmed modifications to flight plan. (Blue dashed) Inactive route

**Vertical Deviation Indicator**
Shows altitude deviation from the selected vertical profile. Displayed in the MAP mode during descent only. Scale is capable of showing deviation of +/-400 feet. If vertical track data fails, the letters VTK will be displayed. Deviation indication functions in the same manner as an ILS glideslope indicator.

**Magnetic Track/Heading Display**
Indicates magnetic track (TRK - MAG) in MAP or PLN modes. Indicates magnetic heading (HDG - MAG) in VOR or APP modes.

**Nautical Miles to Next Waypoint**
Displays distance to next fix on flight plan.

**ETA Display**
Current estimated time of arrival at next waypoint on FMC plan.

**Active Waypoint**
Indicates the next active waypoint in the FMC flight plan. (Displayed in MAP and PLN modes only.)
**MAP Mode (Centered Compass):**
By pressing the CTR (inner) button on the ND Mode selector, the crew can alter the MAP mode display between the enlarged compass rose and the Centered Compass display (below).

The full compass rose displays an entire compass rose similar to a conventional HSI instrument, with markings delineated at major headings. The background moving map remains displayed behind the compass rose.

Crews are cautioned to note that unlike the expanded compass MAP display, the full compass rose MAP display shows the current aircraft location in the center of the display.

When complying with ATC heading vectors, be sure to use the triangular heading indicator on the outside of the compass rose for heading indication.

When attempting to fly a specific track, (as in when tracking a specific VOR radial) use the vertical distance bar and the TRK/MAG numeric display at the top of the compass rose for airplane ground track information.

Airplane heading and airplane ground track indicators will almost always differ to winds aloft, and using the correct indicator for the flight maneuver is important for accurate flight technique.

**PLN Mode:**
PLN mode provides a static map display on the lower two thirds of the ND. The map display is always oriented toward true north. The top third of the display retains the same dynamic heading/track presentation as in MAP mode. PLN mode range and radio tuning remain the same as in MAP mode.

PLN mode can be used to step through an entire flight plan to ‘look ahead’ for navigation and planning purposes. The current ‘Center Point’ of the PLN mode display can be stepped forward using the FMC in RTE LEGS mode (see FMC guide.)

PLAN mode varies slightly if you have selected an LCD cockpit vs. the standard CRT cockpit, but functionality remains largely the same.

**DYNAMIC DISPLAY**
Shows aircraft heading, track, heading bug, tuned VOR information and speed/wind information as in MAP mode.

**STATIC FLIGHT PLAN DISPLAY**
Displays a static route map of the flight plan as currently entered into the FMC. This view is oriented toward True North, and can be stepped through the entire flight plan via the FMC.
VOR Mode:
VOR mode provides an ‘aircraft heading-up’ oriented, expanded compass rose display with specific information related to VOR navigation included. This display shows the following information:

- VOR receiver identification
- Frequency
- Course
- Distance
- Ground Speed
- True air speed
- Wind Direction, relative bearing and speed.
- TO/FROM information

VOR Mode (Centered Compass):
A full compass version of the VOR mode can be displayed by pushing on the ND control selector switch. This will display a full compass rose VOR similar to a conventional HSI display.

AIRCRAFT TRACK VECTOR
Shows actual aircraft track corrected for wind deviation.

HEADING INDICATOR
Displays aircraft magnetic heading at top of display.

COURSE DEVIATION INDICATOR
Shows left/right deviation from course

COURSE DEFLECTION INDICATOR:

TO/FROM FLAG
Displays current to/from/off status of selected VOR.

Range selection, weather radar and other capabilities of the PLN mode are the same as in MAP mode.

Altering aircraft heading until the CDI matches the desired ground track will greatly simplify the process of correcting for crosswind conditions while flying.

Range selection, weather radar and other capabilities of the PLN mode are the same as in MAP mode.

Weather radar display is inhibited in the full compass rose mode to reduce clutter and information overload.
**APP Mode:**
APP mode provides an 'aircraft heading-up' oriented expanded compass rose display with specific information related to ILS approach navigation included. This display shows the following information:

- ILS nav data source
- Frequency
- Course / Track
- DME distance
- ADF Bearing functions
- Ground speed
- True air speed
- Wind direction, relative bearing and speed
- Localizer and glideslope deviation.

**APP Mode (Centered Compass):**
With the ND mode selector in APP, pushing the mode control switch will provide a full compass rose display similar to a conventional HSI display. Weather radar is inhibited in the full compass rose display to reduce clutter.

**ILS STATION FREQUENCY/COURSE/DME**
Displays current ILS use, frequency, course and DME information.

**GLIDESLOPE DEVIATION INDICATOR**
Standard glideslope deviation indicator.

Range selection, weather radar and other capabilities of the APP mode are the same as in MAP mode.

**AIRCRAFT TRACK VECTOR LINE**
Displays actual aircraft track when corrected for wind deflection.

Crews accustomed to using MAP mode displays are cautioned to be aware that in APP mode, aircraft heading is always displayed at the top of the compass rose, while the aircraft track is displayed by a dynamic course deflection indicator (CDI) which provides a representation of aircraft ground track.

Altering aircraft heading until the CDI matches the desired ground track will greatly simplify the process of correcting for crosswind conditions while flying.
# NAVIGATION DISPLAY SYMBOLOGY

The following symbols can be displayed on the ND depending on EFIS-MCP switch settings. All symbols appear in colors that group the indications into certain categories as described below:

- **(G)** GREEN  Indicates engaged flight mode displays which are dynamic in condition.
- **(W)** WHITE  Indicates present status situation, scales, armed flight mode displays.
- **(M)** MAGENTA  Indicates command information, pointers, symbols, fly-to-condition.
- **(B)** BLUE  Indicates non-active or background information.
- **(R)** RED  Indicates a critical warning.
- **(A)** AMBER  Cautionary messages.

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<td>Current true airspeed displayed above 80 knots.</td>
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<td>AAAAA</td>
<td>Active Waypoint Identifier (W)</td>
<td>Indicates active LEGS page waypoint currently navigating to.</td>
<td>APP VOR MAP PLN</td>
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<td>VOR L,R</td>
<td>Receiver Reference (M) - Autotuned (G) - Manually</td>
<td>Indicates receiver referenced for the display.</td>
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<td>ILS/VOR Frequency or Identifier Display (G)</td>
<td>Frequency displayed before identifier is decoded. Decoded identifier replaces the frequency. Small fond indicates only DME information is being received.</td>
<td>APP VOR MAP PLN</td>
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<td>74.8 NM</td>
<td>Distance Display (W)</td>
<td>Indicates distance to current active waypoint.</td>
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<td>DME 74.8</td>
<td>DME Based Distance Display (W)</td>
<td>Indicates DME distance to the referenced navaid.</td>
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<td>ETA Display (W)</td>
<td>Indicates FMC calculated ETA for active waypoint.</td>
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<td>CRS 074</td>
<td>Course Display (W)</td>
<td>Indicates VOR or ILS localizer front course.</td>
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<td>TRK 140</td>
<td>Track Orientation (G), Indicator (W) and Reference (G)</td>
<td>Indicates number under pointer is a track. Box displays actual aircraft track.</td>
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<td>HDG 090</td>
<td>Heading Orientation (G), Indicator (W) and Reference (G)</td>
<td>Indicates number under pointer is a heading. Box displays actual aircraft heading.</td>
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<td>Heading Pointer (W)</td>
<td>Indicates airplane heading when selected mode has a TRK orientation.</td>
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<td>Indicates airplane track when selected mode has a HDG orientation.</td>
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<td>Selected Heading Marker (M)</td>
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<td>Inactive routes are displayed with long dashes (B) between waypts.</td>
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<td>RANGE</td>
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<td>When DATA is selected ON, altitude and ETA for route waypoints are displayed.</td>
<td>APP VOR MAP PLN</td>
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<td>When WPT is selected ON, data base waypoints not on the selected route are displayed in ND ranges of 10, 20 or 40 nm.</td>
<td>APP VOR MAP PLN</td>
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<td>Selected Reference Point and Bearing</td>
<td>Displays the reference point selected on the FMS-CDU ‘Fix’ page. Bearing and/or distance from the Fix are displayed with dashes. (G)</td>
<td>APP VOR MAP PLN</td>
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<td>IRS Position (W)</td>
<td>When POS MAP switch selected ON, indicates IRS position relative to FMC position if they differ.</td>
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<td></td>
<td>Weather Radar Returns (R, A, G, M)</td>
<td>Multicolored returns are displayed when the Weather Radar is selected ON. Most intense areas are displayed in red, lesser intensity as amber, and lowest intensity in green. Turbulence is displayed in magenta. (Not modeled)</td>
<td>APP VOR MAP PLN</td>
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<td>Trend Vector (W) [Dashed Line]</td>
<td>Predicts the aircraft directional trend at the end of 30, 60 and 90 second intervals. Each segment represents 30 seconds. Based on bank angle and ground speed.</td>
<td>APP VOR MAP PLN</td>
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<td>Holding Pattern: Active Route (M) Modified Route (W) Inactive Route (B)</td>
<td>A fixed size holding pattern appears when in the flight plan. This pattern increases to correct size when holding. Does not display entry LNAV will command aircraft to fly.</td>
<td>APP VOR MAP PLN</td>
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<tr>
<td></td>
<td>Procedure Turn: Active Route (W) Modified Route (W) Inactive Route (B)</td>
<td>A fixed size procedure turn appears when in the flight plan. This pattern increases to correct size when holding. Does not display entry LNAV will fly.</td>
<td>APP VOR MAP PLN</td>
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<tr>
<td></td>
<td>Altitude Interception Range (G)</td>
<td>Displays the range where the MCP altitude will be reached. Based on vertical speed and groundspeed.</td>
<td>APP VOR MAP PLN</td>
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<td>T/D</td>
<td>Represents the FMC calculated T/C (Top of Climb), T/D (Top of Descent), S/C (Step Climb), and E/D (End of Descent). Deceleration and predicted altitude/ETA points have no identifier.</td>
<td>APP VOR MAP PLN</td>
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<tr>
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<td>Marker Beacon (W)</td>
<td>Displayed when in data base and required for a particular approach procedure. (Not modeled)</td>
<td>APP VOR MAP PLN</td>
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<tr>
<td></td>
<td>Course Deviation Indicator (M) and Scale. (W)</td>
<td>Displays LOC or VOR course deviation. Deviation indicator points in direction of VOR course or ILS selected course set in the CDU NAV RAD page.</td>
<td>APP VOR MAP PLN</td>
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<td><img src="image1" alt="Selected Course Pointer" /></td>
<td>Selected Course Pointer (W) and Line (M)</td>
<td>Displays selected course set in the CDU NAV RAD page.</td>
<td>APP VOR MAP PLN</td>
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<tr>
<td><img src="image2" alt="Glideslope Pointer" /></td>
<td>Glideslope Pointer (M) and Deviation Scale (M)</td>
<td>Displays glideslope position and deviation in ILS mode.</td>
<td>APP VOR MAP PLN</td>
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<td><img src="image3" alt="North Pointer" /></td>
<td>North Pointer (G)</td>
<td>Indicates map background is oriented and referenced to true north.</td>
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<td><img src="image4" alt="Vertical Pointer and Deviation Scale" /></td>
<td>Vertical Pointer and Deviation Scale (W)</td>
<td>Displays vertical deviation from selected vertical profile (pointer) during a descent only. Scale indicates ±400 feet deviation. Digital display provided when pointer over ±400 feet.</td>
<td>APP VOR MAP PLN</td>
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<td><img src="image5" alt="TO/FROM Indicator" /></td>
<td>TO/FROM Indicator (W)</td>
<td>Located near airplane symbol. Displays VOR TO/FROM indication.</td>
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<td><img src="image6" alt="TO FROM Display" /></td>
<td>TO FROM Display (W)</td>
<td>Displays VOR TO/FROM indication.</td>
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<td><img src="image7" alt="STA WPT ARPT" /></td>
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<td>Displays map data as selected respective EFIS control panel.</td>
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<td><img src="image8" alt="VOR L, R ADF L, R" /></td>
<td>VOR (G) or ADF (B) Reference.</td>
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<td>APP VOR MAP PLN</td>
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<td><img src="image9" alt="CDU L, C, R" /></td>
<td>MAP source annunciation. (G)</td>
<td>Displays ND source if CDU is selected on respective NAV source selector. (Not modeled in V1.x)</td>
<td>APP VOR MAP PLN</td>
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<tr>
<td><img src="image10" alt="VOR L, R ILS L, C, R" /></td>
<td>Source Nav Data (G)</td>
<td>Displays source of nav radio data.</td>
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<td><img src="image12" alt="DD VD LOC" /></td>
<td>FMC-Radio update status (G)</td>
<td>Displays FMC radio update mode. DD = DME, DME VD = VOR, DME LOC = Localizer.</td>
<td>APP VOR MAP PLN</td>
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PRIMARY EICAS DISPLAY

Overview: The primary EICAS display is the upper, midships CRT. The primary EICAS is located in a place where it is easily viewed and monitored by all cockpit crewmembers.

Designed to provide maximum information usability with minimum clutter, the primary EICAS provides a concise picture of engine operating performance, cabin altitude indications, duct pressure, fuel status, flap and gear indication and any alert or status messages which may require the attention of the crew.

The primary EICAS is not a dynamic display, as it is the primary method for crews to receive and monitor the status of a number of primary flight systems. As such, the manner in which information on the display cannot be customized.

The information displayed on the primary EICAS is displayed in zones, which are laid out as follows:

- **Primary Engine Indications:** Graphically displays N1 thrust setting for each engine. N1 limits are depicted by a horizontal amber bar, with engine limits depicted by a red horizontal bar. Throttle target setting is shown by a white horizontal bar. N1 thrust settings and current climb/cruise power mode is displayed in green at the top of the engine instrumentation display.

- **Alert/Caution List:** Dynamic display list depicts any system faults detected.

- **In Flight Engine Start Limits:** Envelope for an engine start in flight is displayed in the event an in-flight start is necessary.

- **Gear Indicator:** Displays landing gear status.

- **Flaps Indicator:** Displays flap status as a single vertical bar with degree numbers in green. In the event of a flap system fault, a wider display depicting each moving flap section will become visible.

- **Fuel Indicator:** Current Fuel Status.

- **Duct Pressure Indicator:** Displays current duct pressure for bleed duct system.

- **Cabin Altitude Indication:** Current cabin altitude and pressurization system status.
SECONaRy EICaS DiSPLay

Overview: The secondary EICAS display is the lower midships CRT. The secondary EICAS is located directly ahead of the throttle quadrant, immediately below the primary EICAS, where it is easily viewed and monitored by both cockpit crew members.

The secondary EICAS provides system status and secondary engine indications to the crew. Seven different display modes plus a specialized status display are offered, and can be accessed through the EFIS-MCP.

Full Screen Synoptic Modes:
(Accessed by pressing associated Mode Selector Switch on the EFIS Mode Control Panel.)

- DRS – Status display for all hatches and doors.
- ECS – Environmental system status and overview.
- ELEC – Electrical system status and overview.
- ENG – Secondary engine indications.
- FUEL – Fuel system status and overview.
- GEAR – Gear status and condition.
- HYD – Hydraulic system status and overview.

Status Display:
(Accessed by pressing STAT Mode Selector Switch on the EIFS Mode Control Panel.)

- Hydraulic System Status
- APU Operation Indications
- Oxygen System Indications
- Status Message List
- Flight Control Position Indication

Secondary EICAS Display Modes: The secondary EICAS has eight independent display modes which can be used by the crew to monitor and assess the status of major systems aboard the aircraft. These modes, which are described more thoroughly in the respective Aircraft Systems chapter, are accessed by pressing the associated Secondary EICAS display mode switch on the EICAS-MCP.
Secondary EICAS MCP: The secondary EICAS is controlled using the EICAS MCP. The EICAS MCP is located on the right end of the Autopilot Mode Control Panel, or via a popup menu in the 2D cockpit.

The EICAS MCP allows the crew to interface with the primary and secondary EICAS displays through the use of individual status screen selector buttons, and CANCEL/RECALL pressure switches for controlling the Primary EICAS caution/warning list.

ENG Synoptic: The ENG display provides secondary engine performance information such as N2 rotation, Fuel Flow, Oil pressure, temperature and quantity, as well as engine vibration indication.

STAT Synoptic: The STAT display provides status information for numerous systems onboard the aircraft including hydraulics, the APU, battery indication and flight control position information.

ELEC Synoptic: The ELEC synoptic provides a graphical overview of the electrical system condition and operation, including power sources (Ground power, APU generators, engine generators) busses, bus tie breakers and an overview of electrical flow.
**FUEL Synoptic:** The FUEL synoptic provides a status and operation overview of the fuel system. Easily one of the most complex systems on the aircraft, graphical information describing quantity, use and flow is presented in a manner to simplify the crew’s workload.

**ECS Synoptic:** The ECS synoptic provides an overview of the Environmental Control System, and includes pressurization, temperature, pneumatic air source and flow information, as well as anti ice system operation and configuration.

**HYD Synoptic:** The Hydraulic synoptic provides operation and condition information related to the hydraulic system pumps, quantity, pressure and temperature information as well as usage and flow.

**DRS Synoptic:** The doors synoptic provides a simple condition overview of all exterior and service entries to the aircraft.
**GEAR Synoptic:** The gear synoptic provides an overview of landing gear condition, as well as door position and tire/brake temperature conditions on each main and body landing gear, as well as the nose gear tires.
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FLIGHT MANAGEMENT SYSTEMS

Overview: The Flight Management System (FMS) on the 747-400 is designed to provide fully integrated and redundant vertical and lateral flight path management. This is accomplished by a close marriage of functionality between the Flight Management System and the Autopilot Flight Director System (AFDS).

In order to effectively understand how to use the FMC and AFDS, it is important to understand the roles that each of these systems plays in the operation of the aircraft:

The FMS determines “where” the airplane needs to be and communicates this information to the AFDS.

The AFDS determines “how” the airplane will get there and communicates this information to the flight controls, and to the crew via the flight director.

The crew interacts with the FMS primarily through the FMC-CDU, and with the AFDS primarily via the Autopilot Flight Director/Mode Control Panel (AFDS/MCP).

Although the 747-400 FMS is capable of managing all phases of flight from takeoff to touchdown and rollout, the crew is under no obligation to use any of the systems provided. The strength of operating the 747-400 and its advanced systems however, lies in the increased operational efficiency of the aircraft when these systems are in use. The FMS provides greater precision, significantly reduced overall operating expense, reduced wear and tear on the airframe and significantly reduced pilot workload during critical phases of flight.

Flight Management System Outlined:
The 747-400 FMS uses a number of methods to interact with and receive input from the crew:

- Radio Navigation Systems (VOR/ADF, etc).
- Inertial Reference System.
- Air Data Computers.
- Electronic Flight Instrumentation System (EFIS).
- Engine Instrumentation and Crew Alerting System (EICAS).
- Flight Management Computer (FMC).
- Autopilot Flight Director System.

All of these systems operate independently, yet are integrated to control the aircraft in pitch, roll, yaw and acceleration with precision in all phases of flight.

AUTOPILOT FLIGHT DIRECTOR SYSTEM

Overview: The Autopilot Flight Director System integrates functions of the autopilot system, the flight director system, and the automatic stabilizer trim system in order to provide complete flight regime control. The AFDS is comprised of three Flight Control Computers (FCCs) which operate in parallel with each other to provide highly precise command and control.

Any individual FCC can provide full flight management for all modes of flight, except for Autoland, where two and three FCCs are used in order to provide for redundancy and increased accuracy.

The three FCCs are denoted as Left, Center and Right and can be activated by pressing one of the FCC activation switches on the far right side of the AFDS/MCP. Any engaged FCC can be disconnected by pressing the Autopilot Disconnect button on the yoke, or by pressing the DISCONNECT
Each FCC has an independent power source when activated will provide flight control input directly to the flight controls through three independent hydraulic systems. As such, each FCC can be allowed to have full independent control of all aircraft flight control surfaces, or multiple FCCs can be operated in tandem to provide full fail-safe operation for coupled approaches and autoland.

The pitch and roll cues used by the FCCs to control the aircraft can be displayed on the Primary Flight Display by selecting either the Captains or First Officer’s Flight Director switch to ON.

Selecting the Flight Director to ON will cause the AFDS to display it’s pitch and roll cues directly on the Primary Flight Display. The F/D will provide pitch and roll cues that the crew can follow while flying the aircraft by hand, or these cues can be used to provide direct monitoring of autopilot commands to the flight controls.

The flight director steering cues can be displayed in two different formats, depending upon user preference.

The most intuitive format is the Pitch/Roll bar display because it provides and independent pitch bar, and an independent roll bar overlaid upon the Primary Flight Display.

The second format that can be used is a single cue format known as a “Flying V” or “Flying Wing.” While less intuitive for beginners this type of flight director is actually easier to use than the pitch/roll bars above.

(You can choose between your desired flight director format by using the PMDG/OPTIONS menu item within Microsoft Flight Simulator. See Chapter 00_Introduction for more information.)
AFDS Mode Control Panel: The Flight Director is a wonderful tool for reducing pilot workload, but in order to function effectively, the crew must be skilled at instructing the flight director as to the desired flight path.

The Flight Director is controlled by the crew through Autopilot Flight Director System/Mode Control Panel (AFDS/MCP).

The AFDS/MCP is located on the glare shield, and provides direct control of all AFDS functions.

The AFDS/MCP has lighted function switches which allow the crew to control which modes are being used by the autopilot/flight director. These switches are grouped by function, primarily SPEED, ROLL and PITCH.

The AFDS/MCP can sometimes be confusing for pilots unaccustomed to fully integrated autopilots but it is simple to remember that the AFDS/MCP allows the crew to tell the flight director how to manage speed, pitch and roll in order to navigate the airplane along the desired flight path.

(Modes that can be used are described in detail later in this chapter.)

LNAV, VNAV, FLCH, THR and SPD mode are all available for crew selection, as well as heading, airspeed, altitude and vertical speed.

Any activated mode can be disengaged by selecting a different command mode on the MC, or by disengaging all operating autopilots and deselecting the flight director.

If VNAV, LNAV, LOC or APP modes are armed, the mode can be disengaged by pressing the associated switch a second time.

If the aircraft is on an approach and LOC and G/S capture has already occurred, then selecting a different command mode will not disengage the autopilot. When fully coupled for an approach the only method available to disengage the AFDS is to disengage the autopilot and deselect the flight director. Pressing the TO/GA switch will also

disengage the approach after LOC and G/S capture.

Flight Control Computers (FCCs): The function of the FCCs is to integrate the functions of the flight director and the autopilot systems. Each individual FCC provides control commands directly to its associated autopilot control servo. This servo operates the flight controls directly through an individual hydraulic system. The three autopilot servo systems are powered using hydraulic systems 1, 2, and 3.

If only one autopilot is engaged, it is capable of controlling the pitch and roll axes of flight. In this mode, the yaw dampers provide for yaw control when the aircraft receives a roll command from the FCC, resulting in fully coordinated flight using just one autopilot. In the event of a failure affecting the engaged single autopilot, the failure will be announced on the PFD by an amber line drawn through the autopilot mode. An EICAS warning message and alert tones will also alert the crew to such a failure.

If multiple FCCs are engaged, (two or three) and the AFDS has entered approach mode, the FCCs combine to provide pitch, roll and yaw control. Full rudder control is maintained and will automatically provide runway alignment at touchdown, as well as yaw compensation input in the event of an engine failure during a precision approach.

In a multiple autopilot approach with a crosswind, the FCCs will use rudder input and bank angle to slip the aircraft for runway alignment. The bank angle available is limited and in stronger crosswind conditions the FCCs may use a combination of slip and crab to maintain runway alignment.

If a failure affecting all three FCCs occurs on approach, an autopilot disconnect will result. If a failure results in loss of either pitch or roll modes, the associated flight director command bar will be removed from the PFD. In cases where both pitch and roll mode are affected, the flight director will be removed entirely and replaced with a fault flag.

AFDS Systems: The AFDS, in conjunction with the FCC’s, is capable of providing full
regime, three dimensional control of the aircraft in all phases of flight. This is accomplished by autopilot control of the aircraft in three separate regimes:

- Autothrottle
- Roll Mode
- Pitch Mode

During flight, the status of each of these autopilot modes is displayed on the primary flight display at all times. The AFDS mode annunciator provides the crew with important information regarding the current and armed modes for the autothrottle, roll and pitch modes. The lower portion of the AFDS also displays the current command mode of the AFDS system.

**AUTOTHROTTLE Command Modes:**
While thrust can be set manually by the crew at any time, the autothrottle is an efficient and precise method of maintaining accurate and efficient use of engine power throughout the flight envelope. Autothrottle modes which may be announced of the AFDS mode annunciator are:

- **THR:** Thrust autothrottle mode. Thrust setting is based on FMC calculated thrust requirements to maintain a commanded vertical speed such as in a climb to altitude.
- **THR REF:** Thrust is set to maintain current thrust limit setting as calculated/determined through FMC THRUST LIM page. Thrust limit is displayed on upper EICAS display above engine indications.
- **IDLE:** Throttles in transit to idle thrust position.
- **HOLD:** Throttles set but disengaged from autothrottle servo in order to protect against uncommanded thrust setting changes, as in during takeoff roll.
- **SPD:** Speed autothrottle mode. Thrust is set to maintain a commanded aircraft speed. Most often associated with VNAV managed climb or descent modes where pitch and power are modulated to target a particular aircraft speed, not a particular climb/descent performance. Rate of climb or descent will be a result of maintaining desired aircraft target speed through the adjustment of aircraft pitch. Autothrottle will not violate thrust limits or aircraft speed limits.

**ROLL Command Modes:**
The Roll mode commands bank angles so as to result in specific turn rates or velocity vectors. The autopilot will attempt to maintain the desired flight path, which can be dictated by a simple heading bug command setting, or by a complex series of waypoint programmed into the FMC. At no time will any autopilot roll mode exceed the bank limit selector or maneuvering speed limits in order to maintain course. Roll modes which may be displayed on the AFDS mode annunciator are:

- **TO/GA:** Commands bank angle in order to maintain ground track during takeoff or go around maneuver. Ground track will be maintained based on track disposition at time of engagement and behaviors selected via the options menu.
- **LNAV:** Commands bank to follow active FMC route as displayed on the navigation display. If on ground, LNAV mode will arm to engage when passing through 50 feet AGL.
- **HDG SEL:** Commands bank angle to maintain heading selected in MCP heading window.
HDG HOLD: Commands bank to hold present heading. If current bank angle is greater than 15°, will hold heading at time wings are level.

LOC: Commands bank to capture localizer when intercept track does not exceed +/- 60°. Once captured, will command bank to maintain localizer.

ROLLOUT: Mode will announce on passing 1500 feet AGL and engage at 5 feet AGL. Commands to follow runway centerline on touchdown.

ATT: Commands bank angle to maintain current bank at time first Flight Director switch is selected on if Flight Directors and Autopilots have been off.

PITCH Command Modes: Pitch mode commands aircraft pitch to maintain altitude, vertical speed, airspeed or climb/descent path. Pitch mode is nearly always directly linked to actions in the Thrust mode. Pitch mode inputs can come from the MCP altitude command knob, the MCP vertical speed knob or the FMC directly. When used in conjunction with a Thrust mode, Pitch mode becomes a powerful tool to manage climbs and descents to high degrees of accuracy and efficiency, as the autopilot will use both pitch and thrust to maintain commanded airspeed while navigating a vertical climb or descent path. Pitch modes which may be announced on the AFDS mode annunciator are:

TO/GA: Commands pitch angle required for takeoff or go around. On ground, mode is armed and will command for 8° nose up pitch, followed by required flight director climb pitch after ground clearance.

VNAV: VNAV armed to engage on passing 400 feet AGL.

VNAV SPD: Commands pitch up/down to maintain selected airspeed.

VNAV PTH: Commands pitch up/down to maintain selected FMC altitude or FMC calculated VNAV descent path.

VNAV ALT: Commands pitch up/down to maintain MCP commanded altitude.

FLCH SPD: Commands pitch to maintain speed selected in MCP IAS/Mach window during an altitude change. Will change to ALT when MCP altitude is captured.

V/S: Maintains vertical speed selected in MCP V/S window. Will change to ALT when MCP commanded altitude is captured.

ALT: Commands pitch to maintain altitude set in MCP altitude window or when ALT HOLD switch is pushed on MCP.

G/S: Commands pitch to maintain glideslope when intercept track does not exceed +/- 40° of front course. Will follow glideslope once engaged.

FLARE: Announced below 1500 feet, will engage between 60-40 feet AGL. Commands pitch to reduce sink rate. Disengages at touchdown and lowers nosewheel slowly to runway.

AFDS Command Modes: The status of the entire AFDS system is also displayed on the AFDS mode annunciator. This display provides the crew with immediate feedback on the current operating mode of the AFDS system. Displayed modes may be any of the following:

FD: Any flight director is selected ON while autopilots are disengaged. Pilot must manually follow Flight Director steering queues.

CMD: Any autopilot is selected ON and is properly engaged.

LAND 2: Displayed below 1500 AGL to advise crew of autoland degradation due to 1 autopilot failure or being out of synch. Approach and landing is being managed by remaining two autopilots.

LAND 3: Displayed below 1500 AGL to advise crew that all three autopilots have engaged and are coupled for an autoland approach.

NO AUTOLAND: Advises crew of loss of autoland system due to system fault or autopilot failure. No FLARE or ROLLOUT modes are available.
Autoland Status/Fault Modes: The autoland mode is announced directly on the PFD, and provides the crew with important information regarding the status of the autoland system.

LAND 3: Indicates that all three FCCs are coupled and operating for the approach. The LAND 3 indicates that any single failure during the approach will not result in a degradation of autoland system capabilities. This mode is known as Fail-Operational.

If a fault occurs during a multiple autopilot approach, an autoland status message will be displayed on the PFD to alert the crew to the autoland status and any autoland degradations which can be expected. These mode announcements are as follows:

LAND 2: Indicates that only two FCCs are online and functioning for the approach. Any single failure during the approach will not result in a significant deviation from the approach. This mode is known as Fail-Passive.

NO AUTOLAND: Indicated if any failure occurs which inhibits the autopilots ability to land the aircraft.

Any system failure which occurs during an approach that does not directly impact the ability of the aircraft to perform an autoland will not be announced until after touchdown. This is done to prevent crew distraction for failures which do not inhibit the capabilities of the activated autoland mode.

Once below 200 feet AGL, any detected failures in the autoland system will not be announced to the PFD unless they cause a complete failure of the autoland system. In this case, NO AUTOLAND will be displayed on the PFD, and will remain displayed until the autopilots are disengaged and manual control of the aircraft is taken.

Autothrottle: The autothrottle system uses the FMCs to directly control throttle input for maximum fuel conservation. The autothrottle is capable of providing for full flight throttle management from takeoff to rollout.

Whenever engaged, the autothrottle system will provide speed limit protection by modulating thrust to prevent exceeding limits related to flap settings, angle of attack and maximum structural speeds.

The FMC will display the thrust limit for the current regime of flight on the EICAS display, and provides commands directly to the autothrottle so as not to exceed these thrust limits in any mode of flight.

The autothrottle can accept automatic input directly from the FMC entered flight plan whenever VNAV is selected, or manually from the crew via the MCP.

MCP modes available to the crew for selection include, thrust (THR), speed (SPD), flight level change (FLCH) and VNAV. The autothrottle will provide speed protection in all of these modes.

The autothrottle sets thrust by moving all throttles together simultaneously. The autothrottle will maintain the relative position of the throttles, and stop throttle movement at the moment the first throttle reaches the desired thrust setting. The autothrottle then adjusts each engine individually to equalize thrust.

Any throttle can be moved while the autothrottle is engaged, however the autothrottle will return the throttle to its commanded position once it is released.

When the autothrottle mode HOLD is announced on the PFD, the autothrottle servo is disconnected to prevent inadvertent or uncommanded movement of the autothrottle. The HOLD mode engages automatically when the aircraft accelerates above 65 knots during the takeoff. HOLD can also engage in flight in VNAV and FLCH modes if autothrottle movement is overridden or stopped manually.

The autothrottle will disconnect in any situation where a fault is detected in the engaged autothrottle mode, or if any reverse thrust lever is raised to reverse idle. The autothrottle will also disengage if more than one engine fails in flight, or if both FMCs fail.
If the autothrottle is armed in flight, but disengaged, it will automatically re-engage if any pitch or autothrottle mode is selected on the MCP.

Flap limit speeds, angle of attack, and airplane configuration limit speeds are monitored by the AFDS and the FMCs in all pitch and autothrottle modes except V/S mode. If an overspeed is anticipated, either the AFDS will adjust pitch or the autothrottle will adjust thrust to prevent exceeding a speed limitation. (This is performed by whichever system is operating in a speed protected mode at the time.) Since it is not possible for the simulator to provide throttle position control to the joystick, it is recommended that you monitor the current autothrottle position, and anticipate where thrust might need to be in the event that you disengage the Autothrottle. Keeping some sense of awareness of your current thrust requirements will prevent you from being surprised in the event that you accidentally disconnect the autothrottle and have a sudden, rapid increase or decrease in thrust based upon the joystick throttle setting.

FLIGHT MANAGEMENT COMPUTER

Overview: The 747-400 carries two independent FMCs which run in parallel to each other in order to maximize accuracy, and eliminate errors.

The FMCs are accessed through the Left or Right Computer Display Units, (CDUs). A center FMC/CDU is supplied, however it is coupled to the ACARS system and should only be used for access to the FMC in the event of a failure of the left and right CDUs.

The FMCs contain a full database of navigation aids, waypoints, airports, airways, runways, SIDS, STARS, company route information and aircraft performance data.

The FMCs are loaded by ground personnel, and the databases are updated every twenty eight days.

(You can download most-current NAVDATA information from www.navdata.at, and most current SID/STAR data from the downloads page at www.precisionmanuals.com. SID/STAR data is provided for the PMDG FMC by PlanePath, and the files are freely available by download from our site. Most current AIRAC cycle navdata is provided by www.Navdata.at)

During flight, the FMC will monitor the database for a combination of VOR and VOR/DME stations at high angles of intercept to the route of intended flight. During the flight, the FMC will autotune the VHF navigation equipment to provide update and verification of current aircraft position, and to provide position, radial and DME data to the crew for navigation purposes.

The FMCs will use this method of monitoring current aircraft positioning unless this source of information is not available or sufficient. In this situation, the FMC will obtain an average position as computed by the three IRS systems. The FMCs are not capable of updating the IRS system if they detect a discrepancy between the FMC computed position and the IRS computed position.

The FMCs are capable of using the database and aircraft performance information stored in its non-volatile memory to provide complete lateral and vertical navigation. This is accomplished by interfacing with and providing commands to the AFDS and autothrottle systems.

The FMCs will use route, weather and aircraft performance data to operate the aircraft in the most economical fashion for any given flight regime.

For GPS equipped aircraft, the FMCs will use GPS data as a primary navigation data source unless the onboard sensing equipment determines that GPS accuracy
has become degraded or is unavailable. In this instance, the FMCs will revert to VOR cross referencing and IRS position information respectively.

In theory there should be no situation in which the FMCs are unable to receive accurate and current aircraft position data.

**FMC/CDU:** The CDU is the tool the crew uses to interface with the FMC. The CDU also provides a means for the FMC to display information for crew use.

The FMC will display information related to the flight on the EFIS monitors, as well as through a series of CDU menus known as pages.

A CDU line containing small boxes is a signal to the crew that information must be entered for proper FMC operation. A line containing dashes indicates information that is optional for entry, but which will provide for more accurate FMC operation.

The CDUs are very specific about allowing correct data entry into the data fields. The CDU will not accept illogical references, or references which are not usable given the capabilities of the FMC.

The CDU provides a MENU key which allows the crew to select either the FMC functions of the CDU, or access to the ACARS capabilities of the CDU.

*Detailed instructions for operating the FMC/CDUs are provided in chapter 12.*
AFDS MODE CONTROL PANEL

**AFDS MCP:** The AFDS Mode Control Panel is located on the glare shield. This is one of the principle means used by the crew to communicate with and control the AFDS during most phases of flight. The MCP contains switches to select and arm FCCs as well as various pitch, roll and axis modes of the AFDS. In addition, the MCP allows the crew to override an FMC commanded mode, or manually select heading, speed, altitude and vertical speed.

**MCP Layout:** The MCP layout is designed to allow for an intuitive interface between the crew and the AFDS. Similar functions on the MCP are clustered together.

**Flight Director Switches:** Located on either end of the MCP, the Flight Director switches enable or disable the display of flight director command bars on the PFD.

**Thrust/Speed Modes:** All of the AFDS modes which use speed intervention and speed protection are clustered around the IAS/Mach speed selector knob.

**Autothrottle Arm Switch:** When selected ON, this switch arms the autothrottle. The autothrottle will engage when any of the following speed intervention/vertical navigation modes are engaged:

- FLCH
- VNAV

- TO/GA
- THR
- SPD

If the flight director is selected OFF and the autothrottle is armed, the autothrottle will revert to the SPD mode until flight directors are rearmed, or unless THR mode is manually selected.

If VNAV is already engaged at the time the A/T ARM switch is selected ON, the autothrottle will engage in the appropriate mode for the regime of flight.

**Activating TO/GA:** The TAKEOFF/GO-AROUND switch is an important function in the cockpit of a modern airliner, as it allows for the immediate activation of the autothrottle during takeoff, or in the event that a missed approach is required.

It is not possible to “easily” implement switches that are normally found under your hand on the throttles, so we have made a “click spot” available on the AFDS/MCP to simulate a simple interface for TO/GA.

The TO/GA click spot is located on the screw, immediately next to the A/T ARM switch.
THR Switch: If current mode is FLCH, SPD, VNAV SPD, VNAV PTH, VNAV ALT or TO/GA, pressing the THR switch changes the thrust limit to the CLB thrust setting. This setting will be displayed on the Primary EICAS. This does not affect the autothrottle mode, but changes the thrust limit allowed.

If any other mode is currently selected, pressing THR will select the autothrottle THR REF mode and the throttles advance to the currently displayed thrust limit.

Pressing switch will not illuminate light bar.

Inhibited below 400 feet AGL.

SPD Switch: If pressed, the autothrottle is engaged in speed mode. SPD will be annunciated on the PFD and the throttle will control thrust to maintain the IAS/Mach displayed in the IAS/Mach MCP window. SPD mode will not exceed minimum or maximum speed limits, and cannot be engaged while the autothrottle is in THR REF mode.

Selector Knob: Changes the value displayed in the IAS/Mach window and updates the command speed bug on the PFD.

If VNAV mode is engaged, the window will usually be blanked, as the speed input and control commands are being managed by the FMC. If VNAV mode is active and the speed selector knob is pushed then the FMC commanded speed will be displayed.

If the autothrottle is operating in FLCH, SPD or TO/GA mode, the display will not be blanked.

SPD is inactive if in FLCH, VNAV or TO/GA mode.

SEL Switch: Allows the crew to manually select an reading in Knots or Mach.

IAS/Mach Window: Indicates current or selected VNAV speed unless VNAV is already engaged. PFD command airspeed bug is manipulated using this setting. Indicator will be blank when VNAV mode is engaged. When VNAV is engaged, speed and speed bugs are placed under control of the FMC.

Window automatically displays Mach number when accelerating beyond .84 Mach and will automatically revert to knots when decelerating below 310 knots.
FLCH Switch: Pressing FLCH (Flight Level Change) disengages other active pitch modes and integrates pitch and autothrottle control to effect altitude changes.

If the IAS/Mach indicator is blank: Indicator will un-blank and display the FMC target speed. If the FMC target speed is invalid, then FLCH will use the existing airspeed for the climb or descent. If the IAS/Mach indicator is not blank: Command speed for the climb will remain as displayed.

The Autothrottle will adjust power as required to maintain the desired speed during climb or descent. AFDS will use pitch control to moderate speed in association with thrust.

When MCP altitude is reached, the pitch mode changes to altitude hold and ALT is displayed on the PFD. The autothrottle holds the commanded speed and SPD mode is engaged.

Bank Limit Selector: Allows the crew to manually set a bank limit on the aircraft, or to allow the AFDS and FMC to calculate and determine the bank angle limits based on aircraft configuration and performance factors.

AUTO limits AFDS commanded bank angle to 15-25 degrees, depending on TAS, flap position and aircraft weight. (Bank angle will decrease from 25 to 15 degrees at speeds between 332 and 381 knots.)

If LNAV mode is engaged, bank angle will be limited to 15 degrees when speed is below V2 + 90 knots and flaps are up, or an engine fails when flaps are not up, or TAS is greater than 381 knots.

Bank angle is limited to 8 degrees when below 200 feet AGL.

If knob is set to any setting other than auto, then the AFDS bank angle will be limited to that number of degrees regardless of airspeed and aircraft configuration.

HDG Selector Knob: Allows magnetic heading to be selected in the HDG window. If pushed after a heading is selected, the HDG mode will engage and issue commands to the AFDS to fly the selected heading.

HDG Hold Switch: Engages heading hold manually. When pressed, AFDS will maintain current heading. If bank angle exceeds 15 degrees, AFDS will maintain heading at time the wings roll level.

HDG Window: Indicates magnetic heading selected using heading selector knob. If localizer has been captured, HDG window will display localizer inbound course.
VNAV Switch: Pressing the VNAV switch arms or engages the vertical navigation mode of the FMS, and transfers pitch and speed modes of the AFDS and autothrottle to the FMC.

VNAV mode instructs the AFDS to fly a vertical profile as it is described in the FMC and updated or modified by the crew.

If VNAV is engaged, VNAV mode appears in green on the PFD. If VNAV mode is only armed, VNAV mode appears in white on the PFD.

VNAV mode will not engage (but will arm) if the FMC Performance Initialization page is incomplete.

VNAV mode is disengaged by any of the following:

Engaging TO/GA, FLCH, V/S, ALT, or G/S pitch modes or if VNAV switch is pushed a second time before VNAV engagement.

LNAV Switch: Pressing LNAV switch arms or engages the lateral navigation mode of the FMS, and transfers roll and yaw (heading) control for the AFDS to the FMC.

LNAV will engage as long as the aircraft is above 50 AGL and within 2.5 miles of the planned track. If the aircraft is outside of these parameters, LNAV mode will arm and engage when the aircraft moves within these parameters (e.g.- after takeoff).

LNAV mode will be displayed in greed on the PFD if LNAV mode is engaged. If LNAV mode only arms, but does not engage, LNAV mode will be displayed in white on the display.

If LNAV arms, but the aircraft is not on an intercept heading to planned track, the FMC scratch pad will show the text NOT ON INTERCEPT HEADING, and the previously armed roll mode will remain active.

LNAV mode is disengaged by any of the following:

Selecting HDG HOLD or HDG SEL modes. At localizer capture or if LNAV switch is pushed a second time before LNAV engagement.

V/S Switch: engages V/S mode. AFDS will maintain V/S set in V/S window. V/S does not provide speed protection in the climb or descent.

VERT SPD Window: Displays current vertical speed at time V/S speed is pushed to engage V/S mode. Displays selected vertical speed as selected using V/S knob. Range is –8000 fpm to +6000 fpm.
**ALT Window:** Displays altitude as selected using the altitude selector knob. Displayed altitude is target altitude for all AFDS, FMS and altitude alert functions. AFDS and FMC will not allow a climb or descent through the displayed altitude. If altitude has been captured, AFDS and FMC will not allow the aircraft to depart from displayed altitude unless a V/S mode has been selected.

**Altitude Selector Knob:** Allows selection of altitude in the ALT window. The Altitude Selection Knob has a pressure switch and can be pressed to the following effect:

During a climb or descent, pushing the altitude selection knob will delete the next waypoint altitude constraint between the airplane and the altitude displayed in the ALT window. (For example: during a step descent, pressing the altitude selection knob will delete the next level off point, provided it is above the MCP altitude displayed in the ALT window.)

If climbing, and no waypoint related altitude restrictions exist, pressing the ALT knob will transfer the MCP ALT value to the FMC.

When pushed during cruise, the MCP ALT knob will transfer the MCP ALT value to the FMC, and the new altitude becomes the cruise altitude. If in VNAV ALT or VNAV PTH modes, VNAV will automatically initiate the required climb or descent.

If at cruise, and within 50nm of the Top Of Descent point, selecting a lower altitude in the MCP altitude window, then pressing the MCP ALT knob causes the DES NOW feature to become active, and the AFDS will initiate a 1,250 ft/min descent rate until intercepting the VNAV calculated descent path, at which point it will enter the VNAV descent path.

**ALT HOLD Switch:** Manually engages altitude hold mode. AFDS will capture and hold the altitude as indicated at the time the switch is pushed.

**A/P FCC Engage CMD Switches:**
Pressing switch engages associated FCC and places it in CMD mode. If both flight director switches are off, autopilot will engage in roll mode of HDG HOLD or ATT, and pitch mode will be V/S.

**FCC DISENGAGE Bar:** Pulling down forces all autopilots to disengage, or prevents them from being activated.
**APP Switch:** Arms or engages the AFDS to capture and track the localizer and glide slope. LOC and G/S are armed (displayed in white on PFD) only prior to actual capture of localizer and glideslope. AFDS can capture localizer or glideslope in any order, and upon capture each will display in green to show that LOC and G/S modes are both active.

(Some carriers have a modified AFDS to allow G/S capture ONLY if LOC capture has already taken place. You can select the format you wish from the PMDG/OPTIONS menu within Flight Simulator.)

LOC capture can occur when aircraft track is within 120 degrees of the front course, G/S capture can occur when the intercept track angle is within 80 degrees of the localizer course.

Once LOC and G/S capture have occurred, additional functioning autopilot FCCs will arm for engagement as the aircraft descends through 1,500 AGL. When the additional FCC's engage, the autopilot systems will connect to isolated power sources.

APP mode can be terminated prior to localizer or glide slope capture by pushing the APP switch a second time, or by selecting LOC, LNAV or VNAV modes to override APP mode.

APP mode will also disengage if localizer is captured and different roll mode is selected. If the glideslope only has been captured, selection of a different pitch mode will disengage the APP mode. If TO/GA is selected, or the flight directors are selected OFF at any time, APP mode will disengage.

**LOC Switch:** Arms or engages the AFDS to capture and track the localizer. LOC is armed only (displayed in white on PFD) prior to actual localizer capture. The current AFDS roll mode will remain active until localizer capture and LOC capture can occur if aircraft track is within 120 degrees of localizer course. LOC display will change to green when LOC mode becomes active upon localizer capture.

LOC mode can be disengaged by pressing the LOC switch a second time prior to LOC capture, or by selecting the flight directors OFF, or engaging the TO/GA mode.
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# MANUAL FLIGHT TECHNIQUES

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**GROUND TAXI OPERATIONS**

**Overview:** The significant size of the 747-400 requires additional vigilance on the part of the crew to ensure safe operation in the ground environment. Special care should be taken to ensure that tight maneuvering spaces are avoided unless guidemen are used to prevent collision with ground structures or equipment. In addition, the relative height of the cockpit view perspective can make judging distance difficult and crews should use additional caution.

**Turning Radius:** The 747-400 has an extraordinary pavement requirement in order to conduct a 180 degree turn. A minimum of 153 feet of pavement width is required to reverse course on the ground in a single turn. In spite of this, the 747-400 has a relatively tight turning radius which facilitates movement on standard 75 foot wide taxiways.

**Taxi Turns:** The use of body gear steering allows the 747-400 to make a 90 degree easily even on 75 foot wide taxiways. In any case where body gear steering is unavailable or should fail, crews are advised not to attempt turns of 90 degrees or greater on taxiways less than 100 feet wide.

The cockpit of the 747-400 is located seven feet ahead of the nose gear. This allows both crew members relatively unobstructed views during turns.

**Turning Procedure:** To safely conduct a turn on 75 foot wide taxiways, allow the cockpit to travel approximately twenty feet beyond the centerline of the desired taxiway before commencing the turn. (12 feet for steering radius and 7 feet for cockpit offset distance.) This will ensure that the aircraft will safely negotiate a 90 degree turn. This same procedure applies when lining the aircraft up on a runway or gate area lead-in line.

**FOD Prevention:** When taxiing on 75 foot wide taxiways, both outboard engines will extend over unpaved surfaces. Extreme caution should be used when selecting thrust settings for these engines in order to prevent FOD damage to the engines, nacelles and rear fuselage areas. If in doubt, use the inboard engines for taxiing and leave the outboard engines at idle thrust.

**Taxiing In Congested Areas:** The 747-400 cockpit affords a relatively good vantage point for taxi operations. Care should be exercised, however, as a number of areas surrounding the aircraft are not visible to the cockpit crew, and could represent potential collision hazards for unseen personnel and equipment operating within close proximity to the aircraft. Affirmative communications with ground handling personnel should be maintained prior to movement.

When taxiing in congested areas, the winglets can be used to assist with depth perception and gauging the distance to the wing tip. Due to the location of the center of the turning radius, a minimum of 12 feet in lateral clearance is required for the wing tips as the wing will project forward slightly during the turn. The wing tips will describe the most outward arc of the 747-400s turning radius, so 73 feet of forward clearance is required if measuring from the nose of the aircraft.

The captain should always taxi the aircraft, unless for safety reasons this is not possible.

When approaching the gate area, the first officer should do all possible to provide guidance and obstacle clearance information to the captain, who may be watching the guideman or Accupark system and be unaware of an approaching hazard.

**FOD Hazards:** Aside from the already mentioned hazard of the outboard engines projecting over unpaved areas, crews should be mindful that snow plowed into wind rows, snow removal equipment, construction vehicles, mounds of construction debris, and small upward
slopes adjoining the taxiway can pose a serious hazard to the outboard engines.

Never attempt to taxi beyond an obstacle by assuming the wing will have vertical clearance. When completely fueled, the downward wing flex will result in engine pod clearance of just 4 feet on the inboard engines and just 5 feet on the outboard.

**Engine Thrust:** At low gross weights (less than 600,000 lbs) it is possible to taxi with only two engines running. At medium gross weight (less than 650,000 lbs) it is possible to taxi with three engines running. At higher gross weights, all four engines should be started prior to taxi.

Due in part to the distance separating the cockpit and the engines, engine noise level will be very low from the pilot’s perspective and N1% readings should always be used for determining safe taxi thrust levels.

The aircraft will respond slowly to throttle movement, and crews should never advance the throttles beyond 40% N1 without having obtained clearance from ground personnel to ensure damage is not done to surrounding buildings, equipment or aircraft.

Care should also be taken to note that at higher N1 settings, the jet blast may kick up debris from unimproved surfaces, causing potential damage to the aft fuselage, horizontal and vertical stabilizers, as well as potential injury to ground personnel.

Once forward movement is established, idle thrust is usually sufficient to maintain a safe taxi speed.

**Taxi Speed:** Care should be taken to manage the taxi speed of the 747-400, particularly at high gross weights. If the expected takeoff runway is a long distance from the gate, a slower taxi speed is recommended to protect against tire side wall overheating.

When negotiating turns, proper care should be taken to ensure excessive side loading is not placed on the tires or landing gear, especially at high gross weights.

The following speeds are the maximum allowable taxi speeds:

- Straight Taxiway: 25 knots
- 45 Degree Turn: 15 knots
- 90 Degree Turn: 10 knots

From the cockpit it will be very difficult to accurately judge ground speed, and crews are advised to use the ground speed readout on the upper EICAS for speed management.

**Brake Heating/Cooling:** Proper care should be taken not to overheat the brake assemblies while taxiing, as this will reduce their effectiveness in the event of a rejected takeoff.

If braking is needed in order to reduce taxi speed, first reduce thrust to idle, then smoothly apply brake pressure until the desired taxi speed is reached. Do not apply, remove and re-apply brake pressure (“riding the brakes”) in order to manage taxi speed, as this reduces the effectiveness of brake cooling.

Differential braking is not recommended while taxiing.

**Directional Control Issues:** The large surface area of the vertical stabilizer will cause the 747-400 to have a tendency to ‘weathervane’ on windy days.

On wet taxiways, care should be taken when steering to prevent nose wheel skidding, as this may result in loss of directional control. In the event of a nose wheel skid, do not turn the steering tiller to the point of activating body gear steering, as this will aggravate the condition as the body gear turn into the direction of the skid. Use differential braking or thrust as necessary to correct the skid and bring the aircraft to a complete stop before continuing.
TAKEOFF PROCEDURES

Takeoff Speeds: The speeds appropriate for the takeoff weight of the aircraft should have been selected and confirmed in the TAKEOFF PERF page of the FMC during the initial cockpit setup. If the FMC has not registered confirmed takeoff speeds, an amber NO V-SPD warning will be displayed on the PFD, near the top of the airspeed scale.

Takeoff speeds are computed using crew input, and the appropriate V speed indicators and flaps setting markers will be displayed on the airspeed scale. Not all settings will be visible at any given time.

Takeoff Position: Under normal operating conditions the extended runway requirements and relatively wide turning radius of the 747-400 do not allow a ‘running takeoff’ to be made. The takeoff roll should begin deliberately from a full stop after the aircraft has been properly aligned with the runway centerline.

If a short delay is anticipated once in the takeoff position, the parking brake should be set in order to protect against inadvertent movement of the aircraft due to thrust, wind or runway slope conditions. Due to the height of the cockpit above ground level, movement may not be obvious to a crew immersed in other tasks.

Upon receipt of the takeoff clearance, the aircraft lights should be configured according to the appropriate checklist, and the parking brake released.

Throttle Advance: The throttles on the 747-400 are shorter than the throttles on previous versions of the aircraft. As such, there is less ‘throw’ when bringing the throttles up from idle to the takeoff thrust position.

If the autothrottle is not being used to set takeoff thrust, the PF should advance the throttles until reaching approximately 60% N1. Once engine readings have stabilized, the throttles should be advanced to takeoff power, with final throttle adjustments being made before the aircraft has accelerated to 80 knots.

After reaching 80 knots in the takeoff roll, the throttles should only be adjusted to keep the engines within operating parameters.

If the autothrottle is being used to set takeoff thrust, the PF should bring the throttles smoothly forward until approximately 70% N1 is displayed on the EICAS. Once engine indications have stabilized, the TO/GA switch should be pressed.

As the throttles advance to their FMC determined position, it is important that the PF back the throttles up with a hand, and the hand should only be removed upon reaching V1. Observe also the autothrottle annunciator or on the PFD should read THR REF.

In all cases, the crew should be mindful that the engine power settings do not exceed the green maximum power settings displayed above the engine power strips on the EICAS display.

Takeoff Roll: At the beginning of the takeoff role, the PF should maintain slight forward pressure on the controls in order to ensure proper directional control through firm contact between the nose wheels and the runway surface. This is not to imply than use of the tiller above more than 20 knots is acceptable.

Directional control should be maintained through the use of coordinated rudder and aileron input to ensure a straight takeoff with minimum roll tendency on rotation.

The PNF will call out “80 knots” at the appropriate time, as an indication to the PF that the aircraft has entered into the high speed regime of the takeoff.

At 80 knots, the PF should begin to release the forward pressure held on the flight controls.
The PNF will call “V1” when the indicated aircraft speed is still 5 knots lower than the actual V1 speeds setting. This buffer is included in recognition of the fact that a no-go decision immediately before V1 can be more effectively made if the PF is aware of the rate of acceleration to V1.

Upon reaching V1, the PF should remove the hand which was used to back up the throttles. This is done to enforce the go decision, and to prevent a reactive decision to reject a takeoff after reaching V1.

At Vr, the PNF will call “Rotate,” as a signal for the PF to begin applying back pressure on the controls to raise the nose of the aircraft from the runway.

A proper rate of rotation is 3° per second until a target pitch attitude of approximately 8 - 10° nose up is attained. Tail contact with the runway will occur at pitch attitudes exceeding 11° nose up. In gusty conditions, the rotation may be delayed slightly in order to prevent inadvertent over-rotation induced by wind gusts.

A proper rate of rotation will lead to the aircraft attaining V2 at 35 feet above the runway surface. Early, rapid or excessive rotation can extend the takeoff run, cause a tail strike condition, and/or activate the stick shaker and stall warning.

Likewise, under-rotation can be equally hazardous due to the tendency to elongate the takeoff roll.

At proper rotation rates, where the airplane is rotated at 3 degrees /second into the flight director bars, the distance that a fully loaded 747-400 will cover from the Vr until the aircraft is passes through 35 feet AGL is typically 2,500ft.

If rotated at half of the normal rotation rate (1.5 degrees/second) the distance a fully loaded 747-400 will travel from Vr to 35° AGL increases to 3,500 feet.

If the airplane is under-rotated and allowed to lift off at a higher speed than planned, the distance between Vr and 35° AGL increases to 3,700.

Crosswind Takeoff: As with other aircraft types, the most effective method to maintain directional control during the takeoff is to use rudder for directional control as necessary, and aileron input to control roll tendency.

As the aircraft accelerates, the control inputs should be gradually reduced so as to achieve a smooth liftoff without banking the wings. An uneven bank angle on rotation produces a risk of engine nacelle damage from striking the runway surface.

Rejected Takeoff: Given the size and required takeoff speeds of the 747-400, it is extremely important the crews understand that a decision to reject a takeoff is not made because the airplane can stop. A
decision to reject a takeoff is made because the airplane will not fly.
Once entering the high speed regime of the takeoff role, a decision to reject the takeoff should only be made if, from the captain's perspective, a failure occurring prior to V1 sufficiently calls into question the ability of the aircraft to fly safely. Crews should keep in mind that rejecting the takeoff at high speed may place the aircraft at higher risk than the initial failure.

A decision to reject the takeoff should be made with authority, and in time that braking can be applied before V1 is reached. The pilot flying should quickly reduce the throttles to idle, disengage the autothrottle and apply reverse thrust.

If set to RTO, the autobrakes should activate when the throttles are returned to idle. If the autobrakes do not activate, the crew should apply maximum manual braking commensurate with safety.

Reverse thrust should be applied normally, with maximum symmetric thrust being used in the event of an engine failure.

**Engine Failure During Takeoff:** In the event that an engine fails on takeoff but a decision to continue the takeoff is made, directional control must be maintained by applying rudder to the side opposite that of the failed engine. The amount of rudder required to maintain directional control will depend on aircraft weight, crosswind influence, airspeed at the time of the failure and which engine failed. It is important that only enough rudder be applied to maintain directional stability as additional rudder will produce excess drag or cause the aircraft to yaw away from the failed engine. This condition is undesirable because it may result in yaw oscillations during the takeoff roll which will reduce the overall controllability of the aircraft.

After an engine failure, avoid rotating the aircraft early or excessively. Rotate smoothly at Vr and continue the takeoff normally, accelerating to V2. The pitch attitude during the early climb will be slightly lower than that normally required for an all engines operating takeoff. (Usually 2° lower than the normal climb out angle.) Maintain V2 until reaching the Engine Out Acceleration Height. (E/O Accel Ht.) as set in the FMC takeoff page. On passing the E/O Acceleration Height, lower the nose by one half of the climb pitch attitude, and begin a normal acceleration and flap retraction sequence. (e.g. from 15° to 8° pitch.) Do not descend during the acceleration sequence. After completion of the flap retraction sequence, reduce thrust to the maximum continuous thrust setting, (CON) and continue the climb profile.

In the event the engine failure occurs after reaching V2, but before reaching V2 + 10, maintain the speed at which the aircraft was travelling at the time of the engine failure. Use pitch to maintain airspeed, and accept whatever rate of climb results unless obstacle clearance is an issue. Climb to the E/O Acceleration Height and commence the acceleration and flap retraction as described above.

If the engine failure occurs at V2 + 10, then use pitch to maintain this speed until reaching the E/O Acceleration Height and commencing the acceleration and flap retraction sequence as described above.

If the engine failure occurs at a speed greater than V2 + 10, use pitch to reduce speed to V2 + 10 and climb to the flap retraction/acceleration altitude. This technique will give the best rate of climb for the given available thrust. The above described procedure for acceleration and flap retraction applies.

Failure of an engine on one side of the aircraft will cause a yaw tendency toward the failed engine. Opposite rudder input should be applied using trim with enough rudder deflection to eliminate the aircraft's tendency to change heading. The aircraft should be considered properly trimmed if yaw tendency is eliminated and the yoke can be held without aileron input. Although a slight banking may be noticed, using ailerons to level the wings will cause an increase in aerodynamic drag, resulting in a less efficient wingform, reduced lift effectiveness and reduced climb performance.
**Double Engine Failure:** In the event that a second engine fails, continue with the E/O Acceleration Height procedure. In some cases, a second engine failure at high gross weight and slow speed will require a slight reduction in thrust on the surviving outboard engine in order to maintain control of the aircraft. This is due to the decreased effectiveness of the rudder at slow airspeeds, and will become less of a concern as the aircraft accelerates. For this reason it is extremely important that the aircraft not be decelerated after a second engine failure.
CLIMBOUT PROCEDURES

Initial Climb: In a normal takeoff condition, the pitch attitude required to maintain V2+10 knots in the climb is 15-17° nose up. In light airplane configurations, this pitch attitude may be exceeded in order to maximize the rate of climb. (Provided the airspeed is not allowed to drop below V2+10.)

Some consideration to passenger comfort should be given to if the climb angle required to maintain V2+10 exceeds 25° nose up pitch. If this is a concern, a slight reduction in N1 is the best way to reduce climb angle.

If a turn is required during the initial climbout phase of the flight, bank angle should be limited to 15° or less. In cases where the flight director is being used, bank attitude according to the flight director is satisfactory, as the flight director takes aircraft speed, weight and stall factors into account.

Acceleration in the Climb: If the flight directors are not being used in the climb, the pitch angle should be reduced when climbing through the Flap Acceleration Height as set on the FMC Takeoff page. Pitch angle should be reduced by not more than ½ of the pitch required to maintain V2+10. For example, if 16° nose up was required, then the pitch angle can be reduced to 8° nose up, but not lower. This will allow the aircraft to begin accelerating in the climb.

Flaps should be retracted according to the flap retraction schedule on the airspeed indicator. During the flap retraction sequence, do not select the next flap setting until the aircraft has accelerated beyond the amber warning band (on the airspeed indicator) for the next flap setting.

Acceleration should be continued until reaching 30 REF + 100 or 250 KIAS, whichever is greater. In US airspace where speeds above 250 knots are prohibited below 10,000 MSL, notify ATC of the additional speed requirement prior to reaching 250 knots.

30REF + 100 KIAS is used because it provides the best climb gradient for a given weight and thrust performance. Additionally, in level flight, 30REF+100 provides minimum drag and best fuel economy for a non cruise flight environment.

The maneuvering speed flap schedule is displayed on the airspeed indicator and functions as follows:

<table>
<thead>
<tr>
<th>Flaps</th>
<th>Climb Target Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>30 REF + 100</td>
</tr>
<tr>
<td>1</td>
<td>30 REF + 80</td>
</tr>
<tr>
<td>2</td>
<td>30 REF + 60</td>
</tr>
<tr>
<td>5</td>
<td>30 REF + 40</td>
</tr>
<tr>
<td>10</td>
<td>30 REF + 20</td>
</tr>
<tr>
<td>20</td>
<td>30 REF + 10</td>
</tr>
<tr>
<td>25</td>
<td>25 REF</td>
</tr>
<tr>
<td>30</td>
<td>30 REF</td>
</tr>
</tbody>
</table>

The simplest way to determine 30 REF + 100 is to add 20 knots to the Flaps Up speed bug on the PFD airspeed indicator. 30 REF + 100 can also be determined by checking the FMC Approach page.

If necessary, modify the pitch, power and flap settings as required in order to comply with ATC clearances or SID requirements.

When reaching Flaps 5, the crew should select the Climb Thrust setting by pressing the FLCH switch, the THR switch, or via the FMC Climb page. Verify the appropriate CLB setting is displayed on the EICAS engine display. Once in this mode, engine thrust settings will be automatically adjusted for maximum cost/climb performance given current environmental conditions and climb requirements.

Using the normal flap retraction sequence during the climb/acceleration will provide adequate margin for maneuvering. At gross weights exceeding 750,000lbs, bank angle should be limited to 15° while at airspeeds below 30REF + 100. At all times, however, flight director commands may be followed, as the flight director selects bank angles commensurate with the current flight profile.
**Engine failure in/during climb:** Once above the E/O Acceleration Height, select the ENG OUT mode on the FMC Climb Page. Selecting the engine out mode will change the commands sent to the VNAV system in order to cope with the changed flight characteristics.

After ENG OUT mode is selected, VNAV will continue the climb at engine out climb speed until reaching cruise altitude, or the maximum engine out cruise altitude, whichever is lower.

If the aircraft is above the maximum engine out cruise altitude, VNAV will commence a drift down procedure with level out upon reaching the maximum engine out cruise altitude. Upon reaching the required altitude, VNAV will command a speed change to Long Range Cruise mode. A longer acceleration to cruise speed should be anticipated after level off.

**Double Engine Failure:** In the event of a second engine failure in the climb, it is important to adjust the thrust level of the remaining engines so as to minimize the amount of rudder deflection required to maintain heading. This is especially true if both engines fail on the same side of the aircraft.

Remaining engines should be brought to Maximum Rated thrust as soon as rudder effectiveness permits.

VNAV will manage to the climb or drift down to the two engine out cruise level.

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**CRUISE PROCEDURES**

**Optimum Altitude:** The FMC VNAV Cruise page will display both the Optimum cruise altitude and Maximum Cruise Altitude for the current flight configuration. The Optimum altitude will give the best ratio of ground mileage for fuel consumed.

Normally, a cruise altitude as close to the Optimum altitude should be selected. Flight above the optimum altitude will reduce the margin between cruise speed and stall speed. Flight above optimum altitude should be avoided if autothrottles are inoperative.

**Fuel Economy:** The FMC will continually monitor and report on fuel usage during the course of a flight. If a change in flight conditions reduces the range of the aircraft and causes a fuel reserves reduction, the FMC message INSUFFICIENT FUEL will be displayed.

FMC monitoring of the required fuel level does not remove crew responsibility for monitoring and managing the useful fuel load.

Factors which can cause a change in the required fuel load include, but are not limited to:

- Improper Trim Settings
- Unbalanced Fuel Load
- Excessive Throttle Adjustments
- Flight Higher Than Optimum Altitude
- Lower Than Planned Cruise Altitude
- Temperatures Higher Than Forecast
- Faster Airspeed Than Planned
- Slower Airspeed Than Planned
- Higher than forecast wind conditions.
- Infarcts enroute holding.
- Unforecast altitude changes.

**Known Fuel Consumption Increases:**

Enroute Climb of 4,000 feet: 2,000-3,000lbs
M.01 over planned speed: 2% Increase
2,000 above Optimum Alt: 2% Increase
4,000 above Optimum Alt: 3.4% Increase
4,000 below Optimum Alt: 4% Increase
8,000 below Optimum Alt: 12% Increase
**DESCENT PROCEDURES**

**Leaving Cruise:** The descent process can be conducted manually by taking control of the flight, or by selecting a lower assigned altitude in the MCP and pressing FLCH or VNAV. A descent may also be initiated by entering a lower FL___ in the FMC VNAV Cruise Page.

Higher profile descents may require the use of speed brakes in order to reach altitude or speed targets during the descent. In descents requiring the use of speed brakes, it is important that level off at the lower assigned altitude be anticipated so that speed brakes can be retracted and thrust increased to obtain a smooth level out procedure. Late reduction of speed brakes and cause uncomfortable G loading and passenger discomfort.

The use of flaps to increase aerodynamic drag in order to facilitate a higher descent rate is not recommended in the 747-400, as this places significant wear and tear on the flaps, flap track and flap actuator mechanisms. If additional drag is required, speedbrakes are recommended.

**Speedbrake Usage:** In all cases where speed brakes are used, the speed brakes should be closed before thrust is added. There are no altitude or speed constraints for operating the speed brakes, however, crews should keep in mind that speedbrake usage with greater than Flaps 10 selected causes additional stress loading to be placed on the trailing edge flaps. This stress loading is a direct result of air passing through the wing surface gap left by speed brake deployment. Although this process will not adversely affect controllability of the aircraft, it does place additional wear and tear on the flap track mechanisms.

**APPROACH PROCEDURES**

**Initial Approach:** Crew workload during the approach portion of the flight increases steadily right up to the point of touchdown. As such, the earlier a crew is prepared with all weather, runway and approach information the more distributed the workload will become.

A strong approach briefing allows the crew to plan ahead for various contingencies such as vectoring through congested airspace, unusual approach procedures, emergency procedures, weather related contingencies, etc.

The crew should have all information regarding ATIS, NOTAMS and aircraft performance data collected prior to descending below 10,000 feet.

**Approach Speeds:** The speed bugs displayed on the ND airspeed indicator are continually computed and updated by the FMC. Speeds are based on the aircraft weight and fuel remaining. When speed is maintained at these airspeed/flap limits, a full safety margin for aerodynamic stall is maintained.

The maneuvering speed for a specific flap setting is displayed using a green index marker with the associated flap number beside it.

Prior to entering the approach, the landing flap setting should be selected in the FMC APPROACH REF page. This page will show both the 25 REF and 30 REF speeds given the current aircraft weight. The selected flap setting and REF speed should be selected and entered at Line Select Key 4R. Once selected, the FMC will not continue to adjust the REF speed to reflect continued fuel burn. If significant weight change is experienced due to prolonged holding, reselecting a REF speed is
necessary to update approach and flap maneuvering speeds.

When selecting speeds independently of ATC instructions, selecting an MCP speed which is 10 knots higher than the flap maneuvering speed bug will provide a stable, efficient flight envelope with a comfortable margin for banking turns which may be required by ATC.

**Flaps Usage:** To ensure a normal, stabilized approach, it is good technique to have Flaps 5 selected by the time the initial approach is commenced.

Proper deployment technique is to set the next flap setting as the airspeed passes through the next highest flap setting maneuver speed. For example, selecting flaps 20 will be done as airspeed slows through the flaps 10 maneuver speed.

**Stabilized Approach:** A stabilized approach is important to a consistent and safe landing technique. This is particularly true in the 747-400 aircraft.

A stabilized approach is defined by accomplishment of the following before reaching 1000 feet AGL on an instrument approach or 500 feet AGL on a visual approach:

- Landing configuration (gear and flaps)
- On descent profile (ILS Localizer and glide slope, published non precision profile, or when conditions have been met to allow a visual approach below DH or MDA on a non precision approach.)
- Speed within 5 knots of target REF speed.
- Rate of descent not in excess of 1000 fpm on precision approach or 1200 fpm on non precision approach.
- Engines spooled up normally to maintain speed and rate of descent.

In order to facilitate a stabilized approach, crews should plan to have the landing gear down and the final approach checklist completed prior to crossing the outer marker.

If the approach is unstable, or becomes unstable below 1000 feet on an instrument approach or 500 feet on a visual approach, initiate a go around.

**Precision Approach and Landing (ILS):** The initial approach can be flown using a number of different modes in the autoflight mode, regardless of whether a manual or automatic landing is anticipated. The HDG SEL and LNAV modes can be used for lateral tracking of the flight path and VNAV, FLCH or V/S can be used for altitude changes. Generally VNAV is considered to be the preferred method, as the VNAV program provides speed management not found in the V/S mode, and so can make for a smoother approach with less significant throttle movement and thrust changes. When VNAV mode is not usable, or at the crew’s discretion, FLCH will provide for speed management during a descent, but will result in increased throttle movement and cabin noise during small altitude changes. For small altitude changes, use of the V/S mode will minimize autothrottle thrust changes until the new, lower altitude is reached.

Passenger comfort is maximized and engine wear and tear are minimized when changes in required thrust settings are anticipated and accounted for by the crew. For example, when the landing gear are lowered, timely selection of the next slower speed required for the approach will eliminate the need for the autothrottle to increase thrust in order to compensate for increased drag from the landing gear immediately prior to a thrust change for a decrease in approach speed.

Whenever possible, it is helpful to enter the landing runway into the FMC DEP/ARR page, as this will display an extended runway centerline in the ND MAP mode, which can help with spatial awareness.

When turning onto the localizer intercept heading and commencing the approach, select APP mode on the ND. The expanded compass rose or full compass rose (HSI) provide for the best approach information display.
If LNAV is being used to manage lateral track navigation, use caution to ensure that the aircraft actually captures the ILS localizer. In some cases, the aircraft will continue to fly the LNAV approach heading without actually capturing the localizer, which can lead to dangerous descent conditions if a glideslope capture occurs.

After localizer capture, the heading bug will update to reflect to inbound approach course. If a large intercept angle was being flown, the autopilot will perform one intercept maneuver before stabilizing on the localizer. At intercept angles less than 30 degrees, the autopilot will not require an intercept maneuver.

The aircraft should be configured for final approach prior to reaching the final approach fix, and the MCP speed set to 30 REF + 10 at the first indication of glide slope movement after localizer intercept. This will ensure an accurate glide slope intercept at the appropriate speed for the approach. Landing flaps setting should be selected immediately after capturing the glideslope, with the MCP speed set to final approach speed for the landing flaps setting. Normally, landings will be performed at flaps 25 unless runway or weather conditions dictate the use of flaps 30.

Upon glideslope capture, G/S mode will be the active mode displayed on the PFD.

**Three Engine ILS Approach:** A normal approach should be flown to a flaps 25 or flaps 30 landing. Normal approach speeds should be used. When flying the approach with an engine out, it is important the crew stabilize the aircraft on the final approach speed prior to reaching the outer marker. This will provide an opportunity to re-trim the aircraft as required to eliminate yaw tendencies at the slower approach speeds. Once the aircraft is trimmed, an normal approach and landing can be flown.

In some cases, the crew may desire to zero out any trim influence prior to flying the approach. This will require that the crew manually input the control deflections necessary to eliminate the yaw tendencies of the aircraft. While this is a higher workload solution, it is available to the crew and should be completed prior to reaching the final approach fix.

Crews should resist the temptation to adjust rudder trim after crossing the final approach fix as this may distract crew members from flying the approach effectively.

**Non-Precision Approaches:** When flying non precision approaches, the aircraft must be in the landing configuration prior to reaching the final approach fix. Final Descent checklist should be completed prior to crossing the final approach fix as well. Landing flaps should be set and landing speed selected on the MCP speed selector prior to commencing the descent to the MDA.

A rate of descent should be used which will allow visual acquisition of the runway environment (commensurate with MDA) in time to align the aircraft with the landing runway.

During NDB approaches, the MAP CTR mode provides a good picture of needle tracking throughout the approach.

During VOR approaches, the VOR or MAP modes provides a good situational awareness picture of the approach.

**Circling to Land:** When circle to land minimums are met and wind conditions require such a maneuver, the pilot flying must maintain visual contact with the field once descent below the clouds in completed. When circling, bank angles in excess of 30 degrees should be avoided. Flaps 20 and the associated flaps 20 maneuvering speed is recommended for the approach portion of the procedure as well as the circling maneuver. Once the turn to final is commenced, extend landing flaps and commence a normal visual approach profile.

**Missed Approach:** To execute the missed approach, press the TO/GA switch and immediately rotate the aircraft to the pitch attitude commanded by the flight director. (Approximately 15° nose up.) Select flaps 20, but leave the landing gear in the down position until a positive rate of climb is displayed on the VSI.
LNAV or the MCP Heading Select can be used for lateral track navigation of the missed approach procedure. If altitude and speeds are displayed on the LEGS page, VNAV can be used for vertical profile. Retract flaps on schedule and accelerate as needed for the holding pattern or ATC vectors for an additional approach.

LANDING PROCEDURES

Landing Geometry: Two factors make landing the 747-400 a challenge from the perspective of the pilot: the long wheel base of the aircraft and relative height of the cockpit above the runway.

To make consistently accurate and safe landings, it is important that the pilot have a firm understanding of the 747-400s geometry in the landing configuration.

The standard ICAO glideslope installation requires the glideslope to intersect the runway surface 1,000 feet from the threshold. In this configuration, a 2.5° glideslope will have a runway threshold crossing height (TCH) of 66 feet.

On the 747-400, however, the ILS receivers are located on the nose gear doors, 21 feet below the cockpit. As such, if the aircraft is perfectly on glideslope at threshold crossing and flying at the Flight Director commanded pitch angle of 4° nose up, the pilot’s viewpoint will cross the runway threshold at 87 feet. The landing gear of the 747-400 are located behind and below both the cockpit and the ILS glideslope receivers however, and will cross the runway threshold at only 44 feet.

If the aircraft is flown to the runway in this configuration without a normal flare, the main gear will touch down approximately 500 feet from the runway threshold.

If a moderate flare is accomplished, rather than simply flying the aircraft onto the runway, the flight path of the main landing gear can be expected to lengthen by between 500 and 1000 feet.

It is recommended that the aircraft be flared to touch down on the runway surface between 1,000 and 1,500 feet from the threshold. As such, the pilot should use the 1,500 foot markings on the runway as the visual aim point for the approach.

Coincidentally, this aim point will provide a good visual reference for flying both a 2.5° and 3° glide slope, and result in an appropriately placed touchdown using normal flare technique.

Flare: At 50 feet radio altitude above the runway surface, the throttles should be moved to idle. At 30 feet radio altitude, nose up pitch should be increased from the approach angle to approximately 6° nose up. If accomplished correctly, the aircraft should settle onto the runway without extended floating.

Keeping power added during the flare may cause extended floating in ground effect just above the runway surface, which will significantly increase landing distance. Crews are likewise cautioned not to continue to increase nose up pitch during the flare as this may cause a rapid decay in airspeed, reducing aircraft controllability and reducing the effectiveness of immediate go around thrust should it be needed. In addition, a pitch attitude of 11° nose up will cause fuselage contact with the runway surface upon main gear touchdown.

The recommended approach and landing technique is to fly a visual aim point 1,500 feet down the runway. Reduce thrust to idle beginning at 50 feet, with the flare commencing at 30 feet. Fly the aircraft onto the runway surface and commence the rollout procedure.

Effective use of this procedure will consistently result in a runway touchdown between 1,000 and 1,500 feet from the threshold.
VASI: If landing on a runway equipped with a standard two-bar VASI system, use caution during the last 200 feet of the visual approach. Most VASI systems are configured to provide a 2° - 3° glideslope to intersect the runway surface 1,000 feet from the runway threshold. Crews should use the VASI system for approach guidance initially, but convert to the 1,500 foot aim point method described above for the final approach and touchdown portion of the flight.

If a three-bar VASI is provided for use by long-bodied aircraft, 747-400 crews are advised to use this visual approach cue for guidance to the runway surface as the second bars are aligned to provide a touchdown zone 1,500 – 1,700 feet from the runway threshold.

PAPI: Most major airport facilities are converting to the higher precision PAPI system. PAPI placement relative to the touchdown zone will vary, but is generally aligned to give an approach path intersecting the runway 1,000 feet from the runway threshold. Crews should employ the same methods which apply to standard two bar VASI approaches.

Crosswinds: Due to the large vertical surface of the tail and characteristics unique to the four main gear assembly of the aircraft, the 747-400 requires special handling during crosswind landings.

When the flying a coupled approach, the autopilot will fly most of the approach with the airplane’s nose crabbed into the wind. Passing 500 feet, the autopilot will de-crab the aircraft and fly the remainder of the approach and touchdown in a wing low attitude.

As the airplane touches down on the runway surface, the upwind wing will be lower than the downwind wing, and enough rudder input will be applied to keep the aircraft aligned with the runway centerline.

This is the best technique for landing the aircraft in a crosswind condition, as it provides the best directional control of the aircraft upon touchdown and minimizes wear and tear on the airframe and landing gear.

It is important to note, however, that once the main gear touch the runway surface, a bank angle of greater than 8° will cause the outer engine nacelle to contact the runway surface. This bank angle is the limiting factor in determining the maximum crosswind component of the 747-400 and should be strictly adhered to.

After the nose has been lowered to the runway, rudder and steering tiller input may be required to keep the aircraft aligned with the runway during deceleration due to the reduced effectiveness of spoilers and ailerons after touchdown.

This is increasingly more important if the aircraft touches down on the runway surface with a slight crab. Due to the design of the 747s four wheeled main landing gear trucks, the airplane has a strong tendency to travel in the direction of the main gear. As such, a slight nose into the wind deflection can result in the aircraft travelling toward the upwind side of the runway during the rollout. This should be immediately and precisely correct with rudder input while lowering the nose wheel to the runway surface.

Autobrakes provide the best braking response during crosswind landings because of the difficulty in applying even brake pressure to rudder pedals that are displaced in order to provide rudder deflection for the final phase of the approach. As such, crews are advised to use autobrakes whenever possible on crosswind landings.

Runway Braking: To understand the importance of steady brake pressure application, it is important to understand that the antiskid system which is used to prevent wheel locking and skidding monitors friction between the tires and the runway surface through a deliberate modulation and testing of braking power to the main gear. If the autobrakes are overridden by flight crew application of braking pressure, this process of runway sampling starts again from the beginning. Repeated pumping of the brake pedals by the flight crew can increase the landing roll by as much as 75% in some
cases. Crews are advised to apply a steady rate of pressure on the brake pedals when autobrakes are not used.

The autobrake system allows for settings 1 – 4 and MAX. Autobrakes are recommended for any landing being accomplished on a runway shorter than 10,000 feet, or at high gross landing weights on longer runways. During the approach segment of the flight, select the autobrakes power setting required for the landing.

After touchdown, brake application is indicated by a positive rate of deceleration beginning one or two seconds after touchdown. The braking is applied gradually, with the full selected braking power being applied as the nose wheel touches the runway surface.

If the autobrakes system fails (usually accompanied by an EICAS warning), apply manual brake pressure.

Use of reverse thrust will augment the braking system and reduce wear on the brake systems. Regardless of whether or not reverse thrust is applied, the autobrake system seeks a target rate of deceleration (see Landing chapter), rather than a certain brake power. This will result in a consistent and smooth rate of deceleration after touchdown.

The autobrake system is designed to bring the aircraft to a complete stop upon touchdown, so crew intervention is required if a full stop is not desired. Simply disarm the autobrakes system by selecting OFF after passing through 60 knots and reducing reverse thrust to idle.

Autobrakes may also be disarmed by moving the speedbrake lever to the down position or advancing the throttles.

Reverse Thrust: The 747-400 has a particularly large rudder, which leads to much greater rudder effectiveness at touchdown and rollout speeds than on many other conventional aircraft. As such, there is no need to wait for nose gear touchdown to engage and use reverse thrust during the landing roll.

Application and amount of reverse thrust is subject to the discretion of the flight crew. When touching down on wet or slippery runways, every effort should be made to ensure that only symmetrical reverse thrust is applied. On dry runways, asymmetrical thrust should only be applied with extreme caution, as this may pose a significant directional control problem to the flight crew.

When passing through 80 knots begin moving the throttles so as to reach reverse idle by 60 knots. Use of reverse thrust levels higher than idle when forward speed is below 60 knots increases the potential for FOD ingestion and engine surging due to ingestion of engine exhaust.

The engines should be brought to forward idle by the time taxi speed is reached.

If directional control problems are encountered during the landing rollout, it is important that they be identified and solved quickly in order to keep the aircraft on the runway centerline and under control.

If a skid is detected during the landing roll:

- Reduce reverse thrust to idle if at high levels of reverse thrust.
- Verify correct control inputs for current crosswind conditions. (aileron into the wind and opposite rudder)
- Use forward differential thrust, if necessary to restore directional control.
MISCELLANEOUS FLIGHT TECHNIQUES

Emergency Descent: At the first indication of a cabin altitude/cabin pressure problem, the crew should immediately don oxygen masks. A quick trouble shooting process is to verify that all packs are normal and to close all isolation valves. If this does not remedy the problem, or if it is obvious that cabin altitude is uncontrollable, an emergency descent should be commenced at once.

An emergency descent is best performed under control of the autopilot, as this reduced the crew workload and allows them to focus on issues related to localizing and identifying the aircraft problem.

Immediately select 14,000 feet or Minimum Enroute Altitude, whichever is higher in the MCP Altitude window. Press FLCH, extend the speedbrakes and verify the MCP commanded airspeed is in the usable range.

Passing through 16,000 feet begin preparing for a controlled level out by selecting 290 knots in the MCP speed window. Retract speedbrakes and apply thrust as necessary during the level out and consult the required checklists.

Stalls: An aerodynamic stall in any aircraft configuration, flight mode, or at any altitude is an unacceptable flight condition for the 747-400. At the first warning of an impending stall, (stick shaker or stall buffet):

- Throttles: Full Forward
- Pitch: Adjust to minimize loss of altitude. Intermittent stick shaker is acceptable in order to prevent ground or obstacle contact.
- Wings: Level
- Configuration: Do not change flap or gear settings until recovery from the stall is complete.

Steep Turns: Turns in excess of 30° are not normally accomplished during normal operating modes. For pilot familiarity with the aircraft in all regimes of flight, is important the flight crews be able to manage steeper bank angles should they be necessary or desired.

Entry into a 45° bank should be accomplished with the MCP speed set to 280 KIAS. Level flight can be maintained with only 2.5° - 3.5° of nose up pitch in the turn. Use of stabilizer trim is recommended to eliminate approximately half of the required flight column control input required to maintain level flight in the turn.

Fuel Temperature Issues: At higher atmospheric levels, extremely low ambient air temperatures may cause concern for fuel temperature management. During extended cruise operations, the fuel temperature will trend slowly toward True Air Temperature. When this reaches the lower limit of allowable fuel temperatures (see 4-6) wax crystals will form and settle in the tanks, causing fuel system congestion and possible fuel starvation. Cold soaked fuel can be prevented by descending to lower altitudes where the TAT is higher, or by increasing Mach number. A 0.01Mach increase will result in an increase of up to .7°C in TAT. In severe cases, a descent to lower altitudes will be required.
# PROCEDURES AND PROFILES

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AUTOFLIGHT NORMS

Overview: To a great extent, the advantage of operating the 747-400 aircraft is derived through use of the flight management system. From simple tasks such as providing raw aircraft performance data to much more sophisticated tasks like fully automated flight, the flight management system used aboard the 747-400 can significantly reduce pilot workload and aircraft operating costs. A full review of every available FMS mode is not within the scope of this manual, however, this section will provide a brief overview of recommended techniques.

Aircraft Control: The 747-400 can be controlled through three primary methods:

- Manual control manipulation.
- The Flight Management Computer/Computer Display Unit. (FMC/CDU)
- Mode Control Panel. (MCP)

Manual control is effected through the use of the traditional aircraft controls such as the control column, rudders, throttles and flight instruments.

Control via the FMC/CDU is a direct result of providing performance data and expectations to the Flight Management System through use of the FMC/CDU. This regime of flight is covered more adequately in the FMC Guide.

Control via the MCP is effected through use of the flight management modes and selectors presented to the crew in conjunction with data and performance requirements entered into the FMC/CDU.

In conjunction with one another, the FMC/CDU and MCP present the crew with a very powerful flight management capability.

Control Norms: The close interaction between the FMC and the MCP requires that certain norms be observed when adjusting parameters on the MCP.

Observing these norms will, for the most part, eliminate accidental or unexpected results from the FMS.

Autothrottle: Autothrottles should be used to control engine thrust settings in nearly all phases of flight. In situations where excessive engine ‘hunting’ or excessive thrust changes are caused by turbulence, mountain wave activity, or in the case of flying a manual approach, the throttles can be disengaged.

In some cases, the autothrottle will disengage automatically as a safety of flight mechanism. This can occur if the aircraft is operating too close to the overspeed buffet, to close to the stall buffet, or in some cases if significant turbulence in flight.

If the A/T ARM switch is in the armed position, and either the FLCH or TO/GA switches are pressed, the autothrottle will reengage.

MCP Command Speed Bug: The command speed bug should always be set to the desired steady state speed regardless of the regime of flight or whether the autothrottle is engaged. This will prevent accidental over/under speed conditions. Note that when VNAV is engaged, the MCP speed bug will be blanked, as the speed requirements entered into the FMC take priority unless overridden with a manual MCP speed bug setting.

FMC / CDU: Proper FMC/CDU page display is important if the crew is to gain the maximum information advantage from the FMC. Recommended FMC/CDU display modes are listed below according to the appropriate regime of flight:

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MCP Heading Bug: The MCP heading bug should always be set to the current or next intended heading as appropriate. Setting the bug to the existing heading serves as a reminder to both crew members of an ATC or procedure assigned heading, and makes identification of heading deviations easier. Setting the heading bug to an expected heading can reduce pilot workload during a turn, or during a missed approach.

AFDS Mode Annunciators: Autopilot operating modes (A/T, ROLL and PITCH) are only annunciated at the top of the PFD. It is important that crew members understand, monitor and interpret the information displayed here. Complete list of autothrottle, roll and pitch modes can be found in the PFD chapter.

**TAKEOFF MODES**

Takeoff Modes/Selections: As part of the cockpit preparation, a takeoff and climb thrust mode should have been selected on the FMC TAKEOFF REF page. The MCP heading bug should be set to runway heading, or to a pre assigned ATC “fly heading” command. The MCP command speed bug should be set to V2, and V1 should be correctly displayed on the PFD.

Prior to commencing the takeoff roll, crew members should review the FMC LEGS page for any climb constraints immediately after takeoff. The pilot not flying (PNF) should keep this mode displayed during the takeoff in order to facilitate rapid changes in routing, should they become necessary.

The pilot flying (PF) should display the VNAV CLB page in order to monitor climb requirements and performance.

Climb constraints, heading and speed modifications immediately after takeoff are normally managed through the MCP.

Takeoff: An autothrottle takeoff is accomplished by advancing the throttles manually to 70% N1. After engine thrust settings have stabilized, the TO/GA switch will transfer control of thrust setting to the FMS. Both crew members should back up throttle movement with one hand in the same manner as when setting thrust manually.

At 80 knots, verify the autothrottle mode annunciator shows HOLD as the current mode. The A/T HOLD mode prevents inadvertent movements should an autothrottle or FMS system failure occur. If the HOLD mode fails to engage it will not be displayed on the PFD. This is not a cause for alarm, but it does mean that the throttles are not being protected from uncommanded thrust changes related to a system fault. In this situation it is even more important that crew members back the throttles up during the takeoff roll.

The aircraft should be rotated according to schedule and in accordance with the takeoff discussion in the Manual Flight Techniques section.

The A/T HOLD mode should remain displayed until the autopilot pitch mode transitions out of the TO/GA mode, or until climb thrust is requested through use of the THR switch.

Initial Climb: After rotation, the flight director bars will command pitch and roll attitudes required. Flight director pitch commands will result in an airspeed of V2 + 10 knots in the initial climb, although a rotation after V2 may result in a speed of rotation speed + 10 knots. In either case, the command bars should be followed for optimal aircraft performance.

If LNAV was not armed prior to commencing the takeoff roll, it should be selected after
gear retraction is complete and the climb has been stabilized.

If the route of flight is going to require ATC vector procedures or flight to a certain intercept before being turned over to LNAV, use the MCP commanded heading, speed and altitude bugs until the LNAV mode can be engaged.

NAVAIDS and appropriate radials can be displayed using the NAV RADIO page of the FMC/CDU.

**Usable Pitch Modes:** Under normal circumstances VNAV will be armed prior to commencing the takeoff roll and will take over the autopilot pitch mode at 400 feet AGL. The use of VNAV to manage the takeoff profile is the preferred method, provided the appropriate required VNAV route navigation data was entered into the FMC TAKEOFF REF page prior to takeoff.

An alternate method is to allow the TO/GA mode to manage the vertical profile up to the flap retraction height before selecting either the VNAV or FLCH modes to manage the vertical profile. Both of these modes will use FMC TAKEOFF REF page data to provide optimal aircraft performance, and both modes provide for speed limit protection to prevent overspeed during the flap retraction sequence.

**Autopilot:** The autopilot is certified to be engaged at any altitude above 250 feet AGL. Crews should avoid engaging the autopilot if the aircraft is significantly out of trim or aircraft pitch/roll attitudes vary significantly from the flight director command bars, as this will cause a strong and rapid readjustment of the flight path which may be extremely uncomfortable for passengers.

**Flap Acceleration Height:** When VNAV is engaged, the Auto Flight Director System will automatically commence a reduced rate of climb in order to facilitate forward acceleration.

Retract flaps normally according to the flap retraction schedule displayed on the airspeed indicator, and verify that the appropriate CLB thrust mode is displayed on the EICAS display.

If VNAV is not being used for the climb, select FLCH and set the command speed bug to 30 REF + 100 to initiate the acceleration process. Climb thrust by pressing the MCP THR switch.

Continue the climb and acceleration as allowed according to noise abatement procedures and ATC instructions. If any speed restrictions or minimum crossing altitude restrictions are imposed during the climb, they are normally managed by entering them into the FMC/CDU altitude restriction entry line in the FMC VNAV CLB page.

**CLIMB MODES**

**Climb Speed/Altitude:** The FMC has a functioning internal database of airport information including approaches, SIDs, STARs and in most cases speed restrictions prior to reaching the transition altitude. (In the USA this will always be 250 knots while below 10,000 feet MSL). When VNAV is engaged, the AFDS will accelerate to this restriction speed or 30 REF + 100, whichever is higher, and maintain this speed during the climb. The speed which will be used by the AFDS can be seen by the PF on the FMC VNAV CLB page, which should be visible during this phase of flight.

VNAV will select the higher 30 REF + 100 speed in order to provide for full maneuverability of the aircraft. Typically this speed will exceed 250 knots for aircraft gross weights in excess of 630,000 pounds.

During the climb process, the AFDS will also monitor the LEGS page for any waypoint related speed restrictions or altitude related
restrictions entered into the VNAV CLIMB page. VNAV will immediately adhere to any climb restraints entered into the LEGS page of the FMC/CDU as well as any MCP selected altitude restraints. Generally it is easier to enter and remove ATC climb restraints through use of the MCP command altitude bug.

During the climb, the FMC will provide climb speeds for both the ECON climb thrust mode and the ENG OUT climb thrust mode. In addition, the FMC will also provide the MAX ANGLE climb speed, which will result in the maximum angle of climb for a given aircraft weight. (e.g.: the shortest ground distance covered to reach cruising altitude.)

Although a MAX RATE speed is not provided directly by the FMC, this speed can be approximated by adding 25 knots to the MAX ANGLE speed up to speeds of Mach .84.

The ECON climb speed will provide a constant speed/constant Mach schedule optimized as a function of aircraft weight, selected cruise altitude and predicted Top of Climb wind and temperature conditions.

Both the ECON and ENG OUT speeds can be overridden by IAS/Mach entries directly into the CLIMB page, or by MCP command bug selection.

**Step Climbs:** Step climbs can be performed as necessary by entering the desired altitude directly into the VNAV CRUISE page, or by selecting the new altitude using the MCP command altitude bug and pressing FLCH.

Step climbs can be attached to enroute waypoints or to optimum step points calculated by the FMC.

It is important to note that the FMC calculates optimum step to points by looking at aircraft gross weight, the current cost index, flight conditions, route of flight, speed mode and the difference between the current altitude and the new altitude. The FMC does not, however, take into consideration optimal flight path information based on current wind conditions.

**Optimum Altitude:** Optimum altitude is computed as a function of cost index, flight planned, distance and selected cruise thrust mode. The resultant displayed altitude is where the FMC feels the lowest operating cost per mile can be realized.

**Maximum Altitude:** Maximum altitude is determined by the FMC, and is the highest altitude at which the aircraft can maintain a steady selected cruise speed in the current thrust setting with adequate stall and buffet margins.

---

**CRUISE**

**Cruise Speeds:** The default cruise speed mode for the 747-400 is economy (ECON) cruise. The cruise speed is automatically calculated by the FMC and displayed on both the FMC VNAV CRZ page and the PROGRESS page. Additionally, the computed cruise speed is displayed directly on the PFD airspeed indicator via the command airspeed bug.

The crew may also select an ENG OUT cruise profile on the VNAV CRZ page if required.

ECON cruise is computed as a function of gross weight, cruise altitude, cruise altitude winds and cost index. ECON attempts to provide the lowest operating cost for the current flight parameters, and takes into account changing altitudes, winds and flight performance configuration.

**Cost Index:** The cost index entered by the crew will directly affect the calculated ECON cruise speed. Cost Index values range from 0 to 99, with 0 being the Least Cost cruise option. Entry of Cost Index 0 will result in maximum long range cruise operation for
the 747-400. Generally, cost indexes greater than 60 will be limited by engine thrust limits or airframe Mach speed limits.

**ECON cruise mode:** ECON cruise mode will automatically adjust the ECON cruise airspeed during the flight to account for shifting wind conditions.

Headwinds will increase the speed demanded by ECON cruise as the FMC attempts to minimize total airborne time by finding a least cost function of required fuel burn vs. ground speed and time enroute.

Likewise, tailwinds will cause the FMC to call for a lower ECON cruise speed in order to take advantage of greater ground speed as a result of tail winds. In these conditions, the FMC will attempt to minimize total trip fuel burn by reducing thrust required to maintain a particular ground speed.

**ENG OUT mode:** The ENG OUT cruise mode can provide significant advantages in the event of an engine failure in the high altitude regime of flight. By selecting ENG OUT cruise mode on the FMC VNAV CRZ page, the crew will immediately be given the best forward airspeed to maximize available altitude and aircraft energy. This will result in the optimum drift down rate and airspeed and will minimize altitude loss during the drift down procedure.

---

**DESCENT**

**Descent Mode:** As in cruise mode, the FMC will attempt to minimize total operating cost of the airplane by providing a least cost speed for the purpose of the descent. The profile used by the FMC will provide a descent at the ECON cruise speed from cruising altitude down to the transition altitude entered on the VNAV page. The FMC will then adjust the forward airspeed to reflect the speed restriction – 10 knots. The descent speed and altitude will further be modified to reflect and waypoint driven altitude and speed restrictions.

For this reason it is extremely important the LEGS pages accurately reflect the planned arrival procedure and profile. The arrival procedure can be entered either manually, or by selecting the procedure from the ARRIVALS page in the FMC.

There are essentially two parts to the descent profile: Descent Path and Descent Speed.

**Descent Path:** For the FMC to calculate a descent path, at least one waypoint must have been entered on the LEGS page with a speed/altitude constraint below cruise altitude. The FMC will then use this information, along with any other LEGS page waypoint related airspeed/altitude restrictions to build a descent profile based on an idle thrust descent. The path will be designed to reflect forecast wind values entered into the DES FORECASTS page.

Occasionally it will not be feasible to perform an idle thrust descent from cruise due to step down descent requirements of some STARs or unusual terrain crossing requirements.

In such instances, or any other instance where an idle thrust descent is not feasible, the FMC will adjust the rate of descent using elevator input to increase or decrease the rate of descent. In such situations, the autothrottle will be used to maintain forward airspeed at the target descent speed during the procedure, or the FMC will call for the use of speedbrakes to prevent acceleration in the descent.

When deceleration is required during a descent from cruise in order to meet a speed restriction (passing through 10,000 feet MSL in the USA, for example) the FMC will use a vertical speed of 500 fpm and idle thrust to effect the deceleration.
Should deceleration be required prior to entering a descent, the FMC will perform the deceleration while still in level flight prior to entering the descent.

**Vertical Path:** The FMC will calculate a vertical path using optimum descent speeds. The descent path will also reflect any waypoint driven altitude restrictions. These restrictions can be entered into the LEGS page, or manually overridden via the MCP altitude setting.

**VNAV Speed Management:** Due to the VNAV system’s speed intervention capabilities, VNAV is a good tool to use during the descent portion of the flight if compliance with ATC speed instructions is required. VNAV will attempt to maintain the vertical profile of the originally planned descent through the addition or reduction of thrust via the autothrottle and application of elevator control inputs.

Crews should use caution, however, as the use of VNAV speed intervention capabilities will tend to result from excursions from the planned descent profile in cases where the new aircraft speed varies significantly from the originally planned descent speed. In this case, use of thrust or speedbrakes may be required to maintain the descent profile.

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**APPROACH**

**LNAV/VNAV Requirements:** The LNAV and VNAV programs provide a powerful tool to assist crews in planning, navigating and flying the approach portion of the flight. In order to be used, LNAV/VNAV requires that a series of waypoints be present on the LEGS page of the FMC. This information can be loaded in a number of ways:

- Approach Selection
- Manual Entry
- Fix/VOR Radial Displays

**Approach Selection:** The FMC/CDU ARRIVALS page allows the crew to select the approach procedure, as well as a STAR procedure, should one be available. By selecting the STAR and approach procedure in this manner, the crew is automatically loading the series of waypoints required by LNAV/VNAV into the LEGS page of the FMC.

If the approach which will be flown does not have an appropriate procedure entered into the FMC database, crews may select a similar approach and modify it once entered into the LEGS page. (For example, an NDB approach can be built from a similar VOR approach with minimal effort if many of the waypoints used are identical. This will reduce crew workload and programming time considerably.) Crews are advised to use caution, however, as a manually adjusted program may no longer provide adequate obstruction and terrain clearance once modified.

**Manual Waypoint Entry:** This is the longhand method of building an approach in the FMC/CDU LEGS page. Approach procedures can be built by using waypoints, bearing/distance fixes from waypoints, existing intersections, radials and even latitude/longitude combinations.

This type of approach profile planning will require significant time and crew attention. As such, plan on having this information entered prior to descending below 18,000 feet.

**Fix and VOR Radial Displays:** If a waypoint is entered with the appropriate radial are entered into the FIX page, a representative course line will be created on the MAP display. Similarly, manual tuning of a VOR will cause a radial line to be displayed on the MAP displayed, although this radial cannot be tracked by LNAV unless it is entered directly into the LEGS page.

**Use of Procedure Turns:** Some non precision approaches will require the use of a procedure turn to align with the inbound course. Because of the high forward airspeed requirements of the 747-400, it is important the crews pay special attention to
the 10 mile protected airspace placed around non precision approaches.

When flying a procedure turn, selecting flaps 5 and setting the flaps 5 maneuvering speed + 10 knots will generally provide a safe and manageable speed during non precision approaches.

In addition, use of the MAP display mode will provide additional spatial awareness to the crew, and assist in minimizing crew workload during this critical phase of flight.

**PRECISION APPROACHES (ILS)**

**Initial Approach:** During the approach phase of the flight, HDG SEL or LNAV can be used for lateral flight path tracking, and VNAV, FLCH or V/S for the vertical profile. Use of LNAV and VNAV requires that the approach be defined in the LEGS pages, as discussed above.

In cases where ATC restrictions and vectoring do not remove the airplane from the planned flight path, VNAV and LNAV can be used to bring the aircraft down to the point of initial approach entry. If ATC issues vectors or constraints on airspeed and altitude, these changes are best managed through the MCP HDG, SPD and ALT modes, as re-arranging information on the FMC/CDU LEGS page at low altitude will remove one crew member from flying the airplane.

During earlier phases of the approach, the crew may find that time is available to update the approach path information in the legs page. Subject to time constraints, this is an encouraged activity, as it will provide the autoflight mechanisms with more appropriate raw flight and navigation data.

If entering updated information into the FMC is not feasible due to heavy traffic in the terminal area, turbulence, aircraft control issues or because of an extremely busy ATC environment, crews are encouraged to use the off path descent circles to assist in vertical flight path guidance during the approach.

Use of the ‘direct to’ capabilities of the FMC will clean up the display if additional approach information is not desired.

During the descent portion of the approach, VNAV and FLCH are the recommended descent modes, as both modes will also manage aircraft speed in the vertical profile. V/S should be used for small altitude changes.

**NAV Display Modes:** The NAV display provides a number of display modes. Moving between display modes at the appropriate time in the approach will allow the crew to use them effectively during a precision approach.

During the initial approach phase, the MAP view allows the crew to maintain spatial awareness through the use of an appropriately scaled view of the approach and surrounding environs. Once the aircraft has been placed on a heading to intercept the localizer and glideslope, switching to APP mode will provide either a standard HSI style full compass rose view with glideslope and course deviation indicator, or an expanded compass view of the same instrument.

Use of the ND APP display mode is useful for managing a precision approach in crosswind conditions, as the display provides both heading and course track information overlaid with deviation from the localizer. This allows for simple interpretation of drift angle correction needed to maintain the localizer inbound course, thus significantly reducing pilot workload.

**Final Approach (Cat I):** If LNAV is being used to manage lateral track navigation, use caution to ensure that the aircraft actually captures the ILS localizer. In some cases, the aircraft will continue to fly the LNAV...
approach heading without actually capturing the localizer, which can lead to dangerous descent conditions if a glideslope capture occurs.

After localizer capture, the heading bug will update to reflect to inbound approach course. If a large intercept angle was being flown, the autopilot will perform one intercept maneuver before stabilizing on the localizer. At intercept angles less than 30 degrees, the autopilot will not require an intercept maneuver.

At the first sign of glideslope movement toward capture, immediately select flaps 20 and set the MCP command speed bug to 20 REF + 10 knots. The final approach checklist should be completed and the landing gear lowered prior to crossing the final approach fix.

At glideslope capture, the PFD annunciator will change to G/S. Immediately select landing flaps and change the MCP command speed bug to the landing REF speed.

At decision height, disconnect the autopilot and continue the remainder of the approach and landing by hand. Disconnect the autothrottle by touchdown.

**Final Approach (Cat II/III):** When weather conditions are below Cat I minimums, autoland must be used to land the 747-400. Due to cockpit height and wheel base length, the minimums used in Cat II and Cat III operations do not allow for manual control landings from an automated approach.

The initial approach phase of flight is identical to the Cat I initial approach, however as the airplane descends below 1,500 feet, the FLARE and ROLLOUT autopilot modes will arm and be displayed on the PFD. In addition, the PFD will show LAND 2 or LAND 3 as active.

Once LAND 2 or LAND 3 is annunciated, the multi autopilot approach has commenced. During this phase of flight, the autopilot will control all pitch and roll modes, as well as autothrottle, rudder and spoilers.

Should autopilot disconnection be necessary after LAND 2 or LAND 3 annunciation, crews are advised to use caution regarding rudder input, as the rudder will return to the position dictated by the rudder trim indicator. In extreme cases, such as a single or double engine failure, this trimmed position can be significantly different from the rudder position being held by the autopilot. Crews should be prepared to exert rudder pressure to maintain coordinated flight if the autopilots are disconnected.

Prior to reaching DH, both pilots should monitor the approach for correctness and accuracy. If an autoland fault which would require higher landing minimums is detected prior to reaching DH, then the approach should not proceed below these minimums unless visual contact is made with the landing environment.

If an aircraft system fault is announced on the EICAS prior to reaching the DH, crew members should identify the problem and ensure that it will not impact the autopilot’s ability to fly the airplane. If the aircraft system is not determined to be critical to the autoland approach, continue the approach as normal, performing any abnormal checklists required once the aircraft has safely landed.

Once below DH, the duplicate systems of the autopilot should allow for safe control of the aircraft in spite of any failures that might take place. Crews should only interact with the aircraft controls or disconnect the autopilot if it is clearly evident that the autopilot is not performing correctly.

In some cases, aircraft system faults will be detected and announced on the EICAS system after the aircraft has passed below DH. During the Cat IIIb certification of the aircraft and flight systems, careful consideration was given to testing the capabilities of the autoland system and its ability to land the aircraft in spite of both minor and major system faults. Crew members should resist the desire to override the autopilot or flight control inputs once below DH, as the autopilot will still land the aircraft safely.
This can be difficult, especially in a situation where the failure (such as an engine failure or fire) would normally require immediate and decisive crew action. Crew action can be initiated once the aircraft has begun the deceleration part of the rollout.

On landing, the crew should monitor the flare, touchdown and landing rollout. Verify spoiler deployment and autobrakes usage. Reverse thrust should be applied manually. The autopilot should remain engaged until a safe stop or runway turnoff can be made and proper visual contact with the ground is assured.

**Missed Approaches:** The TO/GA switch must be pressed to initiate an automatic go around via the FMS. Once the TO/GA switch has been pressed, the aircraft will enter a go around profile for pitch and power. If desired, LNAV and VNAV may need to be reselected after initiating a go-around.

Select flaps 20 and set the command speed bug for 20 REF + 10. Once a positive rate of climb is assured, raise the landing gear. Monitor acceleration and retract the flaps on schedule, just as in a manual go around.

## NON PRECISION APPROACHES

**LNAV/VNAV:** Although a non precision approach can be flown entirely by hand, use of the automated flight systems can greatly reduce pilot workload, and improve safety when flying non precision approaches. Use of the autopilot altitude modes and descent modes can prevent flight path excursions below authorized altitudes.

The use of LNAV/VNAV systems requires the same level of planning and preparation as a precision approach, however the AFDS system will not track an NDB or VOR course in the same manner in which it tracks a localizer course. In order to fly a specific radial or course, this information must have been entered into the LEGS page of the FMC/CDU beforehand.

Once again, the ability of the pilot to tailor the ND display modes provides an excellent and powerful method to navigate with precision during the approach.

**MAP mode:** Generally provides the best overall situational awareness during the initial approach, and allows the crew to gain a situational awareness of what courses and turns will be required to enter the aircraft onto the final approach course. This mode is also of benefit with the final approach course does not align directly with the runway, as it allows the crew to determine the maneuvers which will be required to align the aircraft with the runway.

**VOR mode:** The ND VOR mode is useful when flying VOR or NDB approaches that require tracking of a specific course. VOR CTR mode is most useful, because it places the aircraft at the center of the compass rose and the VOR/ADF needles track can be easily read for bearing to station information. In addition, the VOR mode supplies both heading and track information, which allows flight crews to make simple heading corrections to maintain the correct track for a published approach.

If a VOR or ADF approach is to be flown, use LNAV to manage lateral track navigation. If the approach profile is not described properly on the LEGS page, crews may need to use the MCP HDG SEL mode.

If a localizer only approach is being flown, use the LOC mode.

**Final Approach:** In order to be properly stabilized on the approach course as early as possible, flaps 10 should be set by the time the aircraft is turned onto the final inbound course. The MDA should already have been set.

Once the aircraft has leveled on the inbound course, set the MCP altitude command bug to the MDA, or the next 100 foot increment above the MDA if the MDA is a non-hundred
number. (Ex: 350 foot MDA would be set as 400 feet on the MCP altitude command bug.)

Approximately 5 miles from the final approach fix, lower the landing gear and set flaps 20. Select 20 REF + 10 on the MCP command speed bug. Final approach checklists should be completed before crossing the final approach fix.

At the final approach fix, select landing flaps and set the MCP speed bug to landing REF speed. Commence the descent after crossing the final approach fix, and set the V/S mode to manage the rate of descent as necessary. Do not select a rate of descent greater than 1,200 fpm.

When passing the MDA, set the missed approach altitude into the MCP altitude command bug in order to minimize workload in the event of a missed approach.

The autothrottle should be disconnected prior to touchdown.
TAKEOFF PROFILE - NORMAL

- Accelerate to Economy Climb Speed
- Retract Flaps on Flap/Speed Schedule
- Set Climb Thrust
- Accelerate to Flaps Up + 20
- Limit Bank Angle to 15° Maximum
- Until Above Flaps Up + 20
- Flaps Up
- Accelerate to Flaps Up + 20
- Limit Bank Angle to 15° Maximum
- V_{2} + 10 to V_{2} + 25
- Close-in Turn After Takeoff: Maintain Takeoff Flap Setting
- V_{2} + 10 to V_{2} + 25
- At VR
- Rotate Smoothly to Target Pitch
- 80 Knots
- Monitor Airspeed
- Straight Climbout
- Gear Up
- V_{2} + 10 to V_{2} + 25
- Positive Rate of Climb
- Accelerate to Flaps Up + 20
- Limit Bank Angle to 20°
- Above Flaps Up + 20
- Turn Complete at or Above Acceleration Height
- Accelerate to Economy Climb Speed
- 10,000 ft
- Flaps Up
- Accelerate to Flaps Up + 20
- Limit Bank Angle to 15° Maximum
- Until Above Flaps Up + 20
- Accelerate to Flaps Up + 20
- Limit Bank Angle to 15° Maximum
- Above Flaps Up + 20
- Accelerate to Flaps Up + 20
- Limit Bank Angle to 15° Maximum
- Until Above Flaps Up + 20
- Accelerate to Flaps Up + 20
- Limit Bank Angle to 15° Maximum
- Above Flaps Up + 20
ILS APPROACH – MANUAL
NON PRECISION APPROACH – USING VNAV
NON-PRECISION APPROACH – USING V/S

1. Approaching intercept heading
2. Set Flaps
3. Intercept heading
4. Arm VNAV or appropriate roll mode
5. Arm MDA(H) and set V/S
6. Descend to MDA(H)
7. Set MDA(H)
8. Set missed approach route in MCP
9. Intercept landing profile and disengage autopilot and disconnect autothrottle
CIRCLE TO LAND FROM INSTRUMENT APPROACH

Configuration at MDA(h)
- Gear down
- Flaps 20
- Arm speedbrake (landing flaps optional)
- Minimum Descent Altitude
- Select AIL, HQLD
- Set required Approach altitude
- Select HDG SEL

Missed Approach
- Make a climbing turn in the shortest direction toward the executed the missed approach
- Intersecting Landing Profile and disengage autthrottle
- Landing checklist
- Landing flaps (if not previously selected)
- Turning Base

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VISUAL APPROACH

- Go-Around/Rejected Landing Gear
- Retract Flaps 20 / Positive Rate of Climb
- Gear Up Schedule After Takeoff Checklist
- Flaps 10 / Retract Flaps on Flap/Speed
- Flaps 5 / Rate of Climb
- 1500 ft / Go-Around
- 2 NM / Flaps
- 2-2 1/2 NM / Flaps
- 700-500 ft / Flaps
- Stabilized on Profile
-零Armed Trim Prior to Touchdown (One Engine Inoperative)
- Turning Base: Start Descent As Required
- Speedbreak

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AIRCRAFT SYSTEMS

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AIR CONDITIONING / PRESSURIZATION

Overview: To provide cabin air conditioning, air from the pneumatic manifold is directed to three air conditioning packs. Ozone is removed by catalytic converters, and after passing through one of the three packs, the conditioned air enters a common air conditioning manifold for distribution to the cabin.

Conditioned air is then circulated to the cockpit, the upper deck area, and one of five main deck cabin condition control zones. Output temperature of the air conditioning packs is determined by the single zone which requires the coolest air output. The air destined for other zones is warmed above this temperature level by the addition of hot air from the pneumatic system (trim air.)

ECS Overhead Panel

Cabin Temperature: Cabin temperature is controlled by air conditioning in seven independent temperature control zones: Five on the main passenger deck, one on the upper deck and one in the cockpit. Conditioned air is provided by three air conditioning packs located below decks in the center section of the airplane. Pack control, cabin air recirculation, fault protection and overheat protection are all automatic. Temperature is controlled automatically to selected levers for the flight deck and passenger zones. A backup mode of temperature control is available in the event of system failures.

The air conditioning packs can operate using pressurized bleed air from the engines, APU or an external pneumatic ground source.

Temperature control is managed by adjusting the temperature of the air conditioned output from the packs to the coolest zone requirement. Other zones are then heated using a modulated amount of trim air to meet commanded temperature requirements in those zones. Unless manually set, the temperature control selectors will target an average cabin temperature of 24ºC.

The forward cargo compartment is heated by the equipment cooling air exhaust from the flight compartment and the equipment center. The aft cargo compartment takes hot bleed air directly from the center bleed air duct. Temperature is regulated by a temperature sensing probe and a regulator valve. Control of aft cargo heat can be effected through use of the Aft Cargo Heat switch on the overhead ECS panel.

The air conditioning system synoptic provides an overview of the aircraft temperature control zones in the upper left corner. This overview includes the master temperature setting, target and average temperature for each zone, plus the current temperature of the forward and aft cargo compartments.

Air Conditioning Packs: Bleed air from the pneumatic manifold passes through two sections of the dual heat exchanger. The first section cools the bleed air then passes it into a compressor for the air cycle machine. As a result of compression the temperature of the air increases, so it is then routed to the secondary section of the dual heat exchanger, where it is cooled. The
compressed, cooled air then passes through the turbine section of the pack where it expands rapidly causing further cooling. A condenser/separator eliminates excess moisture which is produced during the expansion process.

To prevent ice forming in the condenser/separator, the temperature of air flowing through the mechanism is controlled by mixing hot air from the compression stage of the pack.

The air conditioning packs and heat exchangers produce significant amounts of heat during normal operation. Additionally they consume bleed air resources from the engines thus increasing EGT values and reducing engine efficiency. It is recommended that two packs be turned off during takeoff.

The packs themselves are cooled by inducing air flow over the heat exchanger during ground operation, and by ram air during in-flight operation.

**Pack Control:** Pack control is handled by two pack controllers, A and B. Each pack controller has three control channels, one for each pack. If either pack controller fails, control will automatically switch to the other controller.

Pack controllers can be selected automatically, or manually by positioning the pack control selector to NORM, A or B. Provided bleed air is available, this will cause the selected controller to command pack operation.

In the event of a pack overheat or a fault in the pack controller, an EICAS advisory message is displayed, the pack SYSTEM FAULT light illuminates and the respective pack valve closes automatically, resulting in a pack shutdown. Pack three will shut down automatically if any Cargo Fire Extinguishing system is armed, and pack two will shut down automatically if the cabin becomes over-pressurized.

The Pack Controller logic will automatically change the pack control mode between each subsequent flight. The pack control mode can be read from the secondary EICAS screen for the Environmental Control System (ECS screen.) The pack control mode is denoted by the letter A or B associated with each pack.

If left in NORM, the airplane will automatically alternate between A and B on subsequent flights, or the control mode may be selected manually by the crew in the event a particular control mode fails.

**Pack Hi Flow Mode:** Packs normally operate in HI FLOW mode at all times except cruise flight. During cruise, the packs will operate in low flow in order to increase efficiency and reduce pneumatic demands on the engines. This may be overridden by selecting HI FLOW on the pack control switch if desired or necessary. An EICAS memo indicating the HI FLOW setting will be displayed in order to remind the crew that the Hi Flow switch is ON and the pack flow setting is not being managed automatically.

**Recirculation Fans:** In order to recirculate passenger cabin air through the manifold system, four recirculation fans are installed, two overhead and two under floor. The recirculation fans operate in conjunction with the air conditioning packs, and are controlled by the pack controller. Unless manually overridden, the lower recirculation fans will only operate during cruise. This helps to reduce engine bleed air demand and fuel consumption. The fans must be activated using the switches on the overhead ECS panel.

If a fan overheats is detected, electrical power is automatically removed from that fan. If a fan is not operating because of an overheat, it has failed or the Recirculation Fan switch is OFF, system logic reconfigures the pack flow and recirculation fan operating combination to maintain proper ventilation to the cabin.

**Trim Air:** In order to regulate temperature differences between zones, heated air from
the bleed ducts is used to modulate air temperature in different zones. This airflow is called Trim Air, and the control for this function is located on the ECS Overhead Panel.

**Equipment Cooling:** The equipment cooling system provides cooling air for the flight deck electrical equipment and the electronics and equipment center racks. This system directs cooler air from the lower fuselage into the equipment racks and exhausts warmer air to the forward cargo compartment.

The Equipment Cooling system operates in three modes; NORM, STBY and OVRD. The modes are selected using the equipment cooling selector on the ECS portion of the overhead panel.

On the ground without engine power, the NORM setting will automatically cause warmer exhaust air to be ducted to the forward cargo compartment or out the ground exhaust valve if the ambient temperature is greater than 45°F.

With the selector on STBY, the system functions the same as in NORM mode. The system will not exhaust warmer air out the ground exhaust valve, regardless of ambient temperature, however.

With the selector in OVRD, the equipment cooling system is deactivated and an outboard vent is opened, creating airflow across the equipment, through the supply duct and overboard through the use of cabin differential pressure.

**Gasper Operation:** In order to improve airflow to the passenger service units located above each passenger seat row, a gasper system is used to add additional airflow through the overhead ducting. Operation of this system is controlled by the gasper switch on the overhead ECS panel.

**Humidifier:** In order to improve humidity levels which are traditionally very low in pack conditioned air, operation of the humidification system can be controlled using the HUMID switch on the overhead ECS panel. The humidification system reintroduces moisture to the airflow rather than routing it through the evaporator. Humidification levels will vary depending on the number of packs in operation.

**Secondary EICAS Indications:** A synoptic of the air conditioning system is provided on the Environmental Control Systems (ECS) page, which is selected using the ECS switch on the secondary EICAS control panel.

**Main Deck Temperature by Zone:**

**Flight Deck/Upper Deck Temp:**

**Master Target Temperature:**

**FWD and AFT Cargo Zone Temp:**

**Pack Controller and Hi Flow Indication:**
Pressurization Overview: The cabin is pressurized with conditioned air from the air conditioning packs. Cabin altitude is controlled by regulating the discharge of conditioned air through two outflow valves at the rear of the cabin. The system is normally fully automatic but the outflow valves may be positioned manually if required due to a system failure or as a result of some contingency with the normal system or requirement in the event of an onboard smoke source. There are two cabin altitude controllers designated A and B. Although both controllers simultaneously receive identical information, only one controller is active at a time.

Pressurization Control Panel

Cabin Altitude Control: The active cabin altitude controller uses origin airport elevation, cruise altitude and landing altitude information from the FMS and automatically positions the outflow valves to conform to cabin altitude climb and descent rate limits, differential pressure limits and to achieve the correct landing cabin altitude. The initial pressurization, slightly above ambient pressure, begins when the airplane reaches 65 knots ground speed. The cabin altitude controller automatically sets cabin altitude slightly below destination field elevation so the cabin is pressurized slightly on landing. At touchdown, the outflow valves open, depressurizing the cabin.

Landing Altitude: Landing altitude may be entered manually into the cabin altitude controller using the Landing Altitude knob. This switch allows selection of numerical settings from 1,000 feet below sea level to 14,000 feet MSL. Normally the landing altitude is set automatically by information referenced to the FMS. An EICAS advisory message LANDING ALT is displayed if the landing altitude information is not available from the FMC. The message is inhibited if both cabin altitude controllers A and B fail.

Outflow Valves: The outflow valves are located on the bottom of the aircraft aft of the lower aft cargo compartment. They are bifold type valves that operate independently of each other. Each outflow valve has an AC motor and a DC motor. The AC motor is used to position the outflow valve when operating in the automatic mode of operation. An EICAS advisory message OUTFLOW VLV L (R) is displayed if automatic control is inoperative or the manual mode is selected for the respective valve. An EICAS caution message CABIN ALT AUTO is displayed if both cabin altitude controllers are inoperative or both outflow valves are in the manual mode.

If either Outflow Valve Manual switch is ON, the Outflow Valves Manual control may be used to open or close the respective outflow valve using the slower operating DC motor. The outflow valve not selected for manual operation remains under the control of the cabin altitude controller. When an Outflow Valve Manual switch is ON, the cabin altitude controller and the cabin altitude limiter are bypassed for the respective outflow valve. If both Outflow Valve Manual switches are ON, all automatic cabin altitude control functions are bypassed. Outflow valve position indicators are located on the cabin altitude panel and the ECS synoptic.

Cabin Altitude Warning: The EICAS warning message CABIN ALTITUDE is displayed and a siren sounds if cabin altitude exceeds 10,000 feet. The message is no longer displayed and the siren silences when cabin altitude descends below 9,500 feet. The siren may also be silenced by pushing the Master Warning/Caution Reset switch. With the system operating in the automatic mode, the outflow valves automatically close when cabin altitude exceeds 11,000 feet.
AIR CONDITIONING/PRESSURIZATION EICAS MESSAGES:

CABIN ALTITUDE Cabin altitude exceeds 10,000 feet.
CABIN ALT AUTO Failure of both cabin altitude controllers or both outflow valve MANUAL switches ON.
EQUIP COOLING With Equipment Cooling selector in NORM or STBY, airflow is inadequate, or overheat or smoke detected. With selector in OVRD, differential pressure for reverse flow cooling is inadequate, or ground exhaust valve not in commanded position.
>E/E CLNG CARD Message inhibited in flight.
On Ground: Control card failure.
LANDING ALT Disagreement between FMC landing altitude and cabin pressure controller landing altitude.
OUTFLOW VLV L(R) Auto control of L or R outflow Valve inoperative, or MANUAL was selected for the respective valve.
PACK 1, 2, 3 Pack Controller Fault
Pack Operation Fault
Pack overheat or Pack 2 shutdown with either cabin pressure relief valve open.
PACK CONTROL Automatic control of outlet temperature of all packs has failed.
PRESS RELIEF Either pressure relief valve actuates and pack 2 fails to shut down.
TEMP CARGO HEAT Cargo compartment overheat and the temperature control valve failed to close. (Inhibited on ground)
TEMP ZONE Zone duct overheat sensed or master trim air valve failed closed or zone temp controller failed.
Cabin temperature control is in backup mode.
>TRIM AIR OFF Master trim air valve commanded closed.
PACK 1,2,3 OFF Pack 1, 2, 3 off. Inhibited by PACK 1,2,3 advisory message.
PACKS HI FLOW Packs hi flow manually selected by HI FLOW switch.
PACKS OFF All 3 packs selected off.
PACKS 1+2 OFF Packs 1 and 2 selected off.
PACKS 2+3 OFF Packs 2 and 3 are selected off.
PACKS 1+3 OFF Packs 1+3 are selected off.
ELECTRICAL SYSTEM

Overview: The electrical system on the 747-400 is highly automated, and was designed from the beginning to both reduce pilot workload and provide a higher level of dependability. The electrical system provides for automatic system fault detection, automatic system fault isolation and reconfiguration, load management, online power, no-break power switching, AC and DC system status monitoring and master frequency referencing. The electrical system is also designed to automatically configure itself to provide the triple redundant power required by the autopilot system for full autoland capability.

IDG Drive Disconnects: The constant speed drive that operates the IDG in each engine can be separated from the accessory section in the event of a fault or failure. The IDG Drive Disconnect switches located on the Electrical Panel on the overhead provide access to this disconnect function. Disconnecting an IDG drive should only be conducted at the request of maintenance, or in the conduct of an Abnormal Checklist, as the disconnect action will cause the loss of that generator for the remainder of the flight.

When starting or shutting down an engine, it is not uncommon to see the DRIVE annunciation in the IDG Disconnect switch. This annunciation indicates that the constant speed drive lacks sufficient oil pressure or rotational energy to provide adequate power from an IDG.

NOTE: Once an IDG is disconnected, it cannot be reactivated in flight.Disconnected IDGs must be inspected and reset by ground maintenance personnel.

AC Power: Each engine contains an Integrated Drive Generator (IDG) which is attached to a constant speed drive located in the accessory section of its respective engine. The constant speed drive provides a constant, normal rotation for the generator across a broad range of engine RPM.

Each IDG provides 115 volt, 400 hertz AC power to its individual bus, and is capable of providing 90 KVA. Each IDG incorporates a generator, a constant speed drive and an oil cooling system. The oil cooling system is a standard configuration Fuel/Oil heat exchanger which serves the dual purpose of heating the fuel system and cooling the IDG.

We have provided an IDG reconnect option in the PMDG/OPTIONS/VARIOUS menu in order to allow for the practice of failure scenarios that might call for an IDG disconnect in flight.
APU / External Power: While on the ground, it is possible to provide AC power to the 747-400 via an external power source or the Auxiliary Power Unit generator. The electrical system is designed so that both methods of providing electrical power can be used simultaneously on different portions of the electrical system.

Two non-paralleled 90KVA generators are driven by the APU and are capable of providing 115 Volt, 400 hertz AC power to each AC system while the aircraft is on the ground.

To simulate differences in various airport facilities around the world, PMDG has included a logic parameter that will provide External Ground Power for EXT1 when selected from the PMDG/OPTIONS/VARIOUS menu. (See Chapter 00 Introduction for more information.) Occasionally, the ground power will also be made available on EXT2.

Split System Breaker: The electrical system on the 747-400 is divided into two systems, Left and Right. The left system is comprised of Bus 1 and 2, while the right system is comprised of Bus 3 and 4. The two sides are separated by a Split System Breaker (SSB). The SSB condition will alternate between open and closed based on a complex logic designed to ensure redundancy and protection of the entire electrical system.

If the left and right sides of the airplane are powered by non IDG sources (EXT1 and APU2, for example) then the SSB will open, allowing each to power its own side of the airplane.

To understand the behavior of the SSB, it is important to understand that the only power sources that can be paralleled on the 747-400 are IDGs. All other power sources must operate independently on their side of the airplane.

For example if External Power is active on both sides of the airplane, the SSB will be open. If APU power is active on both sides of the airplane, the SSB will be open. If IDGs are powering both sides of the airplane, the SSB will be closed.

It is possible to power the left and right sides of the airplane using dissimilar power sources. If the right side of the airplane is powered by an APU generator, while the left side is powered by Ground Power, then the SSB will open to allow both sides to receive power from the selected source while preventing them from being paralleled.

When first beginning to power the aircraft, the behavior of the SSB will depend upon what power sources are AVAILABLE. (AVAILABLE means that the source is available for use, but has not been selected as an ACTIVE power source.) If only EXT1 is showing as AVAIL on the electrical panel, then the SSB will remain open when EXT1 is selected.

The only way to close the SSB, thus providing power to the entire airplane, is for a power source to be AVAILABLE for the right side of the airplane, whether it is in use or not.

For example, if only EXT1 is available, it will power the left side of the airplane when selected ON. The right side will remain unpowered unless:

EXT2 becomes AVAILABLE.
APU2 becomes AVAILABLE.

It is not necessary to select either EXT2 or APU2 on, it is only necessary that they be available in order to provide power to trigger the SSB to close.

If the second source (either APU or EXT PWR) is selected for the other side of the aircraft, the SSB will open and both systems will run from their selected power sources.

In the event that two power sources are in use powering each the left and the right system, the SSB provides a safety backup in the event one source should fail. If one of
the two power sources fails, the SSB will close automatically, and power will continue to be provided to both the Left and Right systems without interruption.

**Power Switching/Preferencing:** When both systems are being powered by engine driven IDGs, selection of either an APU or EXT power source will automatically take both IDGs on that side of the electrical system offline, and will instead provide power from the newly selected source.

If APU or EXT power is selected on the other side of the electrical system, then the entire electrical system will be powered from non IDG sources. (And the SSB will remain open!)

If the entire system is being powered by non IDG sources, the SSB is open. If an IDG is then brought online on the right side of the system, the IDG will take over power production from the previously selected power source, but the IDG will remain OPEN because the left side of the airplane is being powered by a non IDG source.

If an IDG is then selected for the left side of the electrical system, the SSB will close, and both sides will be powered by IDG sources.

When power is transferred from IDGs to an APU or EXT source, the system automatically synchronizes the electrical current to ensure a no-break power condition is maintained.

**AC Bus Tie System:** There are four AC buses on the 747-400, each is directly powered by its respective IDG, or alternately by the system bus in the event the respective IDG has failed or is offline.

Each of the AC buses is connected to the tie bus by a Bus Tie Breaker (BTB). Placing the BUS TIE switch in AUTO will command the BTB to open and close automatically in order to maintain the integrity of the system in the event of a system fault. If the BUS TIE switch is placed in ISLN, the BTB and the DC ISLN relay will open, separating that AC bus from the rest of the system.

If the power on an AC bus becomes unsynchronized, the BTB will open automatically and the isolated bus will continue to operate from its own IDG.

Conversely, if the IDG is not able to maintain acceptable power quality for the AC bus, then the respective generator control breaker will open and the bus tie will close to power the bus form the synchronous bus.

**Autoland Configuration:** During autoland maneuvers, AC buses 1-3 are automatically isolated in order to provide redundant power to each of the FCCs.

**Batteries:** The 747-400 has two nickel-cadmium batteries. One battery is the main battery and the other powers the APU starter. Each battery has a battery charger which is powered by the external power source. The batteries, if fully charged, can provide power to all standby loads for a minimum of 30 minutes.

**DC Power:** Four 75 amp Transformer-Rectifiers (TR's) are powered, one by each AC bus. The TR's provide power to DC
buses 1-4, respectively. The DC buses can be paralleled or isolated.

**DC Tie Bus:** With the BUS TIE switch in AUTO, each DC isolation relay operates automatically, and will remain closed if no DC faults are detected. With the BUS TIE switch set to ISLN, the respective system is opened, which isolates the DC bus from the tie bus and leaves it powered only by the respective AC bus and TR.

**Battery Busses:** There are four battery busses:

- Main Battery Bus
- Main Hot Battery Bus
- APU Battery Bus
- APU Hot Battery Bus

The hot busses are always connected to their respective batteries and are normally powered by the ground service bus through the battery chargers if the ground service bus is powered.

The main and APU battery busses are normally powered by DC bus 3.

On a cold aircraft with AC bus 3 and/or DC bus 3 unpowered, when the battery switch is pushed ON, the main hot battery bus and the APU hot battery bus automatically power their respective main battery busses.

**Main Standby Power:** Power to the Main and APU Standby busses is primarily controlled by the STANDBY POWER selector in conjunction with the Battery Switch.

Under normal conditions, the Main Standby Bus receives its power from AC bus 3.

In the event that AC bus 3 is unpowered and the STANDBY POWER selector is in the AUTO position, the Main Standby bus will be powered from the main standby inverter. The standby inverter will draw its power from AC bus 1 (via the ground service bus, the main battery charger and the main hot battery bus). The BATTERY switch must be on for this backup to function properly.

If both AC bus 1 and AC bus 3 are unpowered, the standby bus is powered from the main battery through the main hot battery bus and the standby inverter. Battery power can be expected to power the main standby bus for at least 30 minutes. The battery switch must be ON and the standby power selector must be in the AUTO position for this transfer to take place.

If the STANDBY POWER selector is rotated to the BAT position and the battery switch is ON, the standby bus is powered by the main battery via the main hot battery bus and the standby inverter. The APU battery bus is powered by the APU battery through the APU hot battery bus. (In this configuration the APU battery chargers are disabled.)

The standby bus can be powered in this configuration for at least 30 minutes. (This configuration is not used in any flight operation and is used primarily by maintenance.)

**APU Standby Power:** With the STANDBY POWER selector in AUTO, flight critical items can also be powered by the APU standby power bus automatically in the event of a critical loss of AC power.

The APU standby bus will automatically provide power to the primary EICAS, captains PFD, ND and CDU, the VOR receivers and the ILS receivers.

**Transfer Busses:** Many of the captain’s and first officer’s flight instruments receive AC power from their respective transfer busses. The captain’s transfer bus is normally powered by AC bus 3 and the first officer’s transfer bus is normally powered by AC bus 2. AC bus 1 provides automatic backup for both transfer busses. There are no flight deck controls or indicators for the transfer busses.

**Captains Transfer Bus Equipment:**
- Avionics and Warnings
- System Status Assembly
- Center Air Data Computer
- Center Engine Instrumentation Unit
- Left FMC
- Left High Frequency Radio
- Left Navigation Display
- Left Primary Flight Display
- APU Standby Bus

**First Officer's Transfer Bus Equipment**
- Secondary EICAS
- Autothrottle Servo
- Right Air Data Computer
- Right EFIS Control Panel
- Right Engine Instrumentation Unit
- Right FMC
- Right High Frequency Radio
- Right Navigation Display
- Right Navigation Display
- Right Primary Flight Display

**Ground Handling Bus:**
The Ground Handling Bus is powered by either APU1 generator or EXT1 power source.

The bus is powered automatically whenever external power or APU power is AVAILABLE, whether or not that power source is selected ON. If both APU and EXT power are available, priority goes to external power. The ground handling bus can only be powered with the aircraft is on the ground. If any three engines are operating above 75% N2 the ground handling bus will inhibit. There are no flight deck indicators for the Ground Handling Bus.

**Ground Handling Bus Equipment:**
- Fueling System
- Cargo Systems
- Cargo Deck Lighting
- Auxiliary Hydraulic Pump 4

**Ground Service Bus:**
The Ground Service Bus is normally powered automatically by AC bus 1. Although not modeled in this version, if AC bus 1 is not powered while the aircraft is on the ground, there is a button at the door 2L flight attendant control panel that allows the Ground Service Bus to be connected to the ground handling bus in order to provide power to the cabin for cleaning, preparation while the aircraft has AVAILABLE power, but is not actively connected.

**Ground Service Bus Equipment:**
- Main and APU battery chargers
- Fuel pump for APU start
- Horizontal stabilizer pump for defueling
- Upper deck doors
- Flight deck floodlights
- Navigation lights
- Cabin and service lighting
- Cabin service power outlets

**Utility and Galley Busses:**
Each main AC bus provides power to a utility bus and a galley bus. Each utility and galley bus is controlled by a separate electrical load control unit (ELCU) which protects the electrical system from utility and galley bus faults and provides load shedding functions. The ELCUs are controlled by the left and right utility power switches located on the overhead electrical panel.

With the left utility power switch ON, the utility and galley busses 1 and 2 are activated and the busses are powered according to ELCU logic. Similarly, the right utility power switch activates utility and galley busses 3 and 4.

A guarded Emergency Power Off switch is located in each galley. If this switch is moved to the OFF position, an EICAS advisory message ELEC UTIL BUS L, R is displayed and the OFF light in the respective utility power switch illuminates. In this event, cycling the utility power switch to OFF then ON will not reset the indications because the switch in the galley is forcing the power disconnect.
The utility power switch should remain in the ON position after cycling, however as this permits the remaining utility and galley busses to be powered.

**Load Shedding:** In the event that AC power availability decreases due to engine or generator failure, the ELCUs reduce AC power load requirements by shutting down the galley buses until AC power availability increases, or until the AC load has been reduced to a level sustainable with the current supply.

During load shedding, associated EICAS alert messages and illumination of the utility switch OFF lights are inhibited. However, the following EICAS advisory messages may be displayed in the order shown depending upon fuel system configuration and the extent of load shedding:

- FUEL PUMP 3 FWD
- FUEL OVRD 2 FWD
- FUEL OVRD 3 FWD
- FUEL OVRD CTR L
- FUEL PUMP 2 FWD

If available power increases, ELCU logic will return power to shed busses to the degree sustainable power is available.

**EICAS ELEC Synoptic:** The EICAS ELEC synoptic displays the current status of the entire bus tie system. The SSB, each of the IDGs, GEN CONT, BUS TIEs and ISLN switches are displayed in graphic format to quickly allow the crew to assess the disposition of the electrical system.

Electrical flow is depicted by heavy green bars. During autoland, the EICAS ELEC display will be inhibited once the Flight Control Computers engage for autoland.
ELECTRICAL CONTROL PANEL DIAGRAMS
(Overhead)

Standby Power Selector:
OFF: Disconnects the main and APU standby buses from all power sources. Standby power is not available.
AUTO: Allows main and APU standby buses to be powered automatically from AC bus 3 or batteries.
BAT: Powers the main and APU standby buses from their respective batteries provided the BATTERY switch is ON.

Battery Switch:
ON: Enables main and APU batteries and enables backup power.
OFF: Disconnects main and APU batteries.

APU GEN ON Lights: Indicates APU power breaker is closed.

APU GEN AVAIL Lights: Indicates that output voltage and frequency of the APU generator are within normal limits and ready.

APU GEN Switches: Allows selection/de-selection of power APU generator power to bus.

EXT PWR Switch: Allows selection/de-selection of external power to bus.

EXT PWR AVAIL Lights: Indicates that external power unit is connected and voltage and frequency are within normal limits.

EXT PWR ON Lights: Indicates external power contactor is closed.

BUS TIE Switches:
AUTO: Allows bus tie breaker and DC isolation relay to close automatically if required.
OFF: bus tie breaker and DC isolation relay open.

UTILITY Power Switches:
ON: Each switch powers two galley and two utility buses unless load reduction is necessary.
OFF: Respective galley and utility buses are disconnected from AC power. (Resets circuitry on buses.)
**BUS TIE ISLN Lights:** Respective AC bus is isolated from the tie bus as the bus tie breaker is opened due to a fault or the switch has been selected OFF.

**GEN CONT Switches:**
- **ON:** Closes the generator field and allows the generator control breaker to close automatically when required.
- **OFF:** Opens generator field and control breaker.

**GEN OFF Lights:** Generator control breaker is open.

**DRIVE DISC Switches:** Disconnects IDG from the engine. Can only be reconnected on the ground.

**DRIVE Lights:** Generator drive has low oil pressure or high oil temperature.

### SECONDARY EICAS DISPLAY - ELECTRICAL SYSTEM SYNOPTIC

**Split System Breaker (SSB):**
- [Closed] Connects both tie bus halves.
- [Open] splits tie bus into two halves.

**ISLN:** Indicates respective BTB is open.


**BUS:** [amber] Bus unpowered. [green] Bus powered.

**GEN CONT:** [ON] Generator field closed.
- [OFF] Generator field open. (Resets)

**DRIVE TEMP/PRESS:** Indicates high drive oil temperature or low drive oil pressure.
**Bus Equipment Overview:** Following is a non-conclusive list describing the equipment powered by the primary busses in the AC and DC systems on the 747-400.

**APU Battery Bus Equipment:**
- APU battery overheat protection
- APU DC fuel pump
- APU fire/bleed duct overheat loops A and B
- Cabin interphone
- Captain’s interphone
- Electronic Engine Control 1-4 channel A
- Engine 1-4 fire/overtt detect loops A and B
- Engine 1-4 speed sensors 1 and 2
- Engine start air control First officer’s interphone
- Left VHF
- Left radio communication panel
- Nacelle anti-ice valve actuate 1-4
- Observer’s interphone
- Passenger address systems 1-4
- Primary landing gear display and control
- Service interphone

**APU Hot Battery Bus Equipment:**
- APU duct overheat APU fire warning horn
- APU inlet door
- APU primary control
- IRU left, center, and right DC
- Left and right outflow valves

**Main Battery Bus:**
- APU alternate control
- E/E cooling smoke override
- Engine 1-4 fuel control valves
- Engine 1-4 fuel crossfeed valves
- Flight deck dome lights
- Flight deck storm lights
- Flight deck, captain’s indicator lights
- Generator drive disconnect 1-4
- Hydraulics EDP supply 1-4
- Left ILS antenna switch
- Left and right manual cabin pressurization
- Left aural warning
- Left stabilizer trim/rudder ratio module
- Left stick shaker
- Oxygen reset
- Oxygen valve and indication
- Parking brake
- Primary trailing edge flap control DC
- Stabilizer trim alternate control Standby
- altimeter vibrator
- Standby attitude indicator
- Standby attitude indicator ILS deviation bars
- Upper yaw damper

**Main Hot Battery Bus:**
- ACARS DC
- APU fire extinguisher
- APU fuel shutoff valve
- Engine 1-4 fire extinguishers A and B
- Engine 1-4 fuel shutoff valve
- Fire switch unlock
- Galley/Utility ELCU control bus 1-4
- Generator Control Units 1-4
- Hydraulic system 2 and 3
- ELCU control
- IRS on battery warning
-Lower cargo fire extinguisher
- Main battery overheat protection

**Main Standby Bus:**
- Avionics and warning system
- Flight control 1L and 2L AC
- Left ADC
- Left EFIS control
- Left EIU
- Left FMS-CDU
- Left ILS
- Left VOR
- Primary trailing edge flap control AC
- RMI
- Standby ignition 1-4
- Standby instrument lights
- Upper EICAS

**APU Standby Bus:**
- Left FMC
- Left PFD
- Left ND

**AC Bus 1:**
- Center FCC
- Center FMS-CDU
- Center ILS
- Center IRU
- Center radio altimeter
- Engine 1 probe heat
- Engines 1-4 igniter 1
- Flight control 1R AC
- L and R wing gear alt extension
- LE flap drive group A control
- Left AOA heat
- Left aux pitot probe heat
- Left pitot probe heat
- Left TAT probe heat
- TR unit 1
- Voice recorder
AC Bus 2:
ACARS AC
Body gear steering control
Flight control 2R AC
Left and right wing anti-ice valves
Lower rudder ratio changer
Right ADF
Right ATC transponder
Right DME Right FCC
Right ILS Right IRU
Right radio altimeter
Right VOR
Right weather radar R/T
TR unit 2
Wheel well fire detection
Window heat 1R, 2L, 3R

AC Bus 3:
Engines 1-4 igniter 2
Engines 2 and 3 probe heat
First officer’s panel lights
Glare shield flood lights
GPWS
LE flap drive group B control
Left ADF
Left ATC transponder
Left DME Left FCC
Left IRU
Left radio altimeter
Left weather radar R/T
Observer’s panel lights
Overhead panel lights 2
Pilot’s main panel flood lights
TCAS
TR unit 3
Upper rudder ratio changer
Window heat 2R and 3L

AC Bus 4:
Captain’s panel lights
Engine 4 probe heat
Engines 1-4 vibration monitor
Glare shield panel lights
Left and right body gear alt extension
Nose gear alt extension
Overhead and P7 panel lights
Overhead panel lights 1
Right AOA heat
Right aux pitot probe heat
Right pitot probe heat
Right TAT probe heat
TR unit 4
Window heat 1L
Windshield washer pump

DC Bus 1:
Auto cabin press controller A
First officer’s digital display lights
First officer’s indicator lights
Flight control 1R DC
Flight deck door release
Fuel system management card A
Fuel transfer valve main 1
Fuel transfer valve reserve 2A and 3A
Ground safety relay
HYDIM system 4
Hydraulic demand pump 1 control
Hydraulic sys 1 EDP depress control
Ignition control
Left center and main 3 jettison valves
Left FMCS autothrottle servo

DC Bus 2:
Auto cabin press controller B
Flight control 2R DC
Fuel system management card B
Fuel transfer valve main 4
Fuel transfer valve reserve 2B and 3B
HYDIM system 3
Hydraulic demand pump 2 control
Hydraulic sys 2 EDP depress control
Landing gear alt display and control
Lower yaw damper
Nose gear steering - primary
Outboard aileron lockout
Right center and main 2 jettison valves
Right FMCS autothrottle servo
Right MCP Right refuel
Right stabilizer trim control
Right stabilizer trim rate
Right stabilizer trim shutoff
Right stick shaker
Wing anti-ice control
DC Bus 3:
Aileron trim control
Center VHF
Fuel jettison controller A Fuel quantity 1
HYDIM system 2
Hydraulic demand pump 3 control
Hydraulic quantity indicator
Hydraulic sys 3 EDP depress control
Inboard TE flap control
Left Jettison nozzle valve control
Left MCP
Left stabilizer trim control
Left stabilizer trim rate
Left stabilizer trim shutoff
Left windshield wiper
Master trim air control
Nose gear steering – alternate
Overhead and P7 panel lights
Pack temperature controller A

DC Bus 4:
Fuel jettison controller B
Fuel quantity 2
Hyd sys 4 EDP depress control
HYDIM system 1
Hydraulic demand pump 4 control
Outboard TE flap electric control
Pack temperature controller B
Right Jettison nozzle valve control
Right windshield wiper
Speed brake flight detent
Spoiler and aileron position indication
Windshield washer

ELECTRICAL SYSTEM EICAS MESSAGES:
>BAT DISCH MAIN Respective battery is discharging.
>BAT DISCH APU Respective battery is discharging.
>BATTERY OFF Battery Switch is off.
>DRIVE DISC 1,2,3,4 Generator drive disconnect switch pushed, IDG manually disconnected.
ELEC AC BUS 1,2,3,4 AC Bus is unpowered. Additional related messages displayed for unpowered equipment.
ELEC BUS ISLN 1,2,3,4 Bus tie breaker is open. (Inhibited when ELEC AC BUS is displayed)
ELEC DRIVE 1,2,3,4 Low IDG oil pressure, or high IDG oil temperature. Inhibited when IDG disconnected manually.
ELEC GEN OFF 1,2,3,4 Generator control breaker is open with respective engine running. Inhibited when ELEC AC BUS message is displayed.
>ELEC SSB OPEN Split system breaker is open when commanded closed.
ELEC UTIL BUS L, R, OFF Galley or Utility bus has tripped off, or Utility power switch L or R is positioned off, or Galley Emergency Power Off switch was activated. Inhibited during load shedding.
>STBY POWER OFF Standby bus is unpowered.
>STBY BUS AP APU Standby bus is not powered.
>STBY BUS MAIN Main standby bus is not powered.
ENGINES AND ENGINE SYSTEMS

Overview: The 747-400 has three engine variants certified for the airframe.

- General Electric CF6-80C2BF1F @62,100lbs thrust.
- Rolls Royce RB211- 524H2T @59,500lbs thrust.
- Pratt & Whitney PW4062 @ 63,300 lbs thrust.

Note that there are an array of engine variants by each manufacturer currently flying on the wings of 747-400s. As various engine offerings have been improved upon to match the needs of 747-400 operators, engine model variant availability has changed over time. Operationally the differences between model variants is generally quite small.

The PMDG 747-400 engine mathematical performance model is based upon the GE CF6-80C2BF1F engine model at 58,000lbs of thrust. Extensive engine performance data was used to produce an engine thrust and operative model that most closely resembles its real world counterpart.

We recognize that users may wish to fly a 747-400 that uses engines other than the CF6, (BA for example uses only the RR engine on their airplanes) and as such we have provided all three engine models attached to the visual model of the airplane.

It is important understand that while we have included visual models of each engine type, we have only designed a single mathematical model for engine performance. This mathematical model is based upon the GE CF6 engine.

The Rolls Royce and Pratt & Whitney engines are instrumented significantly differently than the GE engine offering. (The RR engine is a three spool engine, for example, and the PW engine uses EPR rather than N1% for thrust control) As such, producing three engine performance mathematical models would also have required changes to engine displays, engine behavior calculations, autothrottle control laws and numerous small, but significant cockpit items.

We may at a future date offer additional engine performance mathematical models. For most operators, the engine differences between airplanes represent almost insignificant performance differences for the airplane.

The GE CF6 engines are two rotor turbofan engines with the N1 and N2 stages independent of each other. The N1 rotor consists of a fan, a low pressure compressor section and a low pressure turbine section. The N2 rotor consists of a high pressure compressor section and a high pressure turbine section. The N2 section drives the accessory pack for each engine, and the bleed air powered starter connects to the N2 rotor.

Each engine is fully monitored and controlled by an independent Electronic Engine Control (EEC) which monitors throttle input and manages engine control automatically to provide peak efficiency in all regimes of flight. The EEC draws power from a dedicated alternator located within the engine accessory pack, and is not dependent on the aircraft electrical system.

EEC data on engine performance for each engine is displayed via the EICAS system in the cockpit.

Throttle control is provided for the full range of forward and reverse thrust. Fuel control is provided via FUEL CONTROL switches, engine start is controlled by engine START switches and ignition control via IGNITION switches.

Electronic Engine Controls: The EEC is a system of sensors, actuators and vibrometers located within the engine nacelle, the engine casing and within the engine itself. The EEC reads and interprets raw data from each sensor as well as control...
input from cockpit controls and switches. The EEC maintains full control authority over the engine at all times, and provides protection from exceeding engine limitations such as temperature and rotational speed.

**EEC NORMAL Mode:** In the normal mode, the EEC sets thrust by controlling N1% based on the throttle position. The EEC increases thrust from idle to maximum as the throttle is moved through its entire range of motion. Thrust will reach maximum N1 at the full forward throttle position. Maximum N1 is the maximum thrust available from the engine, regardless of flight envelope restrictions. Maximum thrust is available during any phase of flight, regardless of other restrictions.

When accelerating the engine, EEC will monitor parameters within the engine to ensure that no limitations are exceeded. Fuel flow to the engine is strictly controlled in order to prevent over temperature conditions during rapid increases in thrust.

Once engine thrust is stabilized, the EEC will continually adjust engine fuel metering and other parameters based on environmental conditions in order to maintain the thrust setting demanded by the throttles. This eliminates the need for re-trimming the throttles during the climb, or constant engine performance monitoring. As such, a fixed throttle position will deliver the same engine performance throughout a climb or descent.

The EEC will automatically adjust engine performance to compensate for bleed air system loads such as those imposed by wing and engine nacelle anti-ice, cabin pressurization or in flight engine starts.

When idle thrust is selected, the EEC will choose between approach idle or minimum idle thrust setting. Minimum idle is a lower idle setting used during ground and taxi operations. Approach idle is a higher idle power setting used if the flaps and landing gear are out of the UP position. This higher idle power setting will reduce the time needed for the engines to spool from idle to a go around power setting.

The EEC also provides engine overspeed protection. If either the N1 or N2 rotors approach the engine overspeed envelope, the EEC will adjust fuel metering to prevent rotor speed from exceeding the operating limit.

**EEC ALTERNATE Mode:** In the alternate mode, the EEC sets thrust by controlling N1 RPM based on throttle position. The alternate mode does not provide thrust limiting at maximum N1% if Maximum N1 is reached at a throttle position less than full forward. The throttles must be adjusted to maintain desired thrust as environmental conditions and bleed requirements change.

If the EEC detects a fault and can no longer control the engine using the normal mode, it transfers control automatically to the alternate mode. The alternate control mode can also be selected manually using the ELEC ENG CONTROL switch on the overhead panel for each engine respectively.

**EEC Control Panel**

The alternate mode provides equal or greater thrust than the normal mode for the same throttle position. Thrust does not change when the EEC transfers control automatically from the normal to alternate mode. Thrust increases when control is selected manually. When thrust is greater than idle, the throttle should be moved after prior to manually selecting the alternate mode so thrust does not exceed maximum N1%.

The EEC's have redundant systems. A loss of redundancy may degrade EEC operation. If three or more EECs are operating in this degraded condition, the EICAS advisory message ENG CONTROLS is displayed. The EICAS advisory message ENG CONTROL is displayed if one EEC system becomes unreliable. The ENGE CONTROL
and ENG CONTROLS messages are displayed only on the ground.

If control for any EEC transfers from the normal to the alternate mode, the autothrottle disconnects automatically. The autothrottle can be re-engaged after all EECs are again in the normal mode.

**Engine Indication:** Engine parameters as measured by the EEC are displayed on the EICAS system in the cockpit. The primary EICAS display will provide a full time tape depiction of N1 setting and EGT. N2, fuel flow, engine oil and vibration parameters are displayed on the secondary EICAS ENG display.

The vertical tape displays provide valuable information to the crew in the form of numerical and relative data. The numerical performance of each parameter (N1 for example) is displayed, as well as a vertical tape displaying performance relative to the whole range. This also allows for caution ranges and maximum values to be displayed simply.

If an engine is shut down in flight, primary and secondary reporting information on the engine such as N1 and EGT will not be displayed because the power necessary for the EEC to operate will not be available. As such, the EEC will cease functioning and no data will be reported for that engine.

Normal operating range for engine variables is displayed by the vertical white tape. Caution ranges are depicted by a horizontal amber bar. Warning ranges are depicted by a horizontal red bar.

If any indication reaches a caution or warning range, it will change color to indicate that the caution or warning range has been entered. If the secondary CRT has been blanked, it will automatically activate at the ENG page if an abnormal engine indication is detected.

**Engine Vibrometers:** Each engine uses vibrometers to monitor engine vibration in both the N1 and N2 rotors. The rotor which is producing the most vibration will be annunciated on the secondary EICAS engine display. If a system fault prevents the EEC from being able to determine which rotor is causing the highest level of vibration, an average base vibration level for the engine will be displayed under the header of BB, instead of N1 or N2.

**Engine Fuel System:** Fuel is carried to each engine via the fuel ducting system within the wing and engine struts. Fuel transfers through the ducting under pressure from fuel pumps located within the fuel tanks. The first stage engine fuel pump then adds additional pressure to the fuel as it is passed to the Fuel/Oil Heat Exchanger. Hot engine oil from the IDGs warms the fuel as it passes through the Fuel/Oil Heat Exchanger. Fuel is then passed through a filter to remove contaminants, and additional pressure is added by the second stage fuel pump before the fuel passes through the fuel metering unit. The fuel metering unit adjusts fuel flow to the thrust requirements determined by the EEC. Fuel flows, finally, through the engine fuel valve for distribution to the engine itself.

Fuel is allowed to flow to the engine as long as the engine fire shutoff handle is IN, the FUEL CONTROL switch is in the RUN position and the engine fuel pumps are providing fuel pressure. Fuel pumps will provide pressure as long as the N2 rotor is turning.

Fuel flow to the engine is shut off any time the N2 rotor stops turning, the FUEL CONTROL switch is placed outside of RUN, or the fire handle is pulled OUT.

Fuel flow through the fuel system from tank to engines can be monitored by selecting the FUEL synoptic on the secondary EICAS. Valve open/closed position can be monitored, as well as flow through and cross feed. Fuel flow is shown in green.

In the event of a loss of fuel pump pressure to an engine, each engine is able to suction fuel only from its respecting wing tank. Indication of suction fuel feed is displayed on the secondary EICAS in amber.

**Engine Starter/Ignition Systems:** Each engine has a bleed air powered starter motor connected to the N2 rotor of the engine. If no engines are currently
operating, bleed air is normally provided by the APU, but may also be provided by a ground unit with an air pressure bottle.

If bleed air pressure from a ground source is used to start an engine, bleed air duct pressure can be provided to the second engine on the same side by closing the bleed duct valve on the opposite side from the engines being started. To produce enough duct pressure, it may be necessary to advance the throttle on the running engine to approximately 60% N1. Thrust can be reduced to idle once the second engine has started.

After starting both engines on the same side, the bleed ducts can be opened to provide bleed air pressure to start the remaining engines.

Bleed air is transferred to the starter motor when both the start valve and the engine bleed air valve are open. Both valves will open automatically when the START switch is pulled. The START light will illuminate, indicating that the start valve has opened and bleed air is flowing to the engine.

Each engine has two igniters which operate independently of one another, or simultaneously depending on the position of the AUTO IGNITION selector. (Both or Single.)

In order to reduce the likelihood of inadvertent engine stalls, the ignition system will activate any time a start selector is pulled, or if engine nacelle anti-ice is selected ON. The ignition system will also activate any time the CON IGNITION (Continuous Ignition) switch is selected ON, or the flaps are selected out of the UP position.

The ignition system will deactivate when anti-ice is selected off, or when the flaps are in the UP position, or when the fuel control switch is placed in the cutoff position, depending on the flight requirement.

Oil System: Each engine has an independent fuel reservoir. Engine oil is circulated through the engine under pressure to lubricate and cool engine parts.

The oil itself is cooled by passing the oil through a combination of Oil/Air Heat Exchanger and a Fuel/Oil Heat Exchanger. This process both provides heat to the fuel system and cooling to the engine oil system.

Engine oil temperature and pressure are displayed on the secondary EICAS ENG display.

Reverse Thrust Capabilities: Each engine is capable of providing both forward and reverse thrust, depending on the flight situation and crew need. Reverse thrust is available while the aircraft is on the ground.

Each engine has an independent, hydraulically actuated fan air reverser. The hydraulic pressure needed to actuate the reverser comes from the associated engine driven hydraulic system, and as such, loss of the hydraulic system will cause loss of the hydraulics required for reverser operation.

Actuation of the thrust reverser can only occur when the throttles are in the idle position. Actuation causes the reverser sleeve to move aft, exposing a series of shroud vanes designed to redirect fan air forward with the help of fan blocker doors which redirect fan air flow into the vanes rather than through the engine.
Actuation of the reverser system will disengage the autothrottle.

The primary EICAS will display REV in amber next to the engine instrumentation to indicate actuation of the reversers. The REV annunciation will remain amber while the reversers are in transit to the deployed position, or when they are in transit to the stowed position. When REV is annunciated in green, it is safe to apply reverse thrust.

An amber REV indication in flight indicates that the reverser sleeve has released from the stowed position and hydraulic pressure is being used to return the sleeve to the stowed and locked position.

During the application of reverse thrust, the EEC will automatically monitor engine performance, and calculate a maximum N1 and fuel flow for engine reverse thrust in order to prevent exceeding any engine limitations during the reverse thrust.
ENGINE START/CONTROL SWITCHES

**Fuel Control Switch:** [Run] allows fuel flow to the associated engine. [Cutoff] discontinues fuel flow and ignition.

**Fire Warning Lights:** Fire warning lights are located within the fuel control switch post to indicate a fire. Light extinguishes if fire is no longer detected.

**ENGINE START Switches:** Pulling initiates engine start by opening the start valve, engine bleed air valve and arming the appropriate ignition system. At 50% N2, the switch returns to the run position, which closes the start valve and engine bleed air valves.

**STBY IGNITION Selector:** [NORM] AC bus provides power to the selected igniter. Standby bus will automatically provide power if main bus fails.

**AUTO IGNITION Selector:** Allows selected igniter to operate automatically if an engine is being started with N2 less than 50%, or if flaps are out of UP or if engine nacelle anti-ice is selected ON.

**AUTOSTART Selector:** Allows functioning of autostart, which will monitor engine performance and automatically start/re-start engines during engine startup and in flight.

**IGNITION CON Switch:** [ON] Igniter selected on AUTO IGNITION switch will operate continuously as long as the FUEL CONTROL switches are out of CUTOFF.
PRIMARY / SECONDARY EICAS ENGINE DISPLAYS

N1 Display Indicator: Displays actual N1. Changes to red if at N1 limit.

Reference Annunciation: Indicates reference N1 limit for current thrust reference mode. Will indicated REV in amber when reverser is in transit. REV changes to green when reverser deployed.

Thrust Mode Annunciation: Indicates current selected thrust mode from which reference thrust limits are being set by the FMC. Possible settings are:

- TO Maximum Takeoff Thrust
- TO 1 Derate 1 Takeoff (-5%)
- TO 2 Derate 2 Takeoff (-15%)
- D-TO Assumed Temperature Takeoff
- D-TO-1 Derate 1 Assumed Temperature Takeoff
- D-TO-2 Derate 2 Assumed Temperature Takeoff
- CLB Maximum Climb Thrust
- CLB 1 Derate Climb 1 Selected
- CLB 2 Derate Climb 2 Selected
- CON Maximum Continuous Thrust
- CRZ Maximum Cruise
- G/A Maximum Go-Around Thrust

Assumed Temperature: (Not shown here) Indicates assumed temperature as entered into FMC.

Relative Position Indicators: Rising tape display (white on EICAS) indicates relative position of current setting relative to entire available range.

EGT Display Indicator: Displays actual EGT. Displays white while in normal operating range, amber at max continuous limit and red at maximum start or takeoff EGT limit. During takeoff/go around, change to amber is inhibited for five minutes.

Maximum N1 Limit: (Red) Max allow N1.

Reference N1 Indicator: (green) Indicates N1 limit for the thrust mode. Indicates [magenta] target N1 as commanded by the FMC when VNAV is engaged.

Command N1 Position: (white) Indicates current throttle position and N1 that will result from this throttle position.
**NAI Annunciation:** Nacelle Anti Ice annunciation [green] indicates that nacelle anti ice is selected ON.

**WAI Annunciation:** (Not shown here)
Wing Anti Ice annunciation [green] indicates that wing anti ice is selected ON.

**Fuel Flow Indicator:** Displays fuel flow in 1,000lbs / hour

**Oil Pressure Indicator:** Displays oil pressure in digital and scale format.

**Oil Temperature Indicator:** Displays oil temperature in digital and scale format.

**Oil Quantity Indicator:** Displays oil quantity in digital format.

**Vibration Source:** Indicates the vibration source displayed. Displays source with the highest level of vibration.

[N1] – N1 rotor vibration.
[N2] – N2 rotor vibration.
ENGINE THRUST REVERSER ACTIVATION DIAGRAM

REVERSER STOWED

REVERSER UNLOCKED (IN TRANSIT)
REV displayed in amber on EICAS

REVERSER DEPLOYED
REV displayed in green on EICAS
FIRE DETECTION / SUPPRESSION SYSTEMS

Overview: The 747-400 uses a comprehensive system of fire detection and suppression for all four engines, the APU and the cargo spaces. Fire detection (but not suppressions) is provided for the landing gear bays.

The fire detection system is automatically tested when electrical power is first supplied to the aircraft, and fire detection remains continual until power is removed.

The fire detection system used in the engines, APU and cargo spaces consists of a double loop system for redundancy. The system logic will automatically reconfigure itself for single loop operation in the event a system fault is detected in one of the two systems.

Fire/Overheat Indications: Fire warnings are related to the crew through activation of the master warning light, individual illuminated red fire shutoff handles for each of the engines and the APU, as well as the forward and aft cargo compartments. Engine fires will also cause a red warning light to illuminate in the FUEL CONTROL switch for the affected engine, and red warning indications on the primary EICAS will become active.

When activated, the fire warning bell will ring intermittently, so as not to severely disrupt crew communications in a fire emergency. The fire bell will ring for one second, then pause for ten seconds before ringing again. The fire warning bell can be silenced by extinguishing the fire or pushing the master warning light once.

Crew rest area smoke detectors, as well as lavatory smoke detectors, will provide cockpit warning signals.

Overheat indicators are cautionary in nature, and will cause the master caution light to illuminate in conjunction with the associated cautionary EICAS message. An attention alert beeper will sound rapidly, four times in one second to indicate an overheat system fault.

In order to prevent crew distraction during critical phases of flight, the fire warning bell and master warning light are inhibited while the aircraft is between V1 and 400 feet during takeoff, or twenty five seconds, whichever is longer. All other warning methods will still operate during this blackout period.

Cargo Compartment Fire Detection/Suppression: Fire detection in the forward and aft cargo areas of the aircraft is handled by two pairs of flow through type smoke detectors. The flow through smoke detectors use a pneumatic type venturi to induce flow through over a pair of optical sensors.

In order to trigger a FIRE CARGO warning on the primary EICAS (with associated master warning light and sirens) both sensors in a single smoke detection module must detect the presence of smoke.

Fire suppression is provided by four charged fire bottles located in the center of the aircraft. The bottles are armed by pressing the CARGO FIRE EXTINGUISHING ARMED switch on the fire suppression panel. This will arm all four fire suppression bottles to discharge.

The ducting system which connects the four fire suppression bottles is designed so as to allow all four bottles to be discharged into a single cargo compartment.

The fire suppression system is activated by pressing the fire suppression switch on the fire suppression control panel. Pressing this switch will cause bottles A and B to fully discharge into the cargo compartment where the smoke was detected.

After approximately 30 minutes bottles D and C will begin to discharge into the cargo space under a metered flow of suppressant. Combined, the four fire suppression bottles will provide a total of 195 minutes of fire suppression to a single cargo compartment. It is not possible to discharge to multiple cargo compartments.
If the discharge switch is pushed while the aircraft is on the ground, all four bottles discharge immediately, however bottles C and D still maintain a metered flow into the target compartment.

If the fire suppression process is started while airborne, bottles C and D will automatically discharge when the air ground sensor determines that the aircraft has landed.

**Lower Cargo Fire Switches:** The lower cargo fire switches are used for arming a respective compartment should a fire warning be generated.

The FWD switch, when pushed, displays an ARMED indication and accomplishes the following:

- Turns off Pack 3.
- Turns off all fans.
- Arms respective squibs in the cargo extinguisher bottles.
- Configures equipment cooling to override mode and turns off airflow and heat into the forward compartment.

The AFT switch, when pushed, displays an ARMED indication and accomplishes the following:

- Turns off Pack3
- Turns off all fans.
- Arms respective squibs in the cargo extinguisher bottles.
- Configures equipment cooling to override mode and turns off airflow and heat into the forward compartment.
- Turns off aft cargo heat.

**APU Fire Detection/Suppression:** A dual loop fire detection system is used to fire detection in the APU compartment itself. Although the APU uses a dual loop fire detection system, only one of the two loops must detect a fire in order to trigger a fire indication in the cockpit. This varies from the fire detection parameters used for engines because of the location of the APU in relation to critical aircraft control system.

Fire detection by either loop will trigger a fire warning in the cockpit via a master caution light and a FIRE APU indication on the primary EICAS.

**APU Fire/Shutoff Handle:** Illuminates if a fire is detected in the APU. Pulling handle initiates shutdown of APU, closes fuel valve, bleeds and arms the fire suppression system.

**APU BTL DISCH Light:** Indicates low pressure in the APU fire extinguisher bottle.

**Using Fire Handles:** To realistically model the steps required to activate engine/apu fire suppression, we have modeled the need for the pilot to pull the engine/apu fire suppression handle OUT in order to activate the suppression mechanisms.

To model pulling the fire handle OUT, we have used similar techniques for both the 2D and Virtual cockpit:

**Engine fire handles**
- 2D: Click at the base of the handle to pull.
- VC: Click on the panel “behind” the handle to pull.

**APU Fire Handles:**
- 2D: Click on the far right side of handle to pull
- VC: Click on the panel “behind” the handle to pull.

**Engine Fire Detection/Suppression:**
Engine fire detection is provided through the use of a double loop fire detection system which monitors for engine/nacelle fire and overheat conditions. In order for a fire or overheat warning to be tripped, both loops of the fire/overheat detection system must trip.
Fire suppression for the engines is available from two fire suppression bottles installed in each wing. The bottles on the left wing provide fire suppression for engines 1 and 2, while the bottles in the right wing provide fire suppression for engines 3 and 4.

Engine fire suppression is activated by pulling the associated engine fire handle and twisting to discharge either the A or B fire bottle. The fire warning will extinguish when the fire is no longer detected. If greater extinguishing capability is needed, the second fire bottle can be used by twisting the fire handle in the opposite direction.

**Engine Fire/Shutoff Handles:** Illuminates upon fire detection in associated engine. Pull handle to close engine fuel valves and bleeds, disengage engine driven functions and hydraulics and arm fire bottle. Twisting handle activates fire suppression system.

**BTL DISCH Lights:** Indicates low pressure in the associated fire extinguisher bottle.

**Lavatory Fire Detection/Suppression:** Each lavatory has installed a single, standard operation smoke detector which emits an audible signal in the event smoke is detected.

Fire suppression is provided by one dual nozzle, heat activated Halon fire extinguisher located under the sink. The extinguisher operates independently of the smoke detector, and is independent of aircraft power in order to operate. The extinguisher will automatically discharge one stream of Halon directly into the garbage bin, the second will be discharged in the area immediately underneath the sink.

**Wheel Well Fire Detection:** The Wheel Well fire detection system consists of a single loop detector in each main gear wheel well. If a fire condition in any main gear wheel well is sensed by a detection loop, a fire warning is activated. There is no extinguishing system installed for fire in the wheel wells.

**FIRE/Overheat Testing:** In addition to the continuous testing of engine and APU detection systems, testing of all dual loop fire/overheat detectors and cargo compartment smoke detectors occurs automatically when electrical power is initially applied to the aircraft. Pushing the Fire/Overheat Test switch manually initiates the tests. The EICAS warning message TEST IN PROG is displayed when the test is manually initiated. On the actual aircraft it is necessary to hold the test switch in while conducting the Fire/Overheat test. This procedure is not practical within MSFS since it is necessary to check the state of lights/warnings on three different panels, so we have instead modeled this switch as a 10 second test process that will run once the switch is pressed.

After pressing the switch, check for fire/warning lights on the overhead panel, main panel and throttle console.

At the conclusion of the Fire/Overheat test, either a FIRE TEST PASS or a FIRE TEST FAIL message will be displayed.

**Importance of Procedures:** It is vitally important that the appropriate Abnormal procedures be followed in the event of a fire/overheat warning in flight. Failure to follow correct procedure may lead to additional damage to the aircraft and or loss of control in flight.
OVERVIEW OF ENGINE FIRE SUPPRESSION SYSTEM

(Left and Right Wing Identical)
### FIRE CONTROL SYSTEM EICAS MESSAGES:

<table>
<thead>
<tr>
<th>Message</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FIRE CARGO AFT</strong></td>
<td>Smoke detected in the lower aft cargo compartment</td>
</tr>
<tr>
<td><strong>FIRE CARGO FWD</strong></td>
<td>Smoke detected in the lower forward cargo compartment</td>
</tr>
<tr>
<td><strong>FIRE ENG 1,2,3,4</strong></td>
<td>Engine fire condition detected, or airframe vibrations with abnormal engine indications.</td>
</tr>
<tr>
<td><strong>FIRE WHEEL WELL</strong></td>
<td>Fire indication in one of the main gear wheel wells.</td>
</tr>
<tr>
<td><strong>FIRE APU</strong></td>
<td>APU Fire condition detected</td>
</tr>
<tr>
<td><strong>&gt;FIRE TEST PASS</strong></td>
<td>Indicates manual fire test has passed.</td>
</tr>
<tr>
<td><strong>&gt;FIRE TEST FAIL</strong></td>
<td>Indicates manual fire test has failed. (Displays with related failure messages.)</td>
</tr>
<tr>
<td><strong>&gt;TEST IN PROG</strong></td>
<td>Indicates manual fire test in progress</td>
</tr>
<tr>
<td><strong>EQUIP COOLING</strong></td>
<td>Automatic equipment cooling function has failed, or equipment cooling air supply temperature is excessive, or air flow rate to the flight deck Electronics and Equipment bay is low, or smoke is detected in the equipment cooling exhaust air, or ground exhaust valve not in commanded position.</td>
</tr>
<tr>
<td><strong>&gt;SMOKE DR 5 REST</strong></td>
<td>Smoke is detected in door 5 crew rest area. Recirculation fans automatically shut down and air conditioning packs switch to HI FLOW.</td>
</tr>
<tr>
<td><strong>&gt;BOTTLE LOW APU</strong></td>
<td>APU fire extinguisher bottle pressure is low. (Associated annunciator on overhead panel as well.)</td>
</tr>
<tr>
<td><strong>&gt;BTL LOW L (R) ENG A B</strong></td>
<td>Engine fire extinguisher bottle A or B pressure is low. (Associated annunciator on overhead panel as well.)</td>
</tr>
<tr>
<td><strong>&gt;CARGO DET AIR</strong></td>
<td>Insufficient airflow is available for smoke detection.</td>
</tr>
<tr>
<td><strong>&gt;CGO BTL DISCH</strong></td>
<td>On the ground: A cargo fire bottle pressure is low. In flight: Fire bottle A and B are discharged.</td>
</tr>
<tr>
<td><strong>&gt;DET FIRE APU</strong></td>
<td>APU fire detection loops A and B have both failed.</td>
</tr>
<tr>
<td><strong>&gt;DET FIRE/OHT 1,2,3,4</strong></td>
<td>ENGINE fire/overheat detection loops A and B have both failed.</td>
</tr>
<tr>
<td><strong>&gt;SMOKE LAVATORY</strong></td>
<td>Smoke is detected in a lavatory.</td>
</tr>
</tbody>
</table>
FLIGHT CONTROLS

Overview: The flight control system on the 747-400 is powered by the four independent hydraulic systems. Each system provides hydraulic power to the flight controls in order to provide for maximum redundancy.

The primary aircraft controls, rudder, aileron and elevator, are supplemented by hydraulically powered speedbrakes, spoilers and a hydraulically adjustable horizontal stabilizer. The wing trailing edge flaps are also hydraulically powered. The leading edge slats are powered pneumatically.

The flight controls use a computer generated tactile feedback to simulate control pressure to the yoke. Due to the large size of the flight control surfaces, it would not be feasible for direct control feedback, as significant control pressures would be required by the crew at high airspeeds. The flight controls are designed such that the aircraft will respond in a similar fashion to control input regardless of speed, weight and center of gravity.

All flight control surfaces can be controlled by the autopilot just as they are controlled by the crew, with the exception of spoilers and speedbrakes which must be manually activated. Provision is made for additional protective systems, such as a flap load relief system to prevent damage to the flap jacks and fairings.

Elevators: There are four elevator surfaces on the 747-400, two on each side of the aircraft. The inboard elevator surfaces receive hydraulic power from two independent hydraulic systems each and receive control input directly from the control column. The outboard elevator surfaces are mechanically linked to the inboard surfaces, and receive hydraulic power from one independent hydraulic source each. Control deflection is used to actively pitch the nose of the aircraft up or down. Trim control is provided by the horizontal stabilizer.

Elevator Position Indication: The secondary EICAS STAT page contains a display featuring indexing for both elevators.

Horizontal Stabilizer: The horizontal stabilizer is moved by hydraulic power supplied by systems 2 and 3. The hydraulic motors drive a jackscrew actuator which causes the stabilizer to move up or down. Control of this system is via the horizontal stabilizer trim switches in the cockpit.

Stabilizer trim position is shown in the cockpit on the stabilizer trim position indicator. The green band will indicate the normal trim range setting for takeoff.

Autopilot control of the stabilizer trim mechanism is via electric control of the hydraulic actuators, allowing the AFDS system full access to the stabilizer trim range.

Important Note on Trimming: An automatic override system is in place which will disconnect any trim input (either manual or via the Autopilot if the crew places pressure on the control column in the opposite direct of the trim input. If you are experiencing problems with trim inputs, ensure that your controller is properly calibrated.

Ailerons: Each of four ailerons receives hydraulic power from two independent
hydraulic sources each. Loss of any one system will not impair the ability of the crew to deflect the ailerons through their full range of travel.

**Aileron One:** Hydraulic systems 1/2  
**Aileron Two:** Hydraulic systems 1/3  
**Aileron Three:** Hydraulic systems 2/4  
**Aileron Four:** Hydraulic systems 3/4

Two sets of ailerons are provided on each wing. The outboard ailerons are automatically locked out when the flaps are in the UP position and airspeed increases beyond 235 KIAS or .52 Mach. Reducing speed below these threshold limits, or selecting flaps out of UP will restore outboard aileron function.

The inboard aileron set does not lock out in any speed or configuration.

If necessary, aileron trim can be applied in order to maintain wings level flight. The proper procedure is to provide control input sufficient to maintain the desired bank angle, then add or subtract trim until control pressure is no longer required, and the flight controls are level from the perspective of the pilot. This will prevent an inadvertent roll tendency caused by split flap conditions or engine out situations.

When the airplane is parked and hydraulics are depressurized, it is not uncommon to the inboard ailerons deflected downward from their normal, neutral position. The outboard ailerons should not normally exhibit this behavior.

**Spoilers:** Each wing has 6 spoilers. The twelve total spoilers are numbered from left to right, 1 through 6 on the left wing and 7 through 12 on the right wing.

The four inboard spoilers on each wing (Spoiler plates 3,4,5,6 on the left side, and 7,8,9,10 on the right side) function as speedbrakes in flight.

On the ground, all six spoiler panels on each wing function as ground spoilers. The speedbrake and ground spoiler functions are controlled with the speedbrake lever. Spoiler mixers combine behaviors of the roll control and spoiler functions to provide both speedbrake and spoiler control when necessary.

**Spoiler Position Indication:** The position of one spoiler panel on each wing is displayed on the EICAS secondary engine display. On the left wing, the position of the fourth spoiler panel in from the wingtip is displayed. This panel functions as a flight spoiler, speedbrake and ground spoiler. On the right wing, the position of the outboard-most spoiler panel is displayed. This panel functions as a flight spoiler and ground spoiler only. *Therefore, speedbrake extension is not indicated on the right wing spoiler position indicator in flight.*

**Speedbrake Handle Function:** The speedbrake lever input is limited to the mid-travel FLIGHT DETENT position by an automatic stop in flight.

The speedbrakes should not be used with trailing flaps extended past flaps 20 in order to prevent excessive wear on the flap jack mechanisms.

Upon touchdown, all twelve spoilers function as lift canceling devices and will fully deflect on manual command of the speedbrake handle, or automatically if the speedbrake handle is placed in the ARMED position prior to touchdown.

The ground spoilers will activate automatically upon landing when all three conditions are met:

- The Speedbrake lever is in the ARM position.
- Thrust levers 1 and 3 are near the closed position.
- The main landing gear touch down.

The speedbrake lever will be automatically driven to the UP position, extending the spoilers if the following conditions are met:

- The speedbrake lever is in the DOWN position.
- Thrust levers 1 and 3 near the closed position.
- The main landing gear are on the ground.
• Reverse thrust is selected on engines 2 or 4. 

This provides automatic ground spoiler function for Rejected Take Off conditions and provides a backup to the automatic ground spoiler function for landing if the speedbrake lever is not armed during the approach.

For Go-Around protection or rejected landings, if thrust lever 1 or 3 is advanced from the closed position, the speedbrake lever is automatically driven to the DOWN position. This function occurs regardless of whether the ground spoilers were automatically or manually extended.

The speedbrake lever can always be manually extended or returned to the down position.

In the event of a hydraulic system failure, the spoilers and speed brakes will lock in the down position in order to prevent spoiler float and the loss of associated lift.

**Rudder:** Yaw control is provided by two rudder devices; the upper rudder and lower rudder. Each rudder control surface is powered by two independent hydraulic systems, and accepts control input via a rudder ratio changer which modulates rudder deflection based on airspeed.

Rudder trim is applied by deflecting the rudder manually to the desired position, then adding rudder input until the control pedals reach a new neutral position. Electrical control of the hydraulic actuators on the rudder will deflect the rudder the commanded amount.

The rudder function is supplemented by two fully independent yaw damper systems designed to improve aircraft directional stability, and to improve aircraft roll rate and turn performance during turns.

The yaw dampers receive hydraulic control from hydraulic systems 2 and 3. Yaw damper deflections are applied directly to the rudder control surfaces in proportion to any turn or yaw tendencies detected by the IRS yaw sensors located in the nose and tail of the aircraft.

Yaw damper rudder input cannot be sensed by the crew via the rudder pedals, and will not interfere with crew rudder input.
FLIGHT CONTROL CONFIGURATION

Leading Edge Slats:
Inboard Spoilers (Speed Brakes):
  Inboard Aileron:
  Outboard Spoilers:
  Outboard Aileron:

Inboard Trailing Edge Flaps:
Outboard Trailing Edge Flaps:
Horizontal Stabilizer:

Inboard Elevator:
Outboard Elevator:
Leading and Trailing Edge Flaps: The leading and trailing edge flaps are operated by either a primary drive system or a secondary drive system. The primary drive system is normal for all phases of flight unless a system fault has been detected which prevents the primary system from functioning. The secondary system can then be used to change flap configurations.

Flap movement is managed by three independent flap control units which provide flap position information to the EICAS display, provide for flap load relief if required, and prevent asymmetric flap deployment.

Trailing edge flaps are driven by hydraulic power, while the leading edge flaps are driven by pneumatic power. Flap position is commanded by the flap position handle.

If the flaps fail to move to, or reach the commanded position, the flap control units will automatically switch to the secondary actuation and display mode for the affected flap group. When secondary mode is actuated, the flap drive mechanisms are driven using electric power. Flap groups will switch to secondary operation in symmetry between the wings, which prevents asymmetric flap deployment.

Secondary flap deployment is significantly slower than primary flap deployment.

Due to limitations within the simulator, it is not possible to adequately model the significant time difference between primary and secondary flap actuation.

When any trailing edge flap groups switch to secondary deployment due to a hydraulic pressure failure, they will automatically return to primary deployment if hydraulic power is restored. If the trailing edge flaps are switched to secondary mode while hydraulic power is available, however, they will not return to primary mode until they have been fully retracted and the hydraulic mode system automatically resets.

Leading edge flaps operating in secondary mode will always remain in secondary mode until reaching the commanded flap position, regardless of whether or not pneumatic power becomes available.

An alternate flap deployment method is available to the crew which allows all flaps to be electrically driven. When the alternate flaps actuator is set to ALTN, the flap position command handle becomes inoperative, and flap setting needs to be determined by commanding the flaps ALTN drive up or down as needed.

Trailing Edge Flaps: The trailing edge flaps are comprised of an inboard and an outboard set on each wing. All four sets of trailing edge flaps are driven by separate hydraulic systems. The outboard flaps are driven by systems 1 or 4, while the inboard trailing edge flaps are driven by systems 2 or 3.

In the event of the loss of any hydraulic system, that trailing edge flap set will automatically revert to secondary flap deployment.

A flap load relief system, managed by the flap control units protects the trailing edge flap system from being operated at excessive airspeeds while in the flaps 25 or flaps 30 range. At airspeeds in excess of 178 knots, the flaps control units will reposition the flaps from the 30 position to the 25 position. At airspeeds in excess of 203 knots, the flaps control units will reposition the flaps from the flaps 25 position to the flaps 20 position.

If the flaps are being deployed using the secondary or alternate system, flap load relief is not available.

Leading Edge Slats: Each wing has three separate sets of leading edge slats. These groups are geographically divided on the wing by the wing pylons, and are described by their location on the wing. The flap groups are OUTBOARD, MIDSPAN and INBOARD respectively.

Each wing has a total of fourteen leading edge slats. The eleven outboard and mid-span slats are variable camber flaps, while
the three inboard slats are of the Krueger type.

The leading edge slats deployment and retraction schedule is tied to the flap command positions of flaps 1 and flaps 5. With the flap command handle is moved from UP to 1, the inboard and mid-span slats deploy. When the command handle is moved from flaps 1 to flaps 5, the outboard slats deploy.

For all leading edge slats, there is only an extended and retracted position. There is no mid range position.

If the ALTN flap deployment method is required due to a system failure or液压 failure, all leading edge flap groups deploy simultaneously. Crews are cautioned that the airplane may tend to balloon at the flaps 1 setting due to the abnormal deployment of the outboard leading edge slats group at this setting.

When reverse thrust is selected after touchdown, the inboard and mid-span slats retract in order to dump lift from the primary lifting surfaces of the wing, as well as to improve the structural life of the leading edge devices.

**Flap Position Indicators:** Flap indications are provided on the primary EICAS display, and are driven directly by the flap control units and the associated flap position sensors located within the flap systems.

During normal operation, the flap position indicator is comprised of a single vertical tape with a horizontal band to depict the command flap setting and a white vertical tape to depict current flap position. On landing, the leading edge slat retraction sequence will cause the flap position indicator to show flaps are in transit. This is normal.

If any fault is detected which requires the activation of the secondary or alternate flap systems, a larger, expanded flap position indicator is displayed. This indicator will provide graphically, information on the current position of each flap subgroup, as well as any failure information related to the positioning of flap or slat groups. An amber X drawn in the position of any flap group indicates failure of the flaps position sensor.
### FLIGHT CONTROLS EICAS MESSAGES:

<table>
<thead>
<tr>
<th>Message</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAB TRIM UNSCHD</td>
<td>Uncommanded stabilizer motion is detected and automatic cutout does not occur, or alternate stabilizer trim switches are used with the autopilot engaged.</td>
</tr>
<tr>
<td>AILERON LOCKOU</td>
<td>Aileron lockout actuator position disagrees with commanded position.</td>
</tr>
<tr>
<td>FLAPS CONTROL</td>
<td>Flap control units are inoperative, or alternate flap mode is armed.</td>
</tr>
<tr>
<td>FLAPS DRIVE</td>
<td>One or more flap groups have failed to drive in the secondary control mode, or an asymmetry condition is detected.</td>
</tr>
<tr>
<td>FLAPS PRIMARY</td>
<td>One or more flap groups are operating in the secondary control mode.</td>
</tr>
<tr>
<td>&gt;FLAP RELIEF</td>
<td>Flap load relief system is operating.</td>
</tr>
<tr>
<td>&gt;FLT CONT VLVS</td>
<td>Flight control valve is closed.</td>
</tr>
<tr>
<td>RUD RATIO SNGL</td>
<td>Rudder ration changer has failed.</td>
</tr>
<tr>
<td>RUD RATIO DUAL</td>
<td></td>
</tr>
<tr>
<td>SPEEDBRAKE AUTO</td>
<td>Fault detected in the automatic ground spoiler system.</td>
</tr>
<tr>
<td>&gt;SPEEDBRAKES EXT</td>
<td>Speedbrakes are extended at an inappropriate flight condition. (Throttles forward of idle.)</td>
</tr>
<tr>
<td>STAB GREENBAND</td>
<td>Nose gear pressure sensor disagrees with computed stabilizer trim green band. (The airplane is not correctly trimmed for takeoff.)</td>
</tr>
<tr>
<td>&gt;STAB TRIM2 3</td>
<td>Stabilizer trim automatic cutout has occurred or stabilizer trim switch in CUTOUT or trim commanded and respective actuator failed to function.</td>
</tr>
<tr>
<td>&gt;YAW DAMPER UPR</td>
<td>Associated yaw damper failure or respective yaw damper switch is OFF</td>
</tr>
<tr>
<td>LWR</td>
<td></td>
</tr>
</tbody>
</table>
Overview: The fuel system on the 747-400 is designed to provide the maximum capacity possible in order to increase aircraft range, hold time, and service capabilities.

The fuel system is capable of holding 57,164 gallons of Jet-A fuel. At a fuel density of 6.7lbs, this provides a maximum fuel weight of 382,600 pounds.

Fuel is carried in four main tanks, a center wing tank, two wing reserve tanks, and an additional tank located within the horizontal stabilizer. Any engine can draw fuel from any fuel tank on the aircraft, however fuel can only be suction fed from the main wing tanks in the event of fuel pump failures.

A fuel jettison system is available in the event fuel weight needs to be discharged. A “Fuel to Remain” level system is installed.

When the fuel pumps are switched OFF prior to engine start, each main tank switch should display a low pressure light. These lights will be extinguished on the override, center tank and stabilizer tank switches.

The automated fuel loading distribution system logic distributes fuel to minimize wing bending.

Fuel Pump Systems: Each main tank and the stabilizer tank have two AC-powered fuel boost pumps to provide fuel under pressure to the engines. In addition, main tanks 2 and 3 (inboard tanks) and the center wing tank each have two AC powered override fuel jettison pumps.

Each fuel pump has an actuator switch located on the overhead fuel control panel in the cockpit. When AC power is supplied to the aircraft turning the APU start selector to START will automatically activate the main tank 2 aft fuel boost pump. In the event AC power is not available, a DC-powered fuel boost pump will provide fuel pressure. The APU always draws its fuel supply from main tank 2.

When either of the center wing tank fuel pumps detects low fuel pressure, a center wing tank fuel scavenge pump is automatically activated. This pump will scavenge the remaining fuel in the center tank and pump it into main tank 2.

Fueling: Fueling stations for the aircraft are located on either wing, between the two wing engines. Each station contains two identical fueling couples and manual shutoff.
valves. Electrical power for fueling operations must be provided by the APU, aircraft battery or an external power source.

The left wing fueling station contains a fueling control panel just outboard and adjacent to the left wing fueling station. This panel contains all controls necessary for distributing fuel properly and according to the dispatch request.

Manual magnetic-type dripless fuel quantity measuring sticks are located in all fuel tanks.

A vented surge tank is located near the tip of each wing. The vent is a NACA type venturi which will provide positive pressure on the fuel tanks during cruise.

If the stabilizer tank fuel pump is switched ON during fueling operations, this may lead to transfer of fuel destined for the stabilizer tank. This is the only effect that should be anticipated if fuel pumps are active during fueling, and can be prevented by selecting the stabilizer tank fuel pump OFF prior to fueling.

**Fuel Management:** Fuel management logic on the 747-400 is highly automated in order to reduce pilot workload. The automated system logic is also designed to reduce airframe flexing and wing structure stress due to fuel loading.

Heavier fuel loads requiring use of the center wing fuel tank are handled differently than lighter loads not requiring center tank fuel.

**Main Tank Fuel Pumps:** Each main tank contains two AC powered fuel pumps that are each capable of providing adequate fuel for one engine operating at takeoff power, or two engines at cruise power.

On the secondary EICAS fuel page, each pump is depicted with an icon. The color of the icon is descriptive of the pump’s current state.

- **Green:** Pump is selected active and has no faults detected, even if it is not supplying fuel to an engine.
- **Blue:** Pump is selected active, but based upon FMCS logic it has been placed in standby mode.
- **Amber:** A fault is detected in the pump or the pump’s activity disagrees with the FMCS logic.
- **White:** The pump is selected off.

**Main Tank 2 and 3 Override/Jettison Pumps:** Main tanks 2 and 3 also contain two AC powered override/jettison pumps which can operate to a standpipe fuel level of approximately 7,000lbs remaining in the associated tank.

Each override/jettison pump can provide adequate fuel to two engines during takeoff or cruise conditions.

Override/jettison pumps 2 and 3 are inhibited from operating when pressure is detected from both Center Wing Tank override/jettison pumps. Output pressure of the override/jettison pumps is greater than the output of the main fuel pumps.

**Center Wing Tank Fuel Pumps:** The Center Wing Tank contains two AC powered override/jettison pumps. Each override jettison pump can provide adequate fuel for two engines during takeoff or cruise conditions. The output pressure of the override/jettison pumps is greater than the output pressure of the main fuel pumps. With main fuel pumps and override/jettison pumps operating simultaneously, the override/jettison pumps will provide fuel to the engines. However, one CWT override/jettison pump does not override main tank 2 and 3 override/jettison pumps or main tank 1 and 4 main fuel pumps.

**Crossfeed Manifold and Valves:** A common fuel manifold connects all main tanks and the CWT. There are four crossfeed valves in the fuel manifold.

Crossfeed valves 1 and 4 are manual and will remain set in whatever position is commanded by their respective switches.

Crossfeed valves 2 and 3 are automatic, and while responding to position commands from the switches, they will respond...
programmatically to the Fuel Management System Cards in order to direct fuel flow correctly for specific flight modes.

For example, before takeoff if the crossfeed 2 and 3 valves have been commanded open but the fuel control panel switches, the valves will close when takeoff flaps are extended. This provides tank to engine operation for engines 2 and 3.

Following flap retraction, the valves will return to the switch commanded position.

If the Crossfeed valve 2 and 3 switches are set to the closed position, there is no automatic control for these valves and they will remain closed.

**Reserve Tank Transfer Valves:** Each reserve tank contains two transfer valves. These valves automatically transfer fuel by gravity feed from the reserve tank into their respective inboard main fuel tank when the main tank 2 or 3 fuel quantity decreases to 40,000lbs. This feed activity is depicted on the secondary EICAS fuel display.

**Main Tank 1 and 4 Transfer Valves:** Main tank 1 and 4 each contain one transfer valve which allows fuel to transfer by gravity from the outboard main tank to it’s respective inboard main tank. Each valve allows gravity transfer to approximately 7,000lbs remaining in the outboard main tank.

**Manual Operation:** Manual operation of these valves is available while the aircraft is on the ground, primarily for maintenance personnel. This function is not modeled in the PMDG 747-400.

**Automatic Operation:** Automatic operation of these valves occurs during fuel jettison. When either main tank 2 or main tank 3 fuel quantity decreases to 20,000lbs during jettison, both main tank 1 and 4 transfer valves are automatically opened by the Fuel Management System Cards.

**Operating With Center Wing Tank Fuel:** If fuel is contained in the center fuel tank, all crossfeed valves should be opened prior to engine start. In addition all override/jettison and main tank boost pumps should be activated for tanks containing fuel.

Control of the fuel system is handled in an automated fashion by the Fuel System Management Cards. The FSMCs will monitor flap setting and adjust the fuel system logic to provide a redundant fuel supply during takeoff in case of electrical or fuel pump system failures.

The FSMCs will close crossfeed valves 2 and 3 when takeoff flap settings are detected on the ground. The center wing tank will provide fuel to engines 1 and 4, while engines 2 and 3 will receive fuel from their respective main tank. In this configuration, the override/jettison pumps for tanks 2 and 3 will be inhibited from operating.

When flaps are retracted, the FSMCs automatically re-open crossfeed valves 2 and 3, and the center tank will now provide fuel to all four engines.

The FSMCs will monitor the fuel level of the center wing tank. When the center wing tank fuel quantity has decreased to 80,000lbs fuel will be transferred from the stabilizer tank to the center wing tank.

When this fuel transfer is completed, the crew will receive an EICAS advisory message indicating FUEL PUMP STAB. This indicates that the AC-powered fuel pumps in the stabilizer tank have detected
low fuel pressure. Stabilizer pump switches should be selected off when the tank indicates empty.

When the center wing tank fuel quantity is decreased to approximately 2,000lbs, the EICAS advisory message FUEL OVRD CTR will be displayed, indicating one of the override/jettison pumps has detected low output pressure. The center wing tank override/jettison pumps should be selected OFF at this time. The center wing tank scavenge pump will begin operating automatically to transfer remaining fuel to main tank 2. This pump will operate until it detects low output pressure, indicating that the center wing tank is now empty, or until 120 minutes have passed.

Note: When Center Wing Tank quantity has dropped below 5,000lbs there are occasions when the center wing tank pumps cannot provide full override of the outboard main tank pumps. As a result a shared flow situation results with approximately 2,000lbs of fuel being consumed from each outboard main tank prior to display of the EICAS advisory message FUEL OVRD CTR L, R. This condition is normal, and is not indicated by green fuel flow lines on the secondary EICAS fuel display.

The FSMCs will activate override/jettison pumps 2 and 3 when the FUEL OVRD CTR message is displayed. The override/jettison pumps 2 will supply fuel to engines 1 and 2, while override/jettison pumps 3 will fuel engines 3 and 4.

If the crew turns off the center wing tank override/jettison pumps, or experiences a fuel pump failure prior to having used all the fuel contained in the center wing tank, the scavenge pump will begin transferring fuel automatically from the center tank at the same time the FSMCs begin transferring fuel from the reserve wing tanks. This will occur when main tank 2 or 3 fuel quantity decreases to 40,000lbs. Fuel transfers from each reserve tank into its respective main tank 2 or main tank 3 respectively.

When main tank fuel quantity for all four main tanks is equal, the EICAS advisory message FUEL TANK/ENG is displayed. At this time, the crew should verify fuel tank quantities, close crossfeed valve switches 1 and 4, and push off the override/jettison pump switches. Main tank fuel pumps will provide fuel for their respective engines until shutdown.

Operating With Center Wing Tank Empty: When the center wing fuel tank is empty, fuel operations are slightly less complex. If main tank 2 and 3 fuel quantity exceeds main tank 1 and 4 quantity, open all crossfeed valves and turn on all main tank fuel boost and override/jettison pumps. In this configuration, the FSMCs will draw fuel from main tanks 2 and 3 until main tank fuel quantity is equal, at which time the fuel system should be reconfigured as described above for tank-to-engine fuel feed.

If main tank fuel quantities are equal before engine start, open only crossfeed valves 2 and 3 and turn on only the main tank boost pumps. In this configuration main tank fuel pumps will provide fuel for their respective engines until shutdown.

Fuel Quantity Indicating System (FQIS): The FQIS measures the total fuel weight of the aircraft, as well as the fuel weight of each individual tank. This information is displayed both in the cockpit and on the fueling station panels.

The indicating system is comprised of tank units and compensators which measure fuel volume, as well as densitometers which measure fuel density. The fuel weight is then continuously updated to the secondary EICAS and the fueling station panel.

Fuel temperature is only measured from main tank number 1. This information is displayed directly on the primary EICAS.

Fuel Jettison System: The fuel jettison system is designed to allow the crew to automatically jettison fuel to a pre-determined level. This level can be selected by rotating the “Fuel To Remain” knob on the fuel jettison panel.

Selecting either A or B jettison system will display the fuel to remain information on the primary EICAS.
The fuel management system will calculate fuel jettison time and display it on the secondary EICAS fuel page.

When the fuel jettison system is selected, pushing either of the FUEL JETTISON NOZZLE switches ON activates all of the override/jettison pumps in tanks currently containing fuel. The four fuel jettison valves will also be opened, and the number 1 and number 4 main transfer valves armed. The jettison nozzles will open at this time.

Pushing the second FUEL JETTISON NOZZLE switch to ON will open the fuel jettison valves.

Fuel jettison will end automatically when the total fuel quantity is reduced to the fuel to remain quantity selected by the crew. The fuel to remain quantity indication changes color to white and flashes for 5 seconds, and all override/jettison pumps will be deactivated. The fuel system should be manually reconfigured for FSMCs operation at the conclusion of any fuel jettison in order to prevent fuel imbalance or inadvertent fuel starvation of an engine.

**Fuel Transfer:** Fuel can be gravity transferred from main tank 1 to main tank 2 and main tank 4 to main tank 3 respectively. This is accomplished by pressing the FUEL XFER MAIN 1 & 4 switch to ON.

**Secondary EICAS Fuel System Synoptic:**
The fuel synoptic display can be called up on the secondary EICAS display by pressing the FUEL switch on the EICAS control panel. The display shows the current operating status of each individual fuel pump, as well as the fuel quantities of each tank, and the aircraft as a whole. Indicators will also be displayed to show fuel transfer either by gravity or scavenge pumps, as well as normal, under pressure fuel flow (green banding).
FUEL SYSTEM AND EICAS FUEL SYSTEM DEPICTION

- Reserve Tank 3
- Main Tank 4
- Main Tank 3
- Center Wing Tank
- Stabilizer Tank
- Main Tank 2
- Main Tank 1
- Reserve Tank 2
Fuel Crossfeed Valves: Allows transfer between systems when open. Separates tank pumping systems when closed.

CTR Wing Tank Boost Pump Switches: Left and Right Pumps.

MAIN Tank 2 Boost Pump Switches: FWD and AFT pumps.

MAIN Tank 2 OVRD Pump Switches: FWD and AFT pumps.

MAIN Tank 1 Boost Pump Switches: FWD and AFT pumps.

Stab Tank Boost Pump Switches: Left and Right Pumps.

MAIN Tank 3 Boost Pump Switches: FWD and AFT pumps.

MAIN Tank 3 OVRD Pump Switches: FWD and AFT switches.

MAIN Tank 4 Boost Pump Switches: FWD and AFT Pumps.
FUEL CONTROL PANEL / FUEL PUMP SCHEMATIC
FUEL SYSTEM EICAS MESSAGES:

>XFEE D CONFIG One or more fuel crossfeed valves incorrectly configured.

>ENG 1,2,3,4 FUEL VLV Engine fuel valve or fuel spar valve position disagrees with commanded position.

FUEL AUTO MGMT Both fuel management cards have failed and stabilizer fuel has been transferred.

FUEL X FEED 1,2,3,4 Crossfeed valve is not in commanded position.

FUEL IMBALANCE Fuel difference of 6,000lbs between inboard main tanks (2 and 3) and outboard main tanks (1 and 4) after reaching FUEL TANK / ENG condition.

FUEL IMBAL 1-4 Fuel difference of 3,000 pounds between main tanks 1 and 4.

FUEL IMBAL 2-3 Fuel difference of 6,000 pounds between inboard tanks 2 and 3.

>FUEL JETT A B Selected jettison system has failed.

FUEL JETT SYS Fuel total less than fuel to remain and one nozzle valve open or both jettison cards failed.

FUEL PRESSURE ENG Engine is on suction feed

FUEL PUMP 1,2,3,4 FWD Respective fuel pump is inoperative.

FUEL PUMP 1,2,3,4 AFT

FUEL OV RD 2.3 FWD

FUEL OV RD 2.3 AFT

FUEL OV RD CTR L, R

FUEL PUMP STAB L, R

FUEL QTY LOW Fuel quantity is 2,000lbs or less in one or more main tanks.

FUEL RES XFR 2,3 Reserve transfer values not in commanded position.

FUEL STAB XFR Horizontal stabilizer fuel fails to transfer.

>FUEL TANK/ENG Main tank 2 quantity is equal to or less than main tank 1 quantity, or main tank 3 quantity is equal to or less than main tank 4 quantity and crossfeed valve 1 or 4 is open.

>FUEL TEMP LOW Fuel temperature is -37C or less

>FUEL TEMP SYS The fuel temperature system is inoperative.

>JETT NOZZLE L (R) Nozzle valve position disagrees with commanded position.

>JETT NOZZLE ON Fuel jettison nozzle valve is open.

>JETT NOZZ ON L, R Fuel jettison nozzle valve is open.
HYDRAULIC SYSTEM

Overview: The 747-400 has four independent hydraulic systems installed, one per engine. The systems are numbered 1 through 4 in accordance with the engine numbering.

Each hydraulic system is comprised of a hydraulic reservoir, and engine driven demand pump and an air driven demand pump. The engine driven demand pumps are located within the engine nacelle of each engine, and are driven by the accessory drive. The reservoir for each system is located in the engine pylon, above and behind the engine.

Engine number 4 has an electrically driven AUX hydraulic system, which can only be activated while the aircraft is on the ground, and is used primarily to power the brakes during towing operations.

Hydraulic power is used to operate the following systems:

• Autopilot Servos
• Brakes
• Flight Controls
• Landing Gear
• Nose and Body Gear Steering
• Spoilers
• Stabilizer Trim
• Thrust Reversers
• Trailing Edge Flaps

Hydraulic Reservoirs: Each hydraulic system has an independent reservoir which is located in the engine pylon. The reservoir is pressurized using regulated air from the pneumatic system.

Hydraulic reservoir quantity is measured and displayed on the secondary EICAS display. In the event the hydraulic reservoir needs to be replenished, all four systems can be serviced from a single location in the left body gear bay.

Hydraulic fluid is cooled by hydraulic fluid heat exchangers installed in the main fuel tanks. This process provides fuel heating and hydraulic system cooling.

A SYS FAULT light on any of the four hydraulic systems can indicate either low hydraulic pressure, low reservoir quantity or high hydraulic fluid temperature.

Engine Driven Pumps: The engine driven pumps are located in the accessory section of each engine nacelle and connected to the accessory drive. The pumps provide pressure to the hydraulic system when the engine is rotating and the ENGINE PUMP switch is in the ON position. If the engine pump switch is selected OFF, or if the engine fire shutoff handle is pulled, engine driven pump will not operate.

Auxiliary Demand Pumps: There are four auxiliary hydraulic demand pumps on the 747-400. Auxiliary Demand Pump (ADP) 1 and 4 are powered by pneumatic bleed air, while ADP 2 and 3 are driven by AC electric power.

The auxiliary demand pumps can be operated in AUTO or ON (continual). The pumps are normally placed in AUTO which will cause the demand pump for each system to operate whenever low system pressure output is detected from the engine demand pump. The system will also provide pressure if the FUEL CONTROL switch for the engine is placed in the shutoff position.

Hydraulic systems 1 and 4 will activate to provide supplemental pressure when the flaps are in transit, and whenever flaps are selected out of UP during flight. This behavior requires that the Auxiliary Pump selector switch be in the AUTO position.

If an Auxiliary demand pump is activated as a result of low output pressure from an Engine Driven Pump, it will continue to operate for 14 seconds after sensing that it is no longer needed because of correct output pressure from the Engine Driven Pump.

This delay is designed to prevent rapid pressure fluctuations.
The status of the ADPs is shown on the secondary EICAS hydraulic display. ADP pumps can appear in the following status:

Blue: Pump in standby mode programmatically.

Amber: A fault is detected or the pump has failed to activate when required.

White: Normal operating condition.

**Electric AUX System:** Hydraulic system 4 has an electrically driven auxiliary pump installed just aft of the reservoir in the number 4 engine pylon, adjacent to the demand pump. This electric AUX system will provide system pressure to the number 4 hydraulic system for brake operation during ground towing. The system will automatically cease providing pressure once the engine driven pump begins providing output that is within system parameters. If the selector switch is left in the AUX position, an EICAS advisory message will remind the crew to rotate the selector to AUTO.

**Hydraulic System 1:** The number 1 hydraulic system provides hydraulic power to:

- Center Autopilot Servos
- Engine 1 Thrust Reverser
- Flight Controls
- Alternate Brakes
- Trailing Edge Flaps
- Nose and body gear actuation and steering.

**Hydraulic System 2:** The number 2 hydraulic system provides hydraulic power to:

- Right Autopilot Servos
- Engine 2 Thrust Reverser
- Flight Controls
- Alternate Brakes
- Stabilizer Trim

**Hydraulic System 3:** The number 3 hydraulic system provides hydraulic power to:

- Left Autopilot Servos
- Engine 3 Thrust Reverser
- Flight Controls
- Stabilizer Trim

**Hydraulic System 4:** The number 4 hydraulic system provides hydraulic power to:

- Engine 4 Thrust Reverser
- Flight Controls
- Normal Brakes
- Trailing Edge Flaps
- Wing Gear Actuation

**Hydraulic System 4 AUX:** The number 4 AUX hydraulic system provides hydraulic power to:

- Normal Brakes

**EICAS STAT Screen Hydraulic Indicators:**
When the STAT switch is pressed on the EICAS control panel, the flight control status display will be brought up on the secondary EICAS display. The top portion of this screen display is dedicated to providing a basic overview of the hydraulic system status, as displayed below.

**Hydraulic Quantity Warning:** The STAT display provides a LO quantity indicator when hydraulic quantity has dropped to dangerously low levels in the hydraulic reservoir. Warnings displayed in amber.
SECONDARY EICAS DISPLAY - HYDRAULIC SYSTEM SYNOPTIC

**Secondary EICAS HYD Display**: The EICAS HYD display provides valuable information regarding the current state of the hydraulic systems. Graphic and numeric displays of hydraulic quantity, numeric temperature and pressure display, as well as hydraulic pump status indicators and flow schematics make trouble shooting and identifying hydraulic system problems significantly easier.

**HYD Display Examples**: The HYD display below shows four HYD system scenarios.

SYSTEM 1: Engine Driven Pump ON. Aux Pressure Demand Pump ON. (System producing normal HYD power.)

SYSTEM 2: Engine Driven Pump OFF. Aux Demand Pump ON. (System producing normal HYD power.)

SYSTEM 3: Engine Driven Pump OFF. Aux Demand Pump ON. Shutoff Valve CLOSED. (EDP not producing HYD power due to FIRE SHUTOFF handle being activated.)

SYSTEM 4: Engine Demand Pump ON. Air Pressure Demand Pump AUTO. (System configured for normal operation and producing normal HYD power.)

**Engine Driven Pump**: Box will display OFF if pump fails or is selected OFF.

**AUX Demand Pump**: Circle will display OFF if pump fails or is selected OFF.

**Hydraulic Power Flow Bar**: Green flow bar indicates current hydraulic power flow.

**Hydraulic System Numeric Data**: General health of the hydraulic system is displayed here. Out of limits data is displayed in amber or red.

**Shut Off Valve**: If FIRE SHUTOFF handle is pulled, shutoff valve will display a CLOSED position.

**Hydraulic Reservoir Quantity Indicator**: Displays a graphical interpretation of the level of hydraulic fluid contained within the system. Displayed as a percentage of the FULL capacity. As quantity drops, level indicator drops. (Compare SYS 3 and SYS 4.)
SYS FAULT Light: Indicates low output pressure, low reservoir quantity or high fluid temperature.

DEM PUMP PRESS Light: Indicates the DEMAND PUMP selector is OFF, the pump is operating, and output pressure is low. May also indicate that pump has failed to operate.

Demand Pump Selector: Allows crew selection of the appropriate demand pump mode.

OFF: Shuts off appropriate pump.

AUTO: Causes demand pump to operate if the engine driven pump pressure falls below normal levels, or when the FUEL CONTROL selector switch is set to CUTOFF, or when the hydraulic shutoff valve has been commanded closed by the FIRE SHUTOFF valve.

ON: Pump operates continually.

ENG PUMP Switch: When selected ON, allows the engine driven hydraulic pump to provide pressure to the hydraulic system.

ENG PUMP PRESS light: Indicates low engine driven pump output pressure when illuminated.
HYDRAULIC SYSTEM EICAS MESSAGES:
HYD OVHT SYS 1,2,3,4  Excessive hydraulic system temperature.
HYD PRESS DEM 1,2,3,4  Demand pump output pressure is low.
HYD PRESS ENGE 1,2,3,4  Engine pump output pressure is low.
HYD CONTROL 1,4  Auto control of hydraulic system demand pumps is inoperative.
HYD PRESS SYS 1,2,3,4  Loss of system pressure.
>HYD QTY HALF 1,2,3,4  Hydraulic quantity is ½ normal service level.
>HYD QTY LOW 1,2,3,4  Hydraulic quantity is 0.34 normal service level.
ICE AND RAIN PROTECTION

Overview: The 747-400 has a comprehensive package of anti-icing for sensors, probes, engines and flight control surfaces. The operation of these anti-ice systems is largely automatic and requires no interaction from the crew.

Anti-ice systems for engines and wings require only modest attention from the crew.

Probe Heat: Operation of the probe heat system is fully automatic. Four pitot-static probes and two angle of attack probes are electrically heated for anti-ice protection whenever any engine is operating. Two total air temperature probes are electrically heated for anti-ice protection only in flight.

The primary EICAS will display an advisory message to indicate that a probe heater has failed or power to the heater is not present. An EICAS advisory message will also be displayed if ground/air logic has failed to remove power and a TAT probe is heated on the ground.

Nacelle Anti-Ice: The engines receive anti-ice protection through the nacelle anti-ice system. Nacelle anti-ice may be operated in flight and on the ground as required.

When NAI is selected ON, bleed air pressure opens the nacelle anti-ice valve allowing bleed air to flow to the respective engine inlet cowl. However, bleed air is not available for nacelle anti-ice operation when the pressure regulating valve has been closed due to:

- Bleed air overheat
- The High Pressure bleed valve failed to open.
- The start valve is not closed.

When NAI is selected ON with the engine bleed valve closed, the High Pressure bleed valve remains closed, but the NAI receives required bleed air from the system.

An advisory message and the VALVE light located in the NAI switch will illuminate in the event that the NAI valve and switch position disagree. Display of the EICAS message is delayed for three seconds to allow for valve transit time.

NAI should be operated in conditions where visible moisture is present and the temperature is 10°C of less. If NAI is selected ON when the temperature is greater than 12°C or greater, and EICAS advisory message will remind the crew to deselect NAI.

Wing Anti-Ice: Pushing the Wing Anti-Ice (WAI) switch ON opens a valve in each wing that allows bleed air to flow from the engines to a series of spray tube ducts in the leading edge of the wing. WAI is ineffective when the leading edge flaps are extended, and cannot be activated while the aircraft is on the ground.

EICAS displays an advisory message and the WAI valve light illuminates in the event that a valve disagrees with the commanded position of the switch. The EICAS message is delayed three seconds in order to prevent transient messages while the valves are in transit.

WAI should be operated in conditions where visible moisture is present and the temperature is 10°C of less. If WAI is selected ON when the temperature is greater than 12°C or greater, and EICAS
advisory message will remind the crew to deselect WAI.

**Primary EICAS display:** Each of four NAI valves (one per engine) are displayed on the primary EICAS as a status advisory to the crew when NAI is in operation.

Both WAI valves are displayed as advisories when WAI is in operation as well.

**Secondary EICAS display:** The secondary synoptic ECS display also provides the crew with an indication of NAI and WAI activity.

NAI and WAI operation is identified by the NAI and WAI chutes shown on the respective engine and wing valve identifiers shown in green.

The airflow displayed is generated by the displayed valves positions, switch positions and pack status. The display does not show actual air flow and therefore the display may not represent the actual system operation.

**EICAS MESSAGES:**

>ANTI ICE

Any anti-ice system is on and TAT is greater than 12C.

HEAT P/S CAPT F/O

Heater failure on associated probe.

HEAT P/S L, R AUX

HEAT L, R TAT

HEAT L, R AOA

NAI VALVE 1,2,3,4

Nacelle anti-ice valve is not in commanded position.

WAI VALVE LEFT, RIGHT

Wing anti-ice valve is not in commanded position.
LANDING GEAR

Overview: The nose gear on the 747-400 is a standard, two-wheel, non-braked steerable nose gear design. The main landing gear are comprised of four main gear trucks, each with four wheels. The two wing mounted gear are referred to as the Wing Gear, and the fuselage mounted gear are referred to as the Body Gear.

Hydraulic power for the landing gear is provided by systems 1 and 4. System one provides power to the nose and body gear, while system four provides power to the wing gear. In the event of hydraulic failure, an alternate gear extension system is available which electrically releases the uplocks and allows aerodynamic loading and landing gear weight to lower the gear to the locked position.

Braking is provided by both a normal and an alternate system, each equipped with antiskid systems. Autobraking capability is provided for the normal brake system only.

Landing Gear: The main landing gear on the 747-400 is an extremely complex arrangement of wing and body gear with very tight clearance tolerances during the retraction process. As such, each of the wing and body gear assemblies is equipped with sensors to determine if the gear is in the proper position prior to allowing actuation of the landing gear lever.

These sensors require that the wing gear be in a tilted position and the body gear in a centered position before the gear up handle will unlock. Under normal conditions, this will occur within three seconds of aircraft liftoff.

In addition to unlocking the landing gear lever, a number of other aircraft functions are directly linked to the main and body gear tilt sensors, as well as a nose gear liftoff sensor which detects weight on the nose gear assembly. Unless all of these sensors are correctly positioned, the crew may not be able to retract the landing gear, or utilize other air/ground specific systems.

The landing gear doors are powered by the hydraulic system which powers the landing gear sub-system. Hydraulic power is required for landing gear door closure.

During the gear retraction sequence, the autobrake system will apply brake pressure to eliminate will movement before the landing gear are in the up and locked position. The nose gear uses a snubbing process to eliminate wheel movement during the retraction process.

Landing Gear Position Indicators: The landing gear position indicator is displayed on the primary EICAS when the landing gear are extended.

The landing gear position indicator is removed from the EICAS display when the landing gear are in the up and locked position.

Expanded Gear Disagree Indicator: If any abnormal condition exists with the landing gear the EICAS will provide an expanded gear position display to show the disposition of all five gear assemblies. This expanded display will also appear if the ALTN GEAR extension switch is pushed, or if a GEAR DISAGREE warning message is present.

DN indicates gear system down and locked. Crosshatches indicate gear not down and locked.

If any gear position sensor fails, it will be replaced on the expanded EICAS gear indicator with an amber X.

Landing Gear Brake System: The normal brake system is powered by the number 4
hydraulic system, with a brake pressure accumulator.

The 747-400 is equipped with carbon brakes. The braking capabilities provided by carbon brakes are such that automatic brake torque limiting systems are installed to prevent excessive stress from being placed on the landing gear by over braking. If excessive brake torque is sensed by the antiskid system, the wheel transducer will trigger an antiskid signal to alleviate brake pressure on that wheel.

Each wheel is equipped with a brake temperature monitoring system, which provides direct temperature indication to secondary EICAS GEAR display. This display allows the crew to monitor the temperature of each individual brake sub system.

**Antiskid:** The anti skid system is entirely automated, and does not include any cockpit controls. The system receives input from transducers in each main wheel, and uses a reference velocity provided by the IRS ground speed signal to prevent wheel locking, skidding and hydroplaning.

**Autobrakes:** The autobrake system also receives power from hydraulic system 4. The system is designed to operate in conjunction with the automated flight systems to provide predictable deceleration rates during a rejected takeoff, or during landing. The rate of deceleration can be selected by a cockpit control capable of being set to RTO, 1, 2, 3, 4 or MAX AUTO. Setting 1 will provide a deceleration rate of 4 \( \text{ft/sec}^2 \), while MAX AUTO will provide a deceleration rate of up 11 \( \text{ft/sec}^2 \).

The RTO setting will provide maximum braking pressure automatically if the throttles are moved to idle after the aircraft has accelerated beyond 85 knots.

The autobrake system will automatically disarm itself after aircraft liftoff. The system will also disarm in the following situations:

- Advancing any throttle beyond idle forward after touchdown.
- Antiskid System Malfunction.

- Application of brake pressure by the crew,
- Autobrake System Malfunction.
- Moving the autobrake selector switch to DISARM or OFF.
- Moving the speedbrake selector handle to DN after landing.
- Normal Brake System Malfunction.

In the event that the normal braking system provided by hydraulic system 4 is inoperative, an alternate braking system is provided by system 1, or system 2 (should system 1 fail as well.) Brake pressure is selected automatically, and will switch immediately if the system in use begins providing low output pressure.

The alternate braking systems are provided through separate brake lines and through separate metering systems. The alternate brake system has all the normal brake capabilities of antiskid, but does not provide autobrake capability. This will be announced on the primary EICAS if the alternate brake system is being used.

**Ground Steering:** In order to allow for adequate rudder usage during the high speed portion of the takeoff and landing phase of flight, nose gear steering is limited to 7º of deflection from the rudder pedal throw. For proper ground steering, each crew member is provided with a steering tiller which allows the nose wheel steering assembly to be rotated to 70 degrees in either direction. This tiller should be used for taxi operations.

Any time the aircraft ground speed is lower than 15 knots and the steering tiller is used to deflect the nose wheels beyond 20º deflection, the body gear steering is automatically actuated, turning the body gear in the direction opposite the nose gear. This action dramatically reduces the turning radius of the 747-400, as well as reducing the amount of scrubbing received by the body gear tires. If aircraft speed increases beyond 20 knots while body steering is enabled, the system will automatically command the body gear to center their steering mechanisms. An EICAS warning will sound if the body gear are not properly positioned for takeoff. Taking off with the
body gear steering out of synchronization will prevent gear retraction.

Body gear steering is provided by hydraulic system 1. There is no backup system for this function.

**Landing Gear Configuration Warning:** If the aircraft detects the landing gear are not properly configured when the flaps are commanded to flaps 25 or 30, and the aircraft is below 800 feet AGL, a landing gear configuration warning will sound.

This warning will also sound in any case where the landing gear system detects a gear assembly is not locked down, or is improperly positioned. Pushing the GEAR/CONFIG OVRD switch will lock out this automated warning system.

**CONFIG GEAR OVRD:**

**Secondary EICAS Display - Landing Gear Synoptic:** When the EICAS control panel GEAR switch is pressed, the secondary EICAS displays a GEAR overview which depicts the current tire pressure, brake temperature, and door assembly configuration for each landing gear sub assembly. This display can be used to diagnose landing gear problems, as well as to monitor brake temperatures and tire pressures after abnormal takeoff/landing situations.

**Tire Pressure Indication:**

- **Brake Temperature Indication:** Normal range is 0-4 and is displayed in white. Caution range is 5-9 and is displayed in amber.

- **Gear Door Configuration:** Cross hatches indicate door in transit or landing gear out of synch.
LIGHTING SYSTEMS

Overview: The aircraft lighting system provides for flight deck, passenger cabin, cargo and service compartment lighting as well as exterior and emergency lighting.

Storm Lights: The storm light switch is an override switch that sets all interior cockpit lights to a high brightness setting in order to combat night blindness resulting from lightning in close proximity to the airplane. This switch function is not modeled in the PMDG 747-400.

Circuit Breaker/Overhead Panel Dimmer: This dimmer knob controls the night lighting brightness on the overhead panel and circuit breaker panel above and behind the overhead panel. Rotate the knob left/right to actuate its function at night.

Glare shield/Panel Flood Dimmer: This dimmer knob controls the night lighting brightness on the main panel and glareshield. Rotate the knob left/right to actuate its function at night.

Dome Light: This dimmer knob is used to set the brightness of cockpit overhead lighting.

Aisle Stand Panel Flood Dimmer: This dimmer knob controls the night lighting brightness on the center console/aisle stand. Rotate the knob left/right to actuate its function at night.

Landing Lights: Two fixed landing lights are installed in the leading edge of each wing. Each light is controlled by the L or R OUTBD or L or R INDB switch. When a landing light switch is in the ON position, the wing landing light is at maximum brightness if the landing gear are selected DOWN. The light is dimmed automatically when the landing gear are not in the down position. (This dimming functionality is not modeled in the PMDG 747-400)

Runway Turnoff Lights: The two runway turnoff lights are mounted on the nose gear structure and are aimed approximately 65 degrees to the left and right of the airplane centerline.

Runway Turnoff Lights: The L and R RWY TURNOFF switches on the overhead panel control the lights. The air/ground sensing system determines he conditions when the lights illuminate or extinguish based on interface with the air/ground sensor. The turnoff lights will only operate while the aircraft is on the ground.

Taxi Lights: The TAXI light switch on the overhead panel controls the taxi light. The taxi lights are located on the nose landing gear. The air/ground sensing system determines the conditions when the lights illuminate or extinguish provided that the light switch is in the ON position. With the switch ON, the taxi lights illuminate when the air/ground sensing system is in the ground mode.

Beacon Lights: The BEACON light switch on the overhead panel controls the red anti-collision lights. On the aircraft there are two beacon strobes, Lower and Upper that can be operated individually. This functionality is not modeled in the PMDG 747-400, and instead the beacons have an ON and OFF condition.

Navigation Lights: The navigation lights switch controls the aircraft position lights. The position lights are two fixed position
green lights on the right wingtip, and two fixed position red lights on the left wingtip, and two fixed white lights on the tail cone near the APU exhaust outlet.

**Strobe Lights:** The strobe lights switch on the overhead panel controls the three white strobe lights. One strobe light is installed on each wing tip and one on the tail cone.

**Wing Lights:** The wing lights switch on the overhead panel activates wing leading edge illumination lights. The lights illuminate the wing leading edge and engine nacelles. The lights are flush-mounted on the fuselage.

**Logo Lights:** The logo lights are installed on the horizontal stabilizers to illuminate the vertical stabilizer markings to improve visibility of the airplane.

**Indicator Lights Test:** This switch is used to test the function of light bulbs throughout the cockpit. This functionality is not modeled in the PMDG 747-400.

**Screen Dimming:** The PMDG 747-400 has the ability to dim the individual screens within the cockpit. The knobs for this functionality are included in the Virtual Cockpit, and are not available in the 2D cockpit. The dimmer knobs are located to the left/right of each pilot on the edge of the glare shield.

**Emergency Lights:** The passenger emergency exit lights are controlled using the switch on the overhead fire control panel. These lights should be ARMED any time the aircraft is in operation. They should be turned to ON to aid an evacuation, and turned OFF when the airplane is shut down. An EICAS message will alert the crew if the status of the emergency exit lights does not match the operation of the aircraft.
PNEUMATIC SYSTEMS

Overview: The engines, APU or an external air bottle can provide pressure air for the pneumatic system. The pneumatic system on the 747-400 distributes high pressure air to the following systems:

- Air Pressure Driven Hydraulic Demand Pumps.
- Aft Cargo Heat.
- Cabin Air Conditioning.
- Cabin Air Pressurization.
- Cargo Smoke Detection System
- Engine Start.
- Hydraulic Reservoir Pressurization System.
- Nacelle Anti Ice (In conjunction with Engine Bleed Air).
- Potable Water System Pressurization.
- Wing Anti Ice.
- Leading Edge Devices.

External Air: External air can be supplied to the pneumatic system via two separate connectors while the aircraft is on the ground. The connectors are located on the bottom of the fuselage, just aft of the air conditioning packs, and are usually only used to provide engine starting pneumatic pressure in the event APU pneumatic pressure is unavailable. The use of pneumatic air is depicted by a green EXT AIR on the secondary EICAS ECS display.

APU Bleed Air: The APU supplies air through a bleed air valve to the pneumatic system. If started while on the ground, the APU can provide pneumatic support to the single operating air conditioning pack, which will allow full engine power to be dedicated to takeoff thrust. The APU can be used for air conditioning purposes up to 15,000 feet, by which time pneumatic support of the air conditioning packs should have been transferred to the engines.

Engine Bleed Air: Each engine is capable of providing temperature limited bleed air through a pressure regulating valve (PRV). The PRV will automatically meter the amount of bleed air based on system demand and engine thrust setting.

During high thrust conditions, such as takeoff or cruise, the PRV will modulate engine bleed air through the Intermediate pressure bleed valve. During low thrust flight conditions, the PRV will modulate to supply bleed pressure from the high pressure bleed stage, based on system demand.

Engine bleed air temperature is regulated by an engine mounted pre-cooler. The pre-cooler functions as a heat exchanger, using fan air to cool engine bleed air. The system regulates the temperature of engine bleed air by modulating the amount of fan air allowed to enter the heat exchanger.

Engine Bleed Air Valve: The engine bleed air valve regulates the engine bleed air to provide normal bleed air system pressure. It also prevents reverse flow of bleed air from the duct, except during engine starting. If the air pressure in the bleed duct from another source is higher than the bleed air from an engine, the engine bleed valve will close. The engine bleed air valve will open automatically when engine bleed air pressure is sufficient to produce forward air flow.

Engine Bleed Switch: Pushing an engine bleed air switch ON allows the system logic and bleed air pressure to open the HP bleed valve, the Pressure Regulating Valve and then allows bleed air pressure to open the respective engine bleed air valve to introduce air flow into the bleed air duct. The respective engine bleed air switch OFF light is illuminated when an engine bleed air valve is not open.
Nacelle Anti-Ice: Bleed air for NAI operation is available to the engine even if the bleed switch is selected off. The following conditions will prevent bleed air from being available for the engine NAI operation:

- The PRV has failed closed.
- The PRV has been closed due to a bleed air overheat.
- The start valve is not closed.
- The HP bleed valve failed open.

Distribution: The pneumatic system is capable of accepting bleed air from any engine, and distributing it to any unit requiring bleed air. To isolate a pneumatic leak, a bleed duct leak or overheat condition, either of the isolation valves can be selected closed. This will protect the integrity of the rest of the bleed air system.

Pneumatic System Indications: Pneumatic duct pressure in the left and right pneumatic ducts is continually displayed on the primary EICAS. The secondary EICAS ECS display provides a detailed overview of the pneumatic system status based upon switch positions and sensors. The status of each bleed valve and isolation valve can be seen, as well as NAI, WAI functions and current pneumatic system pressure on both sides of the pneumatic system.
SECONDARY EICAS DISPLAY - PNEUMATIC SYSTEM SYNOPTIC

Secondary EICAS Pneumatic Indications: The secondary EICAS pneumatic display is contained on the Environmental Control Systems (ECS) screen. This screen contains environmental control indications, cabin pressurization indications, as well as a schematic of the pneumatic bleed air system.

Pneumatic System Control Panel: The pneumatic system is controlled using the pneumatic system control panel, which is located on the overhead panel. This panel is comprised of controls for both the pneumatic and pack control systems.

Isolation Valve Switch: Open or close associated ISLN valve. VALVE light illuminated indicates associated valve disagrees with switch position.

SYS FAULT Lights: Indicate bleed air overheat or overpressure, pressure regulating valve or high pressure bleed valve open when switch position require them to be closed.

APU Bleed Air Switch: [ON] Valve opens when switch is placed on and APU N1% is greater than 95%. VALVE light illuminated indicates valve position disagrees with commanded switch position.

Engine Bleed Air Switches: [ON] Engine bleed air valve, pressure regulating valve, and high pressure bleed valve open. [OFF] Engine bleed air valve, pressure regulating valve and high pressure bleed valve closed.
CENTER PEDESTAL SYSTEMS

Overview: The center pedestal houses a wide array of functions from communication and ATC to autobrakes and passenger warning signs.

Communications Radios: The communications radios are modeled to incorporate nearly all MSFS functionality. Based on the lack of integrated audio circuitry within MSFS, we have not modeled the ability to monitor audio input on secondary channels.

To use the communications radios, select the desired frequency in the STANDBY window, then use the frequency flip-flop key to move the frequency to the ACTIVE window.

Navigation Radio Signal Monitoring: The radio frequency identifier information is primarily monitored by automatic systems aboard the airplane. When a signal has been positively identified, it’s identifying information accompanies it’s display on the Navigation Display.

Autobrakes: The Autobrakes selector is found on the center pedestal. Select the switch to RTO for Rejected Takeoff activation of the braking system.

Select landing settings of 1 – MAX, based on your desire level of braking upon landing. For a full description of autobrake functionality please see chapter 3.

Flight Control Trimming: Flight control trim controls are found on the center console.

Transponder and TCAS Controls: Transponder and TCAS controls are encapsulated in a single Transponder Control Unit.

Transponder biasing for ABOVE and BELOW traffic, relative altitude (Absolute or Relative) as well as ATC IDENT controls are found here.

The transponder control knob must be set to either TA or TA/RA (Traffic Advisory or Traffic Advisory/Resolution Advisory) in order to display TCAS information on the Navigation Display.
# FLIGHT MANAGEMENT COMPUTER

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Overview: The 747-400 uses a fully integrated Flight Management System, in conjunction with other interfaced equipment such as the Autopilot Flight Director, Autothrottle and Navigation System provides a fully automatic, full regime flight control and information display system. The backbone of the FMS is the Flight Management Computer.

Boeing is currently in the process of upgrading the operating software for the 747-400 FMC/CDU. This simulation was built with the most current available information and may differences from earlier FMC simulations/manuals as a result.

The FMC takes input and sensory information from throughout the aircraft and is capable of providing flight control, navigation, thrust management, map display and performance optimization. The FMC provides output directly to the autoflight systems in the form of flight director steering commands, thrust queues and autoflight mode management.

The FMC is the central backbone of the entire FMS package on the 747-400, and interfaces with the following systems:

- Flight Control Computers (FCCs)
- Air Data Computer
- Fuel Quantity Indicating System
- Weight and Balance Computer
- VOR
- DME
- ILS/MLS Systems
- Inertial Reference System
- Digital Clock
- Autopilot Flight Director System
- Mode Control Panel
- FMC Database
- FMC/CDU (Crew inputs)
- Autothrottle Servo
- Electronic Interface Unit

In addition, the FMC provides commands or information directly to the following systems, although it does not receive information from these systems:

- Integrated Display System (PFD & ND)
- Electronic Engine Controls
- ADF

The FMC performs the following major functions:

- Flight Planning
- Navigation Computation
- Navigation Display
- Navigation Radio Tuning
- Guidance Commands (pitch, roll and thrust)
- Interface to Inertial Reference System (IRS)
- Performance Optimization
- Thrust Limit Calculation
- Autothrottle Control
- Polar Navigation Capability

The FMCs: The 747-400 FMS consists of two Flight Management Computers which are located in the electronics and equipment bay. Each FMC is comprised of five processors, and integrates data received from the air data sensors, crew input, navigation radios, engine and fuel sensory systems, inertial reference system and internal navigation database. This information is then used to provide steering commands to the autoflight systems in both roll and pitch modes, as well as to the autothrottle servos. Navigation and positional data is provided to the Navigation Display.

Each FMC is capable of receiving input independent of the other, and both systems will continually compare input/process results to ensure information consistency on both FMCs. If inconsistencies are detected, a resynchronization process is automatically initiated.

Flight crew interaction with the FMCs takes place via the FMC/CDU (Control Display Unit.) There are three CDUs located in the cockpit of the 747-400. One at the captains side of the throttle console, one at the first
officers side of the throttle console, and one located just aft of the throttles. Normal operation will see the captain and first officers using the CDUs at their individual stations, however the center CDU can be used by a crew member should one of the CDUs fail. The center CDU is usually responsible for managing ACARS functions in an automated fashion.

**CDU:** The CDU is comprised of a data display screen with six line select keys on each side of the screen. The data display screen shows 14 lines of data 24 characters wide. Numeric and Alphabetic keys are provided for crew input. Fifteen function and mode keys are provided to assist the crew in selecting and managing FMC functions.

**CDU Display:** The CDU display screen is comprised of 14 data lines capable of displaying 24 characters across in large or small font. The display is broken into three distinct areas.

*Text in muted font indicates that the function is not available or cannot be modified by the user in the simulator.*

**Title Line:** Top line of the display. Shows title of the current page display.

**Data Lines:** Six pairs of lines which contain data for the display page shown. Lines may also contain prompts for data input by the crew. The upper line in each line pair is called the Header Line, while the lower line is called the Data Line. Lines and line pairs are referenced by their association with the Line Select Keys (LSKs) on either side of the display. (Hence 1L, 4R, etc.)

**Scratchpad:** The last line of the display is a scratchpad which allows for alpha numeric input by the crew, or down-selection of FMC data from other lines.

**Line Select Keys:** The CDU display has six Line Select Keys (LSK) on each side of the screen in order to facilitate data input and manipulation. The keys are identified by their position relative to the display and their sequence from top to bottom. (e.g. The LSKs are identified as either Left or Right and are numbered from 1 to 6 starting at the top.)

The LSKs are used for the following functions:

- Down-selection of data from a particular line to the scratchpad (if the scratchpad is empty.)
- Up-selection of data from the scratchpad to a data line.
- Access to data or function identified by LSK.
Annunciators: Two mode annunciators are modeled in the PMDG 747-400:

MSG: Illuminates when an FMC generated message is displayed in the scratchpad area.

OFST: Illuminates when a parallel offset path is in use.

Function and Mode Keys: The PMDG 747-400 FMC has fifteen function/mode keys located below the CDU display screen. These keys assist in the performance of a number of functions, including page selection and navigation of the FMCs function pages.

INIT REF: Accesses the initialization and reference pages.

RTE: Accesses the route pages.

DEP/ARR: Accesses the departures and arrivals procedure pages.

ATC: Function not modeled.

VNAV: Accesses the VNAV climb cruise and descent pages

FIX: Provides access to fix information pages.

LEGS: Accesses the legs pages.

HOLD: Provides access to the hold pages.

FMC/COMM: Function not modeled.

PROG: Accesses the progress pages.

EXEC: The execute command key for the FMS. The button contains a small lighted bar which will illuminate to indicate a modification has been selected and needs to be confirmed by pressing the execute key. Any page which has modification capability will also have an ERASE prompt to allow the crew member to cancel a selected modification. Selecting either the EXEC key, or pressing the LSK designated by the ERASE cursor will cause the lighted bar to extinguish.

MENU: Provides access other MCDU driven functions, such as ACARS. Key allows movement between FMC functions and ACARS.

NAV/RAD: Accesses the navigation radio tuning page.

PREV PAGE: Accesses individual pages of a multiple page display. (Route pages, for example, tend to be longer than one page.)

NEXT PAGE: Accesses individual pages of a multiple page display.

Two additional keys are located at the bottom of the numerical keypad which will be frequently used:

DEL: A single press of this key inserts the word DELTE into the scratch pad. Upload DELETE to an LSK in order to delete the information contained on that line.

CLR: Single presses of key will cause the last character in the scratchpad to be erased. A longer press of the key will erase entire contents of scratchpad.
FLIGHT MANAGEMENT SYSTEM INTERNAL FUNCTIONS

Performance Management: The Flight Management System (FMS) is capable of managing nearly all aspects of aircraft performance so as to optimize precision and economy of flight. The FMS is only capable of performing this function if it has been properly initialized at the beginning of flight.

The performance model used by the FMS takes into account fuel flow, engine data, altitude, gross weight of the aircraft, flaps, airspeed, Mach, temperature, vertical speed, acceleration and location within a programmed flight plan to determine the optimum performance for the aircraft at any given moment. Crew interface with the FMS comes via the FMC, primarily, but also by the Autopilot Mode Control Panel and flight controls.

The performance management modeling used by the FMS attempts to provide a least cost performance solution for all phases of flight, including climb, cruise and descent. The default cruise performance management setting is ECON, or economy cruise.

The airplane and engine data models are used to provide an optimum vertical profile for the selected performance mode. During the climb, an optimum Mach speed target and a corresponding thrust target are computed by the FMS, with the speed target transmitted to the vertical guidance function of the autoflight director system. The AFDS will then generate commands to the elevator in order to maintain the correct pitch for the required speed. Thrust setting commands are delivered to the autothrottle servos by the FMS, and used in conjunction with the pitch setting commands to maintain the optimum speed and climb as directed by the FMS.

During cruise, an optimum Mach setting is computed and thrust setting commands are delivered to the autothrottle.

During descent, a vertical path is computed based on the flight plan entered into the FMC. The FMS will evaluate expected wind conditions, aircraft speed, altitude, position relative to the planned end-of-descent point and any intermediate altitude or speed constraints between the aircraft and the end-of-descent point. This information will be passed to the AFDS for pitch based speed and vertical speed control and the autothrottles for vertical speed and thrust management. In ideal conditions, an idle thrust optimum descent profile is flown, however in many cases thrust and pitch will be varied to account for wind conditions or to ensure proper tracking of the vertical descent profile.

Navigation Management: The FMS automatically selects and tunes VHR Omni-Range (VOR) and Distance Measuring Equipment (DME) in order to constantly update the position and speed of the aircraft. This information is used in conjunction with the Inertial Reference System (IRS) to ensure accuracy in all phases of flight.

For properly equipped aircraft, the FMS will use GPS as a primary navigation information source unless GPS navigation accuracy is determined to be insufficient according to FMS navigation precision parameters.

The FMS will primarily attempt to combine GPS information, DME position information corrected for slant range and position from three Inertial Reference Units (IRUs). If no usable GPS or VOR/DME information is available, the FMS will monitor aircraft position based on IRS data only, until the aircraft is determined to be in a location where DME/VOR information is once again available for position and velocity cross checking and or GPS information becomes reliable.

The FMS navigation management system will also compute and provide true and magnetic track information, drift angle, magnetic variation for the current aircraft location and vertical flight path information.

The FMC automatically determines which VOR/DME combinations will yield the best
result given their position relative to the aircraft.

**Guidance Management:** Two-dimensional flight path management is available along an FMC programmed flight path in either the vertical navigation mode (VNAV) or lateral navigation mode (LNAV). Both of these modes are selected on the Mode Control Panel (MCP). When used together, the FMS is capable of providing fully integrated three dimensional flight path management along the FMC defined flight path.

The LNAV guidance function compares the airplane’s position generated by the navigation function to the desired flight path according to the FMC programmed flight path. Steering commands are issued to the AFDS in order to keep the aircraft navigating correctly along the programmed route of flight.

In all phases of an LNAV managed flight, the FMS will monitor cross track error, which is defined as the lateral distance separating the aircraft from it’s desired path of flight. Roll and steering commands are provided to the AFDS Flight Control Computers in order to correct the cross track error.

The FMS is capable of providing a great circle Direct-To track to any point on the FMC programmed flight path.

The VNAV guidance function controls the aircraft along the vertical flight path regime as defined by the FMC entered flight path and the aircraft’s performance limitations.

The vertical navigation function takes positional data from the navigation function and the lateral navigation function (if selected) and compares it to the vertical profile as defined in the FMC entered flight plan. The vertical navigation function then provides pitch and thrust commands to the AFDS in order to maintain the proper vertical profile for the current phase of flight.

For vertical performance modes where vertical speed is unconstrained (most climbs) the VNAV system will provide pitch and thrust commands to the AFDS so as to maintain the most efficient climb based on the current thrust mode selected.

When speed is controlled by elevator input, the AFDS autothrottle will be given a target thrust setting by the vertical navigation function.

When vertical speed is controlled by elevator, aircraft speed will be managed by commands to the AFDS autothrottle to adjust thrust as necessary for the descent profile.

**Thrust Management:** The FMS thrust management function is capable of performing autothrottle control law calculations based on commands from the navigation function, as well as direct crew input from the FMC, throttle position, or AFDS autothrottle commands.

The autothrottle control law function provides automatic N1 equalization in all modes of flight, as well as thrust limit protection and N1 thrust requirement calculations to maintain MCP or AFDS required speed and thrust settings.

Autothrottle modes can be selected or overridden by the crew as required.
FMC DISPLAY PAGES ACCESSED WITH MODE KEYS

Overview: The PMDG 747-400 FMC has fifteen mode keys available on the FMC/CDU. These keys provide access to a number of functions within the FMC which will be used by the crew during various phases of flight.

MENU Key: The MENU key provides access to the FMC and other aircraft sub-systems which use the CDU for input or control. When pressed, the MENU key brings up the following display screen on the CDU:

Note that when press the menu key, you are presented with the FMC MENU page, and the title MENU is presented at the top of the page. The page title line will help you to understand where within the FMC function you are currently working.

This same page is the first page displayed by the FMC/CDU when power is initially provided to the aircraft. The MENU page allows the crew to select which FMS sub-systems they wish to access within the CDU. The following options are currently available in the PMDG 747-400 FMC:

- **FMC**: Accesses FMC functions.
- **ACARS**: Accesses the ACARS system.
- **EICAS CP**: Reversion control of EICAS.

The FMC key will bring up the last displayed FMC page. The ACARS key will display the ACARS control page. The EICAS CP line select key will bring up the reversionary control page for the EICAS system.

The FMC and ACARS indicators will be followed by one of the following prompts:

- `<ACT>` Indicates that the sub-system is currently active and operating.
- `<SEL>` Indicates that the pilot has selected the sub-system but the MCDU has not yet established active communications with that sub-system.

There are four items displayed on the MENU display screen which are not currently modeled in the PMDG 747-400. If the LSK for these functions are pressed, the FMC/CDU will simply ignore the request as the functions are not available. These functions are listed below:

- SAT-M
- SAT-S
- ACMS
- CMC
- MEMORY
- EFIS CP
INIT REF Key: When pressed, the INIT REF key will provide access to one of the following pages:

- IDENT
- POS
- PERF
- THRUST LIM
- TAKEOFF
- APPROACH

The FMC will automatically display the page which is most appropriate for the current phase of flight. During the preflight phase, for example, the FMC will begin by displaying the IDENT or POS pages so as to allow the crew to begin initializing the FMC.

During the approach phase of flight, the FMC will automatically choose the APPROACH page, etc.

If the page displayed is not the page desired by the crew, pressing the LSK which has the <INDEX prompt (usually 6L) will return the CDU to the following screen:

The INIT/REF INDEX page allows crew access to the following initialization and reference pages:

- IDENT: Aircraft identification and nav database verification page.
- POS: Position Initialization (on ground) or Position Reference page (in flight).
- PERF: (Located on page 2/2 of PERF page) Performance initialization page (Gross weight, Fuel Loading, Cost Index, etc.)
- THRUST LIM: Thrust performance mode selection page.
- TAKEOFF: Takeoff parameter reference and initialization page.
- APPROACH: Approach reference and initialization page.
- NAV DATA: Nav data reference page.

One function listed on the INIT/REF INDEX page is not currently modeled in the PMDG 747-400:

- MAINT
INIT/REF INDEX KEY DISPLAY DIAGRAM
**RTE Key:** When pressed, the RTE key provides access to the active route or modified active route page. If a route has not been activated by the crew, RTE 1 is automatically displayed.

The route being displayed is described by the title line of the RTE display, and can be any of the following:

- RTE 1 or ACT RTE 1 or MOD RTE 1
  - Route 1 was displayed.
  - Route 1 is active.
  - No route was activated.

- RTE 2 or ACT RTE 2 or MOD RTE 2
  - Route 2 was displayed.
  - Route 2 is active.

**DEP/ARR Key:** The DEP/ARR key accesses the DEPARTURES and ARRIVALS pages and the DEP/ARR INDEX page.

These pages are used to select published departure procedures (Standard Instrument Departures, or SIDs) and published terminal arrival procedures, (Standard Terminal Arrivals, or STARs).

The DEP/ARR INDEX page allows the crew to select (using the appropriate LSKs) the appropriate DEP procedure, or an ARR procedure for either of two routes loaded into the FMC.

**EXEC Key:** The EXEC key is only active when the light bar contained within the key is illuminated. The key is used to confirm and changes to the vertical and lateral route plan.

At any time the EXEC key is active, an <ERASE prompt will appear on the CDU display in order to facilitate cancellation or deletion of a proposed action.

**NEXT PAGE/PREV PAGE Keys:** The NEXT PAGE and PREV PAGE keys are used in conjunction with CDU displays which occupy more than one page on the CDU display. Multiple page CDU displays are indicated by the use of page numbering in the upper right hand corner of the CDU display.

A wrap around feature is included so that if the NEXT PAGE key is pressed again when the current page is the last in the display,
(e.g. 5/5) then the first page of the display (1/5) will be displayed next. This feature also works for the PREV PAGE key.

**NAV RAD Key:** The NAV RAD key accesses the NAV RADIO page, which allows the crew to monitor FMS automated navigation radio tuning, or to manually override the auto-tune sequence.

The NAV RAD page is allows the crew to monitor auto-tuning activity, or to manually tune a desired frequency for VOR1/VOR2, ADF1/ADF2 or the ILS.

A small ‘A’ next to a frequency indicates that the station has been auto-tuned for navigation verification. An ‘M’ indicates that the frequency is manually selected by the crew. Station identifier information appears in the center of the display, along with current redial TO the selected station.

Likewise, desired OBS course for a VOR can be manually entered by up-selecting a course from the scratch pad to either LSK 2L or 2R.

**PROG Key:** The PROG key accesses the flight PROGRESS pages. These pages provide navigation fix, distance to go, fuel, ETE, headwind/crosswind information, cross track and vertical track error, fuel totalizer and fuel usage information to the crew.

**VNAV Key:** The VNAV key accesses the vertical navigation profile pages. These pages are comprised of CLB (climb) CRZ
(cruise) and DES (descent) pages that are differentiated by their title lines.

Much like the INIT REF key, the FMC will automatically display the appropriate VNAV page for the current mode of flight. If other VNAV mode pages are needed, they may be accessed using the NEXT PAGE/PREV PAGE keys.

CLB VNAV PAGE:

VNAV CRZ PAGE:

VNAV DES PAGE:
FLIGHT MANAGEMENT COMPUTER INITIALIZATION

Overview: The flight management computer is easily the most complicated instrument on the flight deck of the 747-400. Proper initialization and usage of the FMC is a key part of crew member knowledge, and will greatly enhance both the accuracy and economy of aircraft operation.

The FMC initialization and usage process is designed as a beginning to end process covering all phases of flight, with multiple options, alternative modes and information displays for each phase.

In order to facilitate effective learning of the FMC process, this manual divides FMC usage into nine specific flight regime/operating methods:

- Database Editing/Management
- Pre-Flight
- Flight Planning
- Takeoff
- Climb
- Cruise
- Radio
- Navigation
- Descent
- Approach

Conventions: Certain conventions should be recognized by crew members in order to input and manipulate data effectively in the FMC/CDU.

Required Entry Boxes: Boxes in any CDU display line indicate that information is required by the FMC in order to be properly initialized. Examples include Gross Weight, Startup Position, etc.

Crew Data Entry/Selection Lines: Dashed lines allow for crew entry of specific data which is unique to each individual flight, such as departure airport, destination airport, speed/altitude restrictions, flap acceleration heights, etc.

Down-selection/Up-selection: In order to facilitate the accurate and efficient transfer of data, a ‘down-selection’ capability is a key component of the FMC/CDU. By pressing the line select key adjacent to any line of data, that data is copied to the scratch pad. By then pressing an LSK you can up-select the information to another line.

For example, pressing LSK next to the GPS POS on the image above transferred the long position data to the scratchpad. Pressing the LSK next to SET IRS POS will up-select the position information to that line, fulfilling the need to update the IRS position data.
PRE-FLIGHT FMC INITIALIZATION PROCESS

Overview: When power is first applied to the aircraft, the FMC conducts a full self test and is then ready for crew preflight interaction. The preflight portion of FMC operation prepares the flight management system for flight by initializing parameters such as aircraft location, destination, weight, fuel load and flight plan.

IDENT Page: When first powered, the FMC will display the MENU page.

Pressing the LSK 1L key, (the <FMC prompt) will enter the FMC function area and display the IDENT page, as follows:

The IDENT page is described by the IDENT title page line at the top of the display screen. The data which appears on the IDENT page allows the crew to verify the accuracy of FMC operation for the known aircraft type, and cannot be changed from within the CDU. The data appearing on this page should not change on a regular basis, but it is important that this preflight check be accomplished in order to protect against system faults or improper system reloads during updates and/or changes to the FMC system or FMC database.

Line 6 at the bottom of the screen contains two prompts, <INDEX, which will display the INIT REF INDEX page, and POS INIT>, which will display the Position Initialization page of the FMC. During the preflight initialization, following the prompts in the 6R position will take the crew member through the entire initialization process.

The following information is provided on the IDENT page:

MODEL: The airplane model is displayed in line 1L.

ENGINES: The installed engine type is displayed in line 1R.

NAV DATA: The navigation database identifier and life cycle information is displayed on line 2 of the CDU. The AIRAC cycle and effective dates are shown here. If the database is out of date, an updated version can be downloaded from http://www.navdata.at.

OP PROGRAM: The operational program identifier is displayed in line 4L. This number is the part number of the FMC’s software operations program. If both FMCs do not have the same software load the system will remain locked at the IDENT page.

DRAG / FUEL FLOW: Aircraft demonstrated drag adjustment (from norm) and the resultant demonstrated fuel flow adjustment (from norm) are displayed in 5L. This information is used on the actual aircraft to account for changes in the aircraft performance relative to it’s original engineering specifications. It is not relevant to the simulator.
Company data identifier is displayed in line 5R.

POS INIT Page: The POS INIT page allows for position initialization of the Inertial Reference System (IRS). The POS INIT page is selected by pressing LSK at the POS INIT> prompt, or by selecting <POS INIT from the INIT/REF INDEX page.

The primary function of this page is to initialize the airplane’s starting position for the Inertial Reference System. This is done by entering a “starting position” into the 6R LSK to satisfy the box prompts that indicate the IRS is in need of starting position data.

The fields displayed on the POS INIT page are as follows:

LAST POS: This reference position is the last recorded position of the aircraft at the time the aircraft was powered down, or at the time the brakes were last set. If determined to be applicable, this information can be down-selected via the scratchpad to satisfy the position initialization requirements of line 4R.

Crews are advised to use caution when down-selecting the LAST POS reference position, as it may contain accumulated IRS drift inaccuracy from the previous flight. In addition, if the aircraft has been towed to a new gate or moved while the IRS was not aligned, the reference position will be inaccurate.

Additionally, if the LAST POS data contains the shutdown information from a flight you ended at a different airport, it will have a significant negative impact on the performance of the FMC for your new flight.

We recommend the use of GPS position when available as it is generally considered to be most accurate and current.

REF AIRPORT: Entry of a reference airport ICAO code (International Civil Aviation Organization) will provide an IRS reference position to become available in 2R. This reference position can be down-selected via the scratchpad to satisfy the position needs of 4R if desired.

This can be easily accomplished by entering the ICAO airport code into the scratch pad:

![Image of POS INIT page with ICAO airport code]

Then up-select to the 2L LSK:

![Image of POS INIT page with additional position information]

This will add the additional position information of the airport starting position to the right side of the CDU screen, thus providing a third option for position information for the FMC.

Note: To give a good example of why the LAST POS information should be used only when carefully checked, we shut the airplane down at the conclusion of a previous flight, then loaded the simulator at a different airport. Notice the vast difference in position information between the GPS position, AIRPORT position and the LAST POSITION displayed on this image!
**GATE:** The gate position reference allows the crew to select a Lat/Lon position reference based upon the gate at which the aircraft is currently parked. This function is dependant upon whether or not the gate position is included in the airport’s SIDSTAR file.

**SET IRS POS:** The prompt boxes at 4R indicate that current aircraft position has not be initialized, or that any of the Inertial Reference Units are in the align mode. (If neither of these conditions is true, then 4R will be blank.)

To satisfy the prompt boxes at line 4R, the reference latitude/longitude position can be entered directly into the scratch pad, then line selected to 4R, or by -selection of the LAST POS or REF AIRPORT or GPS reference position via the scratch pad.

Once the position initialization process is satisfied, the POS INIT page will have three complete reference positions entered in lines 1R, 2R and 4R.

**GMT:** Line 5L displays the current time in GMT according to the airplane’s clock.

**POS INIT Completion:** Once the POS INIT process has been completed, the <INDEX prompt at 6L will display the INIT/REF INDEX page, or the ROUTE> prompt at 6R will display the route pages.

**RTE Page:** The RTE page allows for entry of the origin, destination, company route name and flight number for the planned flight. The RTE page also allows the planned departure runway to be entered in order to facilitate proper use of Standard Instrument Departure procedures stored within the FMC database.

The RTE page is accessed either by pressing the RTE key on the FMC/CDU keypad or by selecting the ROUTE> prompt from the POS INIT page.

The fields displayed on the RTE page are as follows:

**ORIGIN:** The airport of origin for the flight. Valid entries include any four letter ICAO airport code.

**DEST:** Airport of destination. Valid entries include any four letter ICAO airport code.
FLT NO: Airline code and flight number. Valid entries are any alpha numeric combination not including + or -. The flight number will automatically be displayed on the PROGRESS page as well, and may be changed but not deleted. Entry of the flight number into the RTE page will automatically enter the flight number for both RTE 1 and RTE 2.

CO ROUTE: The title name of an FMC database stored Company Route. Entering a CO ROUTE in 2L will open this route for use.

RUNWAY: The runway prompt allows for selection of the departure runway. This will allow the FMC to properly plan navigation from the correct runway navigation point and offer the correct departure procedures for that runway.

RTE 2: Allows for entry and modification of second FMC memory stored route.

ACTIVATE: Upon completion of route selection, whether by CO ROUTE entry, or by manual flight planning (as described later), the route can be activated by selecting the ACTIVATE> key (6R) and pressing the lighted EXEC mode key on the FMC/CDU keypad.

PERF INIT Page: After completing the POS/INIT page, press the INIT/REF key. The FMC will take you to the next logical page in the FMC initialization sequence. This page is the PERF INIT page where some basic performance parameters for the flight are entered into the FMC.

The fields displayed on the PERF INIT page are as follows:

GR WT: Aircraft Gross Weight displayed in thousands of pounds or Kilograms. Immediately to the right of the prompt boxes on line 1L, the FMC Weight and Balance System (WBS) estimated aircraft weight is displayed in small font. GR WT can be confirmed either by entry via the scratch pad, or by selecting (confirming) the 1L WBS estimated figure.

A confirmed GR WT figure is displayed in large font, while an estimated or unconfirmed figure is displayed in small font.

It is possible to delete the GR WT figure in 1L, by selecting DEL, the pressing the 1L key. Deleting the 1L GR WT figure will cause the WBS gross weight figure to be entered into 1L in small font.

GR WT should always equal the aircraft zero fuel weight plus the total fuel weight.

FUEL: The FUEL indicator displays the current fuel weight loaded in thousands of pounds. The fuel weight will always be suffixed by one of the following:

- CALC: Fuel quantity has been calculated by the FMC using fuel flows. Prior to engine start- this value will always equal the quantity of fuel indicated by the Fuel Quantity Indicating System.

- SENSED: Fuel quantity is the FQIS value.

- MANUAL: Fuel quantity has been entered manually via the FMC.
If the FQIS is deactivated or inoperative, prompt boxes will alert the crew to enter fuel quantity manually in line 2L. Fuel quantity cannot be entered or deleted manually when SENSED is the current FUEL mode.

**ZFW:** The aircraft zero fuel weight is displayed in line 3L. Weight is displayed in the thousands of pounds, with an optional decimal point. Prompt boxes alert the crew that the ZFW must be entered manually, however confirmation of GR WT and FUEL fields will automatically update the ZFW field. ZFW figures will be displayed in small font until confirmed by LSK selection. **Note:** You can automatically populate the ZFW data by pressing the associated LSK.

**RESERVES:** The reserve fuel weight is displayed in line 4L. Prompt boxes alert the crew that a reserve fuel weight in thousands of pounds must be entered. If no weight is entered, a default value of 4000 pounds will be assumed.

The value entered for fuel reserves is used by the FMS to determine an insufficient fuel condition, and will also be used to calculate performance predictions for the flight.

**Cost Index:** The cost index number is a scale value from 00 to 99 (0000 to 9999 on actual aircraft) which helps to determine a level of economy for aircraft performance calculation.

Cost index is calculated as the aircraft operating cost divided by fuel cost. \( \left( \frac{\text{$/hour aircraft operating cost}}{\text{Fuel Cost in Cents/Pound}} \right) \) A cost index of 00 will result in the maximum cost economy, with slow climb rates, maximum range cruise and slow descent speeds predicted by the FMC in order to minimize fuel burn. A high cost index will result in higher climb, cruise and descent speeds. The cost index is designed to provide a relative index of the cost of aircraft operation vs. time en-route.

**CRUISE ALT:** The planned cruise altitude is displayed in 1R. Entry is in feet.

**CRZ CG:** Displays the FMC calculated cruise Center of Gravity as a percentage of mean aerodynamic chord (Percent MAC).

**STEP SIZE:** The planned altitude step size is displayed in line 5R. The FMC will default to a standard ICAO step size of 2000 feet. This will result in proper cruise altitude clearance being maintained (e.g. odd flight levels while east bound, even flight levels while west bound.)

The crew may override the STEP SIZE by entering any value as a four digit multiple of 1000 from 0 to 9000. Entering a 0 value will result in no step climbs being made. If no steps are planned, it is important that 0 be entered in this field in order to accurately predict fuel consumption.

Deleting the pilot entered STEP SIZE will revert the figure back to ICAO.
BUILDING A FLIGHT PLAN

Overview: The capability of the FMS to perform complete 2D navigation in either the VNAN or LNAV mode and 3D navigation when these modes are used together is a powerful product of the FMC. In order to utilize this capability to its fullest extent, however, requires that the FMC have a complete and accurate route process programmed throughout the duration of the flight.

The ability of the crew to interact with the FMC, as well as their ability to understand and utilize its capabilities in congested airspace and during busy departure and arrival procedures will both enhance the safety of the operation and improve the accuracy to which the aircraft is flown.

Conventions: One of the most powerful flight planning features the FMC makes available to the crew is the stored FMC database of navaids, waypoints and intersections. For flight planning purposes, the crew is able to use nearly any geographically fixed navigation point, including flight plan defined waypoints such as latitude/longitude points, place/bearing/distance (PBD) waypoints, along-track waypoints, course intersection waypoints, runway extension waypoints, final approach fixes and latitude/longitude reporting points.

Flight plans can be entered into the FMC by manual entry, or by recalling a stored Company Route from the stored FMC database. Once entered, routes can also be saved and recalled in the future as company routes.

Two separate routes can be entered into the FMC, and the crew may switch between active routes while in flight. At all times, the crew should reference the title line of the RTE page to determine which route is currently selected as active.

RTE Page: The route page may be access using the RTE mode key or by select the ROUTE> prompt when displayed on the TAKEOFF REF, POS INIT or POS REF pages.

The RTE page is used to describe the planned route by origin, destination, flight number and, if available, company route name. The page is shown below, with the ICAO identifiers for ORIG and DEST already entered, as well as the airline code/flight number.

CO ROUTE: If a company route was previously stored for this flight, entry of the stored route name into line 3R via the scratchpad will automatically load the flight plan. This will eliminate the need to enter ORIG and DEST, as well as eliminate the need to program the route of flight in the RTE LEGS pages.

We have provided more than 350 routes covering various parts of the world. They are located in the Flight Simulator/PMDG/FLIGHTPLANS directory. Entering ADLBNE001, for example into the 3R LSK will automatically load a flight between Adelaide and Brisbane.

We regret that this version of the FMC does not currently have the ability to actively list all saved routes for easy display within the FMC itself. This is planned for future versions, however!

RWY: The origin airport planned runway can be entered into 3L Valid entries are RWxxY, where xx is the runway number and
Y is the runway designation of L, R or C as applicable.

**Using Airways to define a route:** Once the origin and destination have been entered it is time to begin defining the route of flight using airways in order to minimize the amount of manual data entry conducted by the crew.

Airways are defined using the TO and VIA prompts as follows:

**TO:** This prompt, located on right side is where the name of fixes defining the starting and ending points of segments along the route are entered.

**VIA:** This entry describes how the airplane will reach the associated fix in the TO prompt. The VIA field may contain the following:

- DIRECT
- An airway segment (e.g.: J1, V305)
- A SID identifier (e.g. LOOP6)
- A SID with an enroute transition
- An approach segment identifier (e.g. ILS04R)
- APPR TRANS for approach transitions
- MISSED APPR for missed approach segments
- ‘- - - - - -’ indicating available for entry.

For example, the text DIRECT indicates that the airplane will navigate directly to the fix described under TO, but the name of an airway would indicate that the airplane is to follow a specific airway in order to reach the fix listed under TO.

And example of DIRECT to the SEA VOR is shown below:

![Example of DIRECT to the SEA VOR](image)

**A Defined Airway Segment:** A defined airway segment has pilot defined starting and ending waypoints. A defined airway segment is entered by inserting the airway identifier into the VIA field on the line that follows a TO field containing the airway segments starting waypoint.

Using our previous example of crossing SEA, we can use the SEA VOR as the starting point on a Defined Airway Segment the follows J1 from SEA to the RED BLUFF VOR located just north of Oakland, California.

To do this, we simply enter J1 into the scratch pad and upload to the 2L LSK:

![Entering J1 into the scratch pad](image)

This creates prompt boxes at the 2R LSK to indicate that we are expected to list a fix at which we expect to leave J1. Or, described another way, “where are we taking J1 TO?”

In our example, we will take J1 to the RBL VOR, so we upselect RBL to 2R.

![Upselecting RBL to 2R](image)

In the event that we were transitioning from J1 to J65, for example, we could upselect J65 to VIA and an exit point such as SMF to the TO column. This would instruct the FMC to build the flight plan along J1 until reaching RBL, then change to J65.

**Using Navigation Database Waypoints:** You can define the route of flight by individual waypoints contained within the database by entering and upselected a valid waypoint name into the TO prompt on the RTE page.

**SELECT DESIRED WPT page:** When entering a navigation fix, if an ambiguity results from the fact that more than one fix in
the database shares a common name, the FMC will present the crew with the SELECT DESIRED WPT page from which to select the correct/desired WPT.

The VORs are ordered by distance from the fix prior to the entry selection, or the airplane’s current position if no fixes have been entered. Pressing a left side LSK will select the desired item into the flight plan automatically.

**RTE Page Variable Modes:** Depending on the phase of flight, the RTE page will display one of three prompts at 6R.

**ACTIVATE:** The ACTIVATE prompt is an alert to the crew that the route currently selected is not an active flight plan in the FMC. Selecting ACTIVATE (when the initialization process is complete, or during flight when deliberately changing between RTE 1 and RTE 2) will activate the selected route.

**PERF INIT:** This prompt is shown in flight when a flight plan is currently active in the system. Selecting 6R will display the PERF INIT page.

**OFFSET:** During non-departure/approach phases of flight, the OFFSET prompt will become available at 6R. This prompt allows the crew to select a parallel flight track offset from their planned flight track by a crew specified distance. This procedure can be used for weather avoidance or offset flight track assignments from ATC. Valid entries are LXX (where XX is a distance figure between 1 and 99nm) or RXX or 0, to delete a selected OFFSET.

**RTE LEGS Page:** The RTE LEGS page is another area where manual entry of a flight plan may take place. The RTE LEGS page is used during the flight planning process to define the route of flight for the FMC on a waypoint by waypoint basis and in flight to perform operations such as a DIRECT-TO routing. The RTE LEGS page displays the individual legs of a flight plan as defined by their individual waypoints after the flight plan has been manually entered or selected using the CO ROUTE function or having been entered on the RTE page as described in the earlier section.

The RTE LEGS page is activated by pressing the LEGS key on the FMC/CDU keypad.

Page 1 of the RTE LEGS page is shown for the example KSEA-KSFO flight plan along J1 to RBL as described in the previous section.

The Title line of the page describes which route is currently being displayed on the RTE LEGS page. The upper right hand corner shows which page of the LEGS display is currently being shown. The NEXT PAGE and PREV PAGE keys are used to scan forward and back. Page 2/2 appears as:
At the bottom of the LEGS display, the <RTE 2 LEGS> prompt allows the crew to display RTE 2 legs and waypoints if a RTE 2 has been programmed.

The ACTIVATE> prompt allows the crew to activate the current flight plan, if this has not already been done.

Course To Information: When navigation fixes are shown in the flight plan, the RTE LEGS page provides, for each fix, a course-to-heading. This course heading will appear in lines 1L through 5L, and represents the course that must be flown in order to reach the next waypoint. The course displayed at the first displayed waypoint (1L) is the course from the airplane’s current location to the first waypoint displayed. (In this example, a course of 223 degrees will take us to the SEA VOR.) All other course indications are the course that must be flown from the previous waypoint to the next waypoint in the flight plan.

Leg Distance Information: The center of the RTE LEGS display provides leg distance information for each leg of the flight plan. Once again, the distance displayed at 1L is the distance from the current aircraft position to the first navigation fix in the flight plan. All other distance indications represent the distance between the previous and next legs of the flight plan.

When the Navigation Display is in PLN mode, a <CTR> indicator will appear in the center column of the display as well.

The <CTR> indicator identifies which fix the flight plan is currently centered on when viewed in the PLAN mode on the navigation display.

Note that the <CTR> prompt is next to DREWS intersection, which is displayed at the center of the navigation display.

This process can be used to validate the entry of a flight plan in the FMC.

Speed/Altitude Predictions or Constraints: When the FMC flight plan is fully initialized, the FMC will calculate a set of predicted altitude and speed values for each leg of the flight plan. These predictions appear in
small font in lines 1R through 5R. The FMS will provide these predicted altitude and speed values for each navigation fix unless the crew manually enters constraint values into the flight plan.

Constraint (or desired) values may need to be entered by the crew in order to adhere to published approach procedures or ATC clearances. Constraint values are entered by typing them manually into the scratchpad, then up-selecting them to the desired flight plan leg.

Altitude Constraints: The use of altitude constraints allows the crew to enter either ATC assigned waypoint/altitude constraints, or to program waypoint/constraints assigned by published approach procedures. Altitude constraints are entered by direct entry into the scratchpad, the up-selecting them to the desired line of the flight plan.

The available altitude constraints are as follows:

- AT constraints.
- AT OR ABOVE constraints.
- AT OR BELOW constraints.

AT constraints are used to indicate that the airplane must be at a specific altitude when crossing the associated fix. Entry of AT constraints can be in feet of flight level. (e.g. 18000 or FL180) AT constraints are simply entered into the scratchpad and up-selected to the desired navigation fix LSK.

AT OR ABOVE constraints are used to indicate that the airplane should cross the associated fix at a specific altitude, but may also cross at a higher altitude if the FMS calculates that it is more efficient to do so given the current flight disposition. The AT OR BELOW altitude constraint can be entered in feet or flight level. (e.g. 18000 or FL180) AT OR BELOW constraints are entered into the scratchpad in the format XXXXXB or FLXXXB and up-selected to the desired navigation fix LSK.

Speed Constraints: Speed constraints can be used by the crew to comply with ATC assigned speed constraints directly associated with a particular navigation fix. E.g. “Cross RBL at 300 knots.”

Speed constraints must always be entered in association with an altitude constraint, and are entered numeric format from 100 to 400 knots Calibrated Air Speed, followed by the ‘/’ indicator which separates the speed constraint from the altitude constraint. (e.g. ‘XXX/FL180A’)

ABOVE and BELOW modifiers are not possible for airspeed constraints.

Maximum Number of Flight Plan Legs: The RTE LEGS page is only capable of storing 120 legs per route. The capacity of both RTE 1 and RTE 2 combined allows for a complete flight plan entry of up to 240 legs if necessary.

If a crew member attempts to insert more than 120 legs in either route, the ROUTE FULL prompt will appear in the scratchpad, and the attempted entry will be discarded.
DEFINING AND USING CUSTOM WAYPOINTS

Overview: On of the most powerful features of the PMDG 747-400’s FMC is the ability to define waypoints based upon the location of other, known fixes in the navigation database.

Making custom navigation fixes allows the crew to define a point anywhere in 3D space toward which the airplane can be navigated.

Navigation Fix Entry: Navigation fixes are entered into the left side of the RTE LEGS page individually via the scratchpad, or on the right side of the RTE page under a TO prompt. Navigation identifiers/Fixes can be comprised of the following:

- Airport
- Waypoint
- NDB
- VOR
- VOR/DME
- VORTAC
- DME/TACAN
- Runway
- Latitude/Longitude Points
- Place/Bearing/Distance Points (PBD)
- Along-track waypoints
- Course intersection waypoints
- Runway extension waypoints
- Final approach fixes

Navigation fixes can be entered into the RTE LEGS page in a number of formats. In most cases, crew members will navigate using existing navigation fixes such as published waypoints and VORs. These types of navigation fixes can be entered directly into the RTE LEGS page by name, and will be called from the stored FMC navigation database.

In some cases, however, it becomes necessary for crew members to provide unique navigation fixes or waypoints to the FMC in order to satisfy the changing ATC requirements, or in order to clearly define an unusual published approach for the FMS. In such cases, it is possible for the crew to define navigation waypoints in the FMC using position and altitude data relative to existing waypoint entries.

Currently, the PMDG 747-400's FMC is capable of accepting waypoints in the following formats:

- FMC Navigation Database Defined Waypoints/Fixes.
- Along Track Waypoints.
- Place Bearing/Distance Waypoints (PBDs)
- Latitude/Longitude Waypoints.
- Place Bearing/Place Bearing (Course Intersection) Waypoints

The process for entering these five types of waypoints is described below.

FMC Navigation Database Defined Waypoints: Navigation database defined waypoints can be directly entered into the left fields of the RTE LEGS page by entering the fix name into the scratchpad and up-selecting to the desired line. Valid entries are one to five character alphanumeric entries. If more than one navigation fix shares an identical name, the FMC/MCDU will display the SELECT DESIRED WPT page and the crew will be prompted to select the desired fix.

Navigation Database Defined Waypoints are useful when:
- Navigating along a specific route that is defined by navigation fixes.
- Navigating directly to a specific fix.

Along Track Waypoints: Along track waypoints are commonly used to mark a descent or climb restriction that is issued by ATC in reference to a navigation fix that exists along the route of flight.

Along Track Waypoints are the simplest of the custom waypoints, because they are entered exactly as issued by ATC.

For example, if ATC were to issue the following climb restriction, “descend and maintain FL180 25 miles from RBL VOR”
the crew simply enters the restriction into the FMC as an along track fix by using the following format:

**FFF/#DD**

(Note: The # above should be replaced with either a + or a – sign. + signifies beyond the waypoint while a – signifies before the waypoint.)

This, in this example, we would the following into the scratch pad:

Since we want this fix to **precede** RBL, we up-select the fix to the line containing RBL, and the FMC will insert the fix and move RBL down a line to accommodate the new, custom waypoint.

The along track waypoint that has been created is now listed in the flight plan using the format PPPss, where PPP is the first three letters of the fix name upon which the custom waypoint is based, and ss is a sequence number assigned by the FMC.

**Along Track Waypoints are useful when:**
- ATC has defined some action or restriction along the route of flight that is based on a distance from/to a specific point in the flight plan.
- The crew wishes to define a point in 3D space along the path of flight such as a Descent point or visual approach point.

**Place Bearing/Distance Waypoints:** PBD waypoints can be entered into the left fields of the RTE LEGS page by entering the fix description into the scratchpad and up-selecting to the desired line. PBD waypoints work by describing a geographic point that is at a specific bearing and a specific distance from a navigation fix which is already defined in the flight plan or the FMC navigation database.

PBD waypoints come in handy when defining a point in space that is no currently a navigation fix. For example, if ATC were to request “after crossing RBL proceed direct to point 42 DME on the 280 radial of the HNW VOR” we can easily define this point in the FMC, thus simplifying our navigation solution.

The proper format for entering a PBD waypoint into the scratchpad is as follows:

**PPPPPBBB.B/DDD.D**

Where PPPPP is the existing navigation fix name (1 to 5 alphanumeric characters), BBB.B is the bearing and DDD.D is the distance. (The decimal place is considered to be optional for both bearing and distance.)

Thus, to define the point assigned by ATC, we enter the following into the scratchpad:

Up selecting this PBD waypoint will result in the fix being added to our flight plan in the same PPPss format as described above.
PBD bearing entries from 0 to 360 degrees and distance entries from 0 to 700 miles are valid.

*Place Bearing Distance Waypoints are useful when:*

- The crew must define a waypoint based upon a certain bearing and distance from any other point in the flight plan or navigation database.
- Constructing approaches by hand to simplify navigation to a VFR runway.
- Simplifying off-route navigation.

**Course Intersection (Place Bearing/Place Bearing) Waypoints:** Course Intersection waypoints, also known as Place Bearing/Place Bearing waypoints are fixes defined by the intersection of courses from two different fixes. The PB/PB waypoint garners its name from the fact that the waypoint is being defined at a point which is one bearing from one place and one bearing from another.

For example, if ATC asked that our flight plan to cross the intersection of the 120 radial from HNW and the 000 radio from MOD, we can define the point using a PB/PB waypoint.

The proper format for entering a PB/PB waypoint into the scratchpad is as follows:

```
XXXXXBBB.B/YYYYYBBB.B
```

XXXXX and YYYYY represent the existing navigation fixes which are being used to describe the PB/PB waypoint. BBB.B represents the bearing from each existing fix. The decimal point is optional in the bearing entries.

We then up-select this entry to our flight plan, and the new waypoint is added to our flight plan in the PPPss format. Note that since this is the second waypoint we have constructed using the HNW VOR, the sequence number is incremented.

A second example of the PB/PB in practical application comes from defining points along an approach path. If, for example, an approach or STAR has an altitude restriction that is based upon the intersection of a VOR radial across your path of flight, you can use a PB/PB waypoint to make the point appear visually on your flight plan along with the associated speed/altitude restriction.

PB/PB waypoints can be constructed using any fix in the flight plan or in the FMC navigation database.

**PB/PB Waypoints are useful when:**

- Navigating to a location that is defined by the intersection of two radials from other fixes.
- Defining crossing restrictions and/or speed restrictions that are based upon a radial from a fix crossing your route of flight.

**Latitude/Longitude Waypoints:**

Latitude/Longitude waypoints are pilot entered waypoints defined by a specific geographic reference in a latitude/longitude format.
The proper format for entering a Latitude/Longitude waypoint into the scratchpad is as follows:

NXXXX.X/EXXXX.X
SXXXX.X/WXXXX.X

For example, entry for a latitude/longitude waypoint at the geographic location N78° 38.8' E120° 34.7' would be entered as follows:

![Latitude/Longitude entry example](image)

The entry is then up-selected to the desired line in the RTE LEGS display, where it will be condensed for display in the route, as shown below. The expanded entry can be redisplayed on the scratchpad by pressing the associated LSK.

![Expanded entry display](image)

This type of entry is considered a “long format” Latitude/Longitude entry.

A short form entry is also available that follows the format:

NXXXXX
SXXWXXX

The position N47° 00.0' W93° 00.0' for example can be entered as:

![Short form entry example](image)

Lat/Lon Waypoints are useful when:

- The route of flight is defined using lat/lon navigation points.
- The crew wishes to define lat/lon points as reporting points during oceanic crossings.

SELECT DESIRED WPT Page: In some cases, an ambiguity will occur when entering navigation data if more than one fix shares the same identifier. These types of ambiguities generally only occur with navigation aids that are located in vastly different geographic areas. Given the nature of the 747-400’s range and the storage capability of the FMC navigation database, it becomes important for the crew to validate the navigation aids being entered to ensure accuracy.

The SELECT DESIRED WPT page (below) will be displayed in the event of a navigation fix name ambiguity:

![SELECT DESIRED WPT page](image)

All navigation aids with names identical to that entered in the FMC scratchpad will be displayed. In some cases, the crew member may need to use the NEXT PAGE/PREV PAGE keys to page through multiple displays in order to locate the desired fix.

Specific information related to each fix displayed on the SELECT DESIRED WPT page is provided in order to assist the crew member in selecting the appropriate fix.

Identifier and Fix Type: The identifier which was entered into the scratchpad will appear in small font at the beginning of each line on the display, followed by the fix type represented by each LSK.

Fix types available are as follows:
• ARPT
• DME
• ILS
• ILSDME
• LOC
• MLS
• MLSDME
• NDB
• TACAN
• VOR
• VORDME
• VORTAC
• WPT (waypoint)

**Fix Frequency**: When the fix type is a radio navigation aid, a frequency will be displayed in the appropriate line. Frequencies are displayed in lines 1L through 6L.

**Fix Position**: The latitude/longitude position of the navigation fix is displayed in lines 1R through 6R.

The left or right LSK can be used to select the desired navigation fix from the SELECT DESIRED WPT page. Pressing any of the LSKs will cause that navigation aid to be entered into the flight plan as normal.
FMC ARRIVAL/DEPARTURE PROCEDURES

DEP/ARR INDEX Page: The DEP/ARR INDEX page allows the crew to select published arrival and departure procedures at the origin and destination airports. STAR (Standard Terminal Arrival) and SID (Standard Instrument Departure) procedures are contained in the FMC's navigation database and can be used in conjunction with departures and approaches to the airports for which they exist.

PMDG has long had a strong partnership with PlanePath, the provider of the vast majority of SID/STAR procedures for the PMDG FMC. PlanePath takes one of the few known free access SID/STAR databases and produces a monthly update similar to the Navdata AIRAC cycle.

PlanePath's FMC database is updated on the downloads page of www.precisionmanuals.com on a monthly basis as the new procedures are provided by PlanePath.

A second repository of user designed procedures is available for download from www.navdata.at

We recommend that users check the various user sites for SID/STAR updates, as the existing database covers only a few thousand of the tens of thousands of procedures worldwide.

The DEP/ARR INDEX page is accessed by pressing the DEP/ARR key on the FMC/MCDU keypad.

The 1L, 3L and 6L keys allow for selection of SID procedures stored in the FMC SID database. Keys 1R through 4R and 6R allow for selection of STAR procedures stored in the FMC STAR database. The center of the display shows the crew entered or COMPANY ROUTE entered arrival and departure ICAO airport codes.

Additionally, the display is divided sections for RTE 1, RTE 2 and OTHER. The RTE 1 and RTE 2 sections allow selection of SID and STAR procedures for those respective routes. The OTHER sections allows for inspection of SID and STAR procedures at an airfield entered into the scratchpad.

DEPARTURES Page: Departure procedure selection is made by pressing the appropriate <DEP prompt from the DEP/ARR INDEX page. The <DEP prompt for the active route should be chosen unless the secondary route is being built. Pressing the <DEP prompt key will display a DEPARTURES page for the selected airport. The DEPARTURES page allows the crew to select the SID and associated runway to be used. A sample DEPARTURES page is shown below:

Runway: The available departure runways for the selected airport are listed down the right side of the screen. Pressing an associated LSK will cause all other runways to be removed from the screen and a <SEL> indicator will be placed next to the selected runway to indicate that it has been selected as the departure runway.
Selection of a departure runway before selection of a SID will also instruct the FMC to remove any SID procedures that do not originate from the selected departure runway.

**Standard Instrument Departures:** The SIDS are listed on the left side of the display at 1L through 5L. A SID can be selected by pressing the associated LSK. Once a SID is selected, a <SEL> indicator will appear next to the associated SID to indicate that it has been selected.

If the DEPARTURES page displayed is for the active route or for the airport of origin, selecting a SID or runway will automatically insert the appropriate fixes into the flight plan and update the runway selection on the RTE page. To alert the crew that these changes have been made, and to allow for verification, the EXEC key will illuminate. Pressing the EXEC key will confirm the selections, but a route discontinuity flag will be displayed in the RTE LEGS pages between the newly added SID and the previously programmed route.

Pressing the illuminated EXEC key will confirm the Runway and SID selections and make them active in the flight plan.

When the runway and SID are active in the flight plan, they will change to magenta on the navigation display, and the <SEL> indicators will change to <ACT>.

**ARRIVALS Page:** Arrival procedure selection is made by pressing the appropriate ARR> prompt on the DEP/ARR INDEX page.

There will always exist two ARR> prompts in order to account for the possibility that the flight may need to return to the departure field.

Selecting the ARR> prompt for KSFO will allow the selection of a STAR and eventually a runway for approach and landing.

Similar to the process used for runways and SIDs, it is important that crews understand that the selection of a STAR will cause the FMC to remove from view any runways that are not served by that STAR. Likewise, selecting an arrival runway will remove from view any STARs that do not connect to the selected runway.

**Standard Terminal Arrival Route:** The STARs are listed on the left side of the display at 1L through 5L. A STAR can be selected by pressing the associated LSK. Once a STAR is selected, a <SEL> indicator will appear next to the associated STAR to indicate that it has been selected by the crew.
Approaches: The available approaches for the selected airport and STAR are listed at 1R through 5R. Pressing the associated LSK will illuminate a <SEL> indicator on the selected approach to indicate that it has been selected by the crew.

If the ARRIVALS page displayed is for the active route or for the airport of destination, selecting a STAR or an approach will automatically insert the appropriate fixes into the flight plan. To alert the crew that these changes have been made, and to allow for verification, the EXEC key will illuminate. Pressing the EXEC key will confirm the selections.

Selection of an ARRIVALS procedure does not need to be accomplished during the pre-flight process, but is included here for balance and clarity. Arrival procedures are normally selected during the initial approach planning phase of the flight.

Changing a SID/STAR/RWY: After selecting a SID/STAR or RWY, it may become necessary to change the procedure as a result of the changing ATC environment.

To effect the change, simply bring up the DEP/ARR page using the mode key, and press the LSK adjacent to the item you wish to change. This will repopulate the list of available options and allow a new selection.

It will be necessary to EXEC the changes in order to enter them into the flight plan.
FMC FLIGHT PLAN MODIFICATION

Overview: During the course of a flight it often become necessary to adjust a flight plan in the FMC in order to keep it consistent with ATC clearances, shortened routings or route deviations. Using the appropriate FMC function entry to modify a flight plan greatly reduces crew workload when route of flight changes are necessary.

Direct-To: Direct-To flight plan entries instruct the FMC to fly a course direct to a particular fix. The fix may be part of the active flight plan, active modified flight path, or it may be off the intended path of flight.

Direct-To routings are useful for shortening the route of flight when ATC clearance is obtained to eliminate certain navigation fixes in a stored flight plan, as shown below:

After the desired fix has been entered into the scratchpad, it should be up-selected to 1L by pressing the LSK. This will create a MOD (modification) to the flight plan which will be visible in the FMC and on the navigation display. The flight plan will have been modified to eliminate the waypoints which are being bypassed in the Direct-To operation. If the Direct-To fix is the last fix in the active flight plan, a ROUTE DISCONTINUITY warning will be displayed by the FMC. This warning can be extinguished by selecting the appropriate approach fixes from the DEP/APP display, or by manually entering additional navigation fixes.

Pressing the EXEC key will confirm the change, or pressing <ERASE will cancel the Direct-To selection. Once the <EXEC key has been pressed, the FMS will be updated to fly Direct-To the desired fix.

Intercept Course: An intercept course is similar to the Direct-To operation. An intercept course instructs the FMC to intercept a particular course before flying that course directly to a station.

A Direct-To routing is performed by displaying the ACT RTE LEGS page or the MOD RTE LEGS page, then entering the desired fix into the scratchpad. This can be done by manual entry, or by down-selecting the fix from the displayed flight plan.
Intercept Course entries are useful for complying with SID and STAR transitions, or for complying with an ATC instruction such as, “fly heading 150 until intercepting the 290 degree radial to HFD, then fly direct HFD.”

Any time ATC or published route procedures call for the crew to intercept a specific course or heading to/from a navigation fix, the Intercept Course entry can solve the navigation problem simply via the FMC.

An Intercept Course entry is performed by first displaying the ACT RTE LEGS or MOD RTE LEGS page, then entering the desired navigation fix into the scratchpad, or selecting it to the 1L position as a DIRECT.

Once the desired station has been entered into the scratchpad, it should be up-selected to 1L in the ATC RTE LEGS page.

This will change the RTE LEGS display to allow for an intercept course entry to be entered into 6R, as shown above.

6R LSK will show the current aircraft ground track when it first appears. This line is used to enter the desired track TO the assigned fix.

In the current example, our flight has been instructed to fly a heading of 150 until intercepting the 290 radial. As such, we enter the inbound course of 110 degrees (290-180 = 110 on the inbound course!)

This will instruct the FMS to intercept the desired 290 radial TO the fix. The FMS will compute a great circle course between the current airplane location and the closest point of intercept to the desired course. The airplane will fly this computed course unless the crew overrides the computation by manually entering a heading.

In order to fly the 150 assigned heading to the intercept, set the HDG but to 150 and press the knob to trigger HDG SEL mode. Then re-arm LNAV.

Upon crossing the course, LNAV will turn and fly the course TO the fix as programmed.

Pressing the EXEC key will confirm the change, or pressing <ERASE will cancel the Intercept Course selection. Once the <EXEC key has been pressed, the FMS and flight plan will be updated.

If the crew wishes to fly a particular heading or ATC assigned course until intercept, this can be accomplished by selecting that heading in the MCP heading selector window and pressing the HDG knob.

If LNAV is armed, LNAV will engage and begin tracking the inbound course when the
aircraft approaches the intercept course entered into 6R.

**Inserting A Navigation Fix:** During flight it may become necessary to insert a new navigation fix into the flight plan in order to comply with ATC procedures or instructions.

This is accomplished by first displaying the RTE LEGS page for the active route (press the LEGS key on the FMC/CDU keypad.) The fix identifier can then be typed directly into the RTE LEGS page scratchpad, and up-selected to the desired line of the flight plan.

When up-selecting a navigation fix to an existing flight plan, the FMC will add the new fix to the line selected, and move all following navigation fixes down in the sequence. When inserting fixes into a flight plan, the FMC will display a set of prompt boxes in the line immediately following the new fix, along with the message ROUTE DISCONTINUITY. This alerts the crew that they must confirm for the FMC which navigation fix will follow the newly added fix.

In order to continue navigating normally, the route discontinuity must be removed by telling the FMC which fix is to follow the newly added fix.

To confirm the continuation of the route, the waypoint identifier for the next fix in the desired route sequence should be down-selected to the scratchpad by pressing the associated LSK. This fix identifier can then be up-selected to the line containing the prompt boxes. The FMC will then re-sort the flight plan to allow the updated routing.

Pressing the EXEC key will confirm the change or pressing <ERASE will cancel the Intercept Course selection. Once the <EXEC key has been pressed, the FMS and flight plan will be updated.

**Deleting a Navigation Fix:** Navigation fixes can be deleted from the active flight plan using similar methods.

From the RTE LEGS page, use the NEXT PAGE/PREV PAGE keys until the desired fix is displayed on the page, then press the DEL key on the FMC/CDU keypad.

The DELETE prompt will appear in the scratchpad, indicating that the next LSK pressed will cause deletion of that associated flight plan navigation fix.
The desired fix can then be deleted by pressing the associated LSK. This will cause the FMC to produce a modification to the active route which eliminates that fix from the flight plan.

When deleting fixes from a flight plan, the FMC will display a set of prompt boxes in the line immediately following the deleted fix, along with the message ROUTE DISCONTINUITY. This alerts the crew that they must confirm the route continuity at the point of the deleted navigation fix.

To confirm the continuation of the route, the waypoint identifier for the next fix in the desired route sequence should be down-selected to the scratchpad by pressing the associated LSK.

This fix identifier can then be up-selected to the line containing the prompt boxes. The FMC will then re-sort the flight plan to allow the updated routing.
FMC TAKEOFF PROCEDURES

Overview: The FMC provides a number of functions to assist with the takeoff planning process. Specifically, the FMC is capable of taking input from the crew for calculating takeoff speeds, engine thrust limits, engine takeoff thrust derates and autothrottle management.

These features are used as part of the normal pre-takeoff process, and are described below.

THRUST LIM Page: The thrust limit page provides the crew with the ability to manually select the thrust modes which will be used by the FMS to provide thrust limits and thrust commands to the autothrottle servos.

The THRUST LIM page is displayed by pressing the THRUST LIM prompt when the INIT/REF INDEX page is displayed, or by pressing the 6R THRUST LIM> prompt from the PERF INIT page during pre-flight. A sample THRUST LIM page is shown below:

The THRUST LIM page displays three takeoff thrust limit options at lines 2L through 4L. Lines 2R through 4R display climb thrust limit options.

The top of the THRUST LIM display provides an entry point for a pilot-entered assumed temperature at 1L, a current outside air temperature reading in the center of line 1, and a Thrust Limit Mode indicator in line 1R.

Pilot Entered Assumed Air Temperature: The 1L key provides the crew with the ability to enter an assumed air temperature (SEL). Valid entries are one or two digit entries from 0 to 99. This field cannot be changed once the aircraft exceeds sixty five knots, or after autothrottle engagement. The field will be removed once the aircraft becomes airborne.

How is this used?: If planning a takeoff during a period of time when the temperature is changing rapidly, or if the airplane is currently parked in an area where the ambient temperature is expected to be different than the temperature encountered on the runway, it is prudent to enter the temperature that it is expected the takeoff will be conducted in.

For example, if the airplane is parked in the shade of a large hangar, but the runway is in direct sunlight on a hot day, it can be expected that there will be a performance impacting temperature difference between the current OAT (shown on the screen) and the assumed temperature.

Outside Air Temperature: The Air Data Computer measured OAT is displayed in the center of row 1.

Thrust Limit Mode: The currently selected thrust limit mode is displayed in small font in the header line for 1R. In addition, the N1% limit for this thrust mode is displayed in large font at 1R. If the thrust limit mode has been reduced by the assumed temperature entry, the thrust limit mode entry will be preceded by the “D-” derate indicator.

Following are the available thrust limit modes:

- TO Takeoff
- TO 1 Takeoff 1
- TO 2 Takeoff 2
- GA Go-Around
- CON Continuous
- CRZ Cruise
- CLB Climb
- CLB 1 Climb 1
- CLB 2 Climb 2
Takeoff thrust and Takeoff thrust Derates:
Lines 2L through 4L show the available takeoff thrust limit modes which may be selected by the crew. In order, they are:

- **TO**: Takeoff is the normal takeoff thrust mode.
- **TO 1**: Takeoff 1 is the 5% derated takeoff thrust limit mode.
- **TO 2**: Takeoff 2 is the 15% derated takeoff thrust limit mode.

The takeoff thrust limit mode is selected by pressing the associated LSK. When a mode is selected, the <SEL> indicator will move to the associated line to indicate which mode is currently selected. In addition, the takeoff thrust limit mode will be displayed in 1R. Selecting either TO 1 or TO 2 will override any assumed air temperature figure entered into 1L by the crew.

Climb Thrust and Climb Thrust Derates:
Lines 2R through 4R show the available climb thrust limit modes which may be selected by the crew. In order, they are:

- **CLB**: Climb is the normal climb thrust mode.
- **CLB 1**: Climb 1 is the 10% derated climb thrust limit mode.
- **CLB 2**: Climb 2 is the 20% derated climb thrust limit mode.

The desired climb thrust limit mode is armed by pressing the associated LSK. When a mode is selected, the <ARM> indicator will move to the associated line to indicate which mode is currently armed.

If a derated takeoff thrust limit was selected, the FMC will automatically suggest an optimal climb thrust derate given current temperature or assumed temperature entries. This mode can be changed by simply selecting a different climb thrust mode.

In Flight Thrust Modes: When airborne, the THRUST LIM page will not display takeoff or climb thrust modes. These modes will be replaced by the in-flight thrust limit modes. These modes will be displayed in lines 1L through 3L of the THRUST LIM page, and are as follows:

- **GO AROUND**: Go around thrust limit.
- **CONTINUOUS**: Continuous maximum allowable thrust limit.
- **CRUISE**: Cruise limit thrust.

Go around thrust is a limit mode provided for go around conditions, where high engine thrust settings are required for a short period of time.

Continuous thrust limit mode provides the highest thrust output possible from the engines in continuous operation. This mode is useful in situations involving a single engine failure while the aircraft is at high gross weights, or multiple engine failures at high cruise altitudes. This thrust limit mode will provide the highest thrust output possible without damaging the remaining engines.

Cruise thrust limit mode is the normal operating thrust limit mode for normal cruise flight operations.

TAKEOFF REF Page: The TAKEOFF REF page provides information pertaining to takeoff performance and settings. This information includes such settings as flap acceleration height, engine out acceleration height, thrust reduction height, runway slope and wind condition information, runway condition, takeoff speeds, trim and runway position shift information.

Flap Setting/Flap Acceleration Height: The planned flap setting (flaps 10 or flaps 20)
can be entered at line 1L, along with the desired flap acceleration height. If an invalid takeoff flap setting is entered manually at 1L, an error message will be generated. The takeoff flap setting must be correct in order for the FMC to generate the correct takeoff speeds.

The flap acceleration height is entered in feet, and indicates the altitude above field elevation at which the crew desires to begin acceleration to climb speeds. This information will be used by VNAV to decrease pitch and begin the acceleration process. Valid entries range from 400 to 9999 feet.

This height should take into consideration factors such as terrain elevation surrounding the departure airport, noise abatement requirements and the desire to have at least 1500 feet of altitude above airport elevation before reducing the initial climb rate in order to accelerate for flap retraction.

**Engine Out Acceleration Height:** The crew may manually select an engine-out acceleration height by entering the value into line 2L. This is the height at which the flight director and VNAV will begin to decrease pitch for acceleration and flap retraction in the event of an engine failure during takeoff. Valid entries range from 400 to 9999 feet.

This height should take into consideration factors such as terrain elevation surrounding the departure airport, as well as the ability of the airplane to climb effectively on 3 engines given the departure weight of the aircraft and the navigation procedure required to be flown after departure. This altitude will normally be slightly lower than the standard Flap Retraction/Acceleration height.

**Thrust Reduction:** The thrust reduction altitude described in 3L describes the altitude or flap setting at which thrust is reduced from the takeoff setting to the climb setting. This will occur automatically if VNAV and the autothrottle are engaged. The armed thrust mode, as selected in the THRUST LIM page, is displayed at the center of line 3. This indicates which thrust mode the FMC will use when it begins to reduce power from the initial takeoff setting.

Valid entries for thrust reduction can be any altitude between 400 and 9999 (feet above field elevation) or any flap position entry such as 1, 5. An entry of 5 will arm the thrust reduction to commence when the flaps are retracted past 5 degrees in flight.

**Wind/Slope:** Line 4L provides runway wind/slope information to enhance takeoff performance computations on sloped runways, or runways with a headwind/tailwind component. A headwind is described by the ‘H’ indicator, followed by the headwind component. A tailwind is denoted by the use of a ‘T’ indicator.

The FMC will use this information to adjust the calculated takeoff performance.

Runway upsweep and downslide is indicated by a U or a D respectively.

**Runway Condition:** Line 5L allows for pilot entry of the takeoff runway condition. This information is used by the FMC during the takeoff speed calculation process. Valid entries are DRY for dry and uncluttered runways, and WET for wet or cluttered runways.

**Takeoff Speeds:** V1, VR and V2 reference speeds are displayed in lines 1R through 3R. The speeds are initially displayed in small font, to indicate that they have been computed by the FMC based on pilot entered performance initialization.

The crew is responsible for validating the accuracy of these computed takeoff speeds by manually checking them against the manufacturer specified takeoff speeds.

Takeoff speed should be confirmed to the FMC by pressing each of the three LSKs individually after the speeds have been verified. Once confirmed, the speeds will be displayed in LARGE font.
Takeoff speeds can be overridden or manually entered by the flight crew if desired. Valid entries are any three digit number from 100 to 300.

If any changes are made to the takeoff performance initialization after the V1, Vr, V2 speeds have been selected, the FMC will automatically remove them and display a V SPEEDS DELETED warning. This is an indication to the crew that it is necessary to return to the TAKEOFF REF page and revalidate the takeoff performance.

**Stabilizer Trim / Center of Gravity:** The center of gravity and stabilizer trim settings are displayed on 4R. The CG value will be removed once the airplane is airborne.

**Position Shift on Runway:** Line 5R allows for pilot entry of an updated position along the planned departure runway. This procedure is used to update the FMS that the aircraft is not entering the takeoff roll from the threshold of the planned runway, and instead may be using an intersection departure. The position update function allows the pilot to enter a value representative of ‘distance from actual runway threshold’ to alert the FMS at the time the TO/GA switch is pressed.

This feature is not currently modeled in the PMDG 747-400.
Overview: The FMC provides a number of methods to assist the crew in planning, managing, and effecting a precise and economical climb regime of flight. The FMC accepts climb performance demands from crew member entries, and adjust aircraft performance via the FMS and autothrottle servos.

CLB Page: The climb page allows crew access to current and upcoming climb conditions and climb profile information. The active climb speed mode is always displayed in the CLB page.

The CLB page is accessed through the VNAV key on the FMC/MCDU keypad. A typical CLB page is shown below:

CRZ ALT: The cruise altitude is displayed at 1L with the header of CRZ ALT. The current cruise altitude is displayed if one has been selected and CLB is the active mode. If the current altitude is not displayed, 1L will contain prompt boxes which can be replaced by up-selecting the desired cruise altitude from the scratchpad.

Speed Mode: The currently selected cruise speed mode is displayed in small font at 2L, along with the selected Mach number and calibrated airspeed.

Modes displayed at 2L include:
- ECON SPD: Economy speed mode.
- SEL SPD: Manually selected speed mode.
- MCP SPD: MCP speed mode.
- LIM SPD CLB: Limit speed climb
- E/O SPD: Engine Out speed mode.

ECON CLB is the default climb mode, and will provide the best economy in the climb given the current aircraft configuration and cost index. The ECON CLB mode can be selected by pressing the <ECON prompt when the speed mode is not active.

SEL SPD mode is initiated whenever a speed restriction is being observed.

MCP SPD CLB is initiated by setting a speed in the MCP window and pressing the MCP speed knob.

LIM SPD CLB is active when the desired speed is greater than the maximum aircraft speed, or less than the minimum speed allowed for the current aircraft configuration. This mode is displayed when the FMS is preventing overspeed or stall buffet speeds from being flown.

E/O CLB is active when the ENG OUT> LSK has been pressed following an engine failure in the climb. E/O CLB will provide the best climb gradient speed given the current aircraft configuration.

Speed Transition: The speed transition is displayed in line 3L. The transition speed/altitude defaults to 250/10000, but will change to reflect a higher performance limit speed of the aircraft if aircraft speed performance is a factor due to high gross weights.

Speed Restriction: The SPD RESTR fields at 4L allow for manual crew entry of a speed/altitude restriction. Valid entries in this line follow the format:

SSS/AAAAA
Where SSS is the CAS speed restriction, and AAAAA is the valid altitude for the restriction.

Next Climb Constraint: Line 1R displays the next climb constraint called for by the FMC programmed flight plan. The header line for 1R shows ‘AT’ and the name of the next navigation fix. This line will be blank if no climb constraint exists at the listed navigation fix.

Climb constraints will be displayed in the SSS/AAAAA format, with the above or below modifier attached to the altitude.

Direct entry of a speed/climb constraint cannot be entered directly from this page, and must be entered in the RTE LEGS page.

Transition Altitude: Line 3R displays the transition altitude. This value defaults to 5000 feet MSL, but can be changed by up-selecting a new value from the scratchpad.

Maximum Climb Angle/Maximum Altitude: The speed which will yield the maximum climb angle given the current aircraft configuration is displayed in line 4L.

In the event of an engine failure, the MAX ANGLE speed will be replaced with the engine out maximum altitude figure for the current aircraft configuration.

Engine Out Climb Mode: Selecting the ENG OUT> prompt at 5R will result in FMC calculation of engine-out speed schedules, performance predictions and guidance. When selected, the FMC will detect which engines are not operating, and adjust performance predictions and guidance accordingly. If the FMC detects that all engines are operating, then performance predictions for a single outboard engine failure will be used.

All Engine Climb Mode: If the ENG OUT> prompt was selected, it will be replaced with the ALL ENG> prompt. Selection of this prompt will return FMC calculations to an all engines operating mode.

Climb Direct: In cases where the altitude selected in the MCP altitude window exceeds an altitude restriction defined on the RTE LEGS page, the CLB DIR> prompt will be displayed at 6R. This prompt allows the crew to delete all climb restraints below the MCP selected altitude.

This feature can be used when the route of flight has programmed altitude climb constraints which are cancelled by an ATC command to “climb and maintain” a higher altitude.

When CLB DIR is selected, the EXEC light will illuminate to indicate that the action must be confirmed by the crew. When the EXEC key is pressed, the FMC will initiate a climb directly to the MCP entered altitude, and will cancel all altitude constraints between the airplane and the MCP selected altitude.

FMC Climb Profile Logic: The FMC is programmed for a default climb logic which will select a 250 knots or minimum clean airspeed for a climb to 10,000 feet, followed by an economy climb to cruise altitude. The crew may modify this climb profile via the RTE LEGS page.

In the event that the FMC cannot comply with the next altitude restriction programmed into the RTE LEGS page, (either due to rate of climb or speed related concerns) the prompt UNABLE NEXT ALT will be displayed.

FMC Climb / MCP Altitude Selector Interaction: The process which the FMC uses to process input from both the FMC programmed flight plan and the MCP Altitude Selector is called “Altitude Intervention.” This process allows for deletion of altitude constraints using the MCP knob, as well as level off/resume climb operations.
**Constraint Deletion:** If the airplane is climbing, the pilot may select an altitude in the MCP altitude window that is between the current aircraft altitude and the programmed cruise altitude. Doing so will delete the next altitude constraint between the aircraft altitude and the MCP selected altitude. Subsequently pressing the MCP altitude knob will delete, one at a time, any additional altitude restrictions between the aircraft and the MCP selected altitude.

**Level Off/Resume Climb:** If the MCP altitude knob is set to an altitude that is lower than the programmed cruise altitude, the aircraft will level off at the MCP selected altitude. To resume the climb, a higher altitude should be dialed into the MCP altitude window and the MCP altitude knob should be pressed.

**Cruise Altitude Changes:** Cruise altitude changes can also be effected via the MCP altitude knob. Selecting a higher cruise altitude in the MCP altitude window and pressing the MCP altitude knob will automatically update the cruise altitude to the MCP altitude window selected altitude.
**Overview:** Use of the FMC for cruise flight greatly reduces en-route pilot workload, and simplifies the process of providing the greatest level of operating economy possible with the aircraft. The Cruise capabilities of the FMC include fuel management, engine out operations, VNAV cruise modes and altitude step climb operations.

**CRZ Page:** The CRZ page provides the crew with access to current and upcoming cruise profile information. Information displayed in the CRZ page includes the current commanded cruise altitude, cruise speed, N1% target settings, step climb size, next step to fix, next waypoint ETA and fuel, optimum and maximum cruise altitude and engine out cruise setting information.

A sample CRZ page is shown below:

![CRZ Page Example](image)

**Speed Mode:** The active speed mode is displayed in the title line of the CRZ page display. The prefix ACT indicates that the cruise performance mode is active.

Cruise performance modes which may be displayed are as follows:

- **ECON:** The economy cruise performance mode is the default cruise performance mode, and will yield the lowest aircraft operating cost based on the cost index selected. ECON cruise is only available when all engines are operating.

- **MCP:** MCP selected speed cruise performance mode allows the pilot to select the cruise speed based on the MCP speed window setting. This mode is initiated by selecting a desired speed in the MCP speed window and pressing the MCP speed knob.

- **LIM SPD:** The limit speed cruise performance mode is activated when the target speed exceeds either the upper or lower limits of the aircraft speed performance limitations envelope. Examples include overspeed or buffet margins. The LIM SPD indicator will be visible in any cruise operation where the FMC is providing speed envelope protection.

- **E/O:** The Engine Out cruise performance mode provides the best cruise altitude performance in either the single engine out or double engine out operation. This mode is selected by pressing the ENG OUT> prompt after an engine failure in flight.

- **LRC:** Long range cruise mode can be selected for long flights where speed is traded in order to maintain fuel efficiency for long range flight. To activate LRC, press the LRC prompt at 6L, then EXEC the change when the EXEC key illuminates.

Each of the cruise performance modes listed above will also use a VNAV cruise function in order to provide for vertical guidance. The current VNAV cruise mode is also displayed in the title line of the CRZ page, and the modes are as follows:

- **CRZ:** Cruise operation is indicated when the airplane is in level flight with all engines operative.

- **CRZ CLB:** Cruise climb is indicated when the airplane is climbing to a specified target altitude as defined by a step climb or MCP selected target altitude change.

- **CRZ DES:** Cruise descent is indicated when the airplane is descending to a specified target altitude as defined by the FMC entered flight plan, or by a MCP selected target altitude change.
D/D: Drift down is indicated when the FMC begins a drift down procedure due to engine failure at high altitude. The D/D mode will remain as the active VNAV cruise mode until the maximum engine out altitude has been reached and the aircraft has leveled out.

Cruise Altitude: Line 1L of the CRZ page shows the current selected cruise altitude. This information will always be displayed unless a descent mode is activated. Prompt boxes in the CRZ ALT line indicate that crew entry of cruise altitude is required.

Cruise Speed: As long as an active cruise altitude is selected and the aircraft is not descending, line 2L of the CRZ page will display the current cruise mode in small font. The current target cruise speed will be displayed in both CAS and Mach format using large font.

N1% Target: The N1% target is displayed in line 3L. This figure is calculated by the FMC as the target N1% setting based on current aircraft altitude, speed and gross weight.

Step Size: Line 4L displays the currently selected step size. The value of the step will reflect either a crew entered value or ICAO, for a default 2000 foot ICAO defined step size. This value can be changed directly by up-selecting a new, four digit integer that is a multiple of 1000.

If step climbs are not desired, a value of 0 should be entered into this field.

Step To Next Altitude: The next anticipated step fix is displayed in line 1R of the CRZ page. This information allows the crew to plan for upcoming step climb procedures. If the step climb was derived by the FMC based on the step size schedule, the altitude will be displayed in small font. If the step climb was pilot entered, it will appear in large font.

The Step To field cannot be manually updated until after the aircraft has passed the last planned step climb waypoint, or when an altitude is displayed on this line in small font.

Entries to this field are made in a standard altitude format into the scratchpad and up-selected to the appropriate line.

Step Climb Condition Indicator: Line 2L provides the crew with information related to upcoming step climb status. One of the following will be displayed in 2L:

NOW: Indicates that the aircraft has crossed the specified fix and a step climb to the next step altitude can be commenced.

AT: Indicates that a step climb to the step altitude entered in line 1R can take place at the specified location/fix.

AVAIL AT: Indicates that a step climb to the step altitude entered in line 1R cannot take place at the specified location/fix. This is most likely due to MAX ALT restrictions. The displayed DTG/ETA figures indicate when the planned step climb may be initiated.

TO T/D: Indicates that the aircraft is within 200 miles of the top-of-descent point. The displayed DTG/ETA is to the top-of-descent point.

TO AAAAA: Indicates that the airplane is more than 200 miles from the top-of-descent point, but that an engine out drift down procedure is in progress. AAAAA represents the new cruise altitude as calculated by the FMC.

NONE: Indicates that the FMC has determined that no step climb is necessary, or that no step climb should be made.

Next Waypoint ETA/Fuel: Line 3R displays the current ETA for crossing the next waypoint in the flight plan. This line also displays the expected fuel–on-board figure at the time of waypoint crossing. Fuel computations are made under the assumption that all intermediate step climbs will be performed as normal.

Optimum/Maximum Altitude: Line 4R displays the FMC computed optimum cruise altitude and maximum cruise altitude.
Optimum cruise is calculated based on current aircraft configuration, cost index, trip length and cruise mode.

Maximum cruise altitude is calculated based upon the highest usable altitude given the current aircraft configuration, thrust limits, cruise mode, buffet limits and maximum operating speed.

These figures will be automatically adjusted by the FMC in the event of an engine failure during the cruise portion of the flight.

**Engine Out Cruise Operation:** In the event of an engine failure in flight, selecting the ENG OUT> prompt at 5R will instruct the FMC to provide engine-out speed schedules, performance predictions and flight guidance.

In the event that the aircraft is above the maximum engine out altitude at the time of the engine failure, the cruise altitude will automatically be lowered to the engine out maximum altitude.

**Step Climb Operations:** Although step climb capability and step climb points are calculated by the FMC, the responsibility for actually performing the step climb rests with the crew.

Step climbs are executed by changing the MCP altitude window to reflect the desired new cruise altitude. Pressing the MCP altitude knob will cause the FMC to enter a cruise climb.

No step climbs can be executed without pilot interaction.

The FMC makes fuel and flight performance calculation based on the assumption that all step climbs will be made. If flight conditions preclude making the appropriate step climbs, the step climb indicator should be reset to 0.

Two methods can be used for computing and effecting step climbs.

**Optimum Step Climb:** The optimum step climb looks to gain the greatest benefit from airplane performance improvement as fuel weight is burned off. Because drift climbs are not practical in the controlled airspace environment, the FMC will attempt to average out aircraft performance by providing step climbs which will most closely approximate a drift climb.

The FMC will calculate the step points needed based on factors such as cruise performance mode and current aircraft weight, and will compute climbs based on ICAO step size or the step interval entered into the FMC.

The step climb will be calculated to the next step altitude, but cannot exceed the maximum altitude upon reaching that step point. No step climbs will be initiated within 200 miles of the top-of-descent.

**Planned Step Climb:** Planned step points are specified by the crew using crew entered modifications in the RTE LEGS page of the FMC. A planned step entry is made on the RTE LEGS page by entering the step altitude at a specific waypoint followed by ‘S’ to indicate a step point. The FMC will follow planned steps in the flight plan until no further planned steps are encountered. If the FMC determines that further step climbs can be made, they will be computed under the optimum step climb calculation described earlier.

**Cruise Altitude Modification:** The selected cruise altitude can be modified either by direct entry into the CRZ page, or by selecting a new altitude using the MCP altitude knob. (Pressing the knob will command the altitude change.)

If the MCP altitude is set to an altitude that is higher than the current cruise altitude, the cruise altitude will be updated to the new altitude. If the MCP altitude is set to an altitude that is lower than the current cruise altitude and the aircraft is more than 50 miles from the top-of-descent, the cruise altitude will be updated to the new altitude and a descent commenced.

If the MCP altitude is set to an altitude that is lower than the current cruise altitude and the aircraft is within 50 miles of the top-of-descent, an early descent will be initiated at a rate of 1250 fpm until the normal descent path is intercepted.
FMC DESCENT OPERATIONS

Overview: The FMC descent capabilities provide for descent planning and execution. A planned descent can only exist when a lateral route containing at least one descent constraint is active in the RTE LEGS page.

The descent planning features of the FMC allow the crew to set speed transitions, descent path restrictions, and waypoint dependent speed and altitude constraints.

CRZ Page: The CRZ page displayed when pressing the VNAV key on the FMC contains a single item to help crews maintain awareness of the beginning of descent phase. On line 3, the FMC will display a TO T/D to count down distance to the Top of Descent point for the flight.

DES Page: The descent page provides the crew with access to descent planning and information. The DES page is selected by pressing the VNAV key on the FMC/MCDU keypad. The NEXT PAGE/PREV PAGE keys may need to be used if the aircraft is still at cruise altitude. A sample DES page is displayed below:

The following information is provided on the DES page:

E/D AT: The End of Descent At information displayed in 1L describes the altitude and waypoint at which the descent is planned to end.

ECON SPD: Line 2L contains the descent speed mode information. The current descent speed mode is displayed in small font in the 2L header line. The descent speed is displayed in large font, in the CAS/Mach format.

Descent speed modes available are:

ECON DES: The economy descent mode will yield the lowest aircraft operating cost based on the entered cost index. The ECON DES mode will attempt to provide an idle thrust descent unless wind conditions encountered during the descent require thrust.

MCP SPD DES: The MCP selected speed descent mode is a pilot selected descent speed mode. To initiate this mode, the pilot pushes the MCP speed select knob. The speed of the descent can then be adjusted by selecting the desired speed in the MCP speed selector window.

LIM SPD DES: The limit speed descent mode becomes active in cases where the target descent speed exceeds the capabilities of the airframe in either the overspeed regime, or the stall buffet margin. The limit speed is flown by the vertical guidance function.

END OF DES: The prompt END OF DES is displayed in the descent speed mode line when the aircraft has passed the programmed end of descent constraint waypoint.

SPD TRANS: Line 3L displays the speed transition altitude. The line contains the transition speed, followed by the transition altitude in a SSS/AAAA format. This field
may not be updated manually, but it may be deleted by pressing the FMC/MCDU DELETE key, then pressing 3L.

**SPD RESTR:** Line 4L provides the crew with the ability to enter an altitude dependent speed restriction. The line contains transition speed, followed by the transition altitude in a SSS/AAAAA format. The altitude entry must be an altitude below the cruise altitude, but above the End of Descent altitude.

**AT:** Line 1R contains the descent constraint waypoint as defined in the RTE LEGS page of the flight plan. The header line contains ‘AT’ followed by the navigation fix identifier to which the descent constraint is assigned. The constraint is displayed in the DES page exactly as it appears in the RTE LEGS page. The descent constraint cannot be updated or changed from the DES page, but it may be deleted. Deleting the constraint will remove it from the lateral route.

**DES NOW:** When the aircraft is not currently descending, but the MCP altitude selector is set below the current altitude, the DES NOW prompt will be displayed at 6R. The DES NOW> prompt deletes all climb/cruise constraints and commences an early descent. The rate of descent will be approximately 1250 feet per minute until the aircraft intercepts the originally planned vertical descent path which would have commenced at the top-of-descent mark.

**DES DIR:** When the aircraft is descending and the MCP altitude selector is set below the current aircraft altitude, the DES DIR> prompt will be displayed. Pressing the associated LSK will delete all altitude constraints between the aircraft and the MCP selected altitude and the FMC will command a descent to reach the MCP altitude. Upon reaching the MCP selected altitude, the vertical guidance function of the FMC will capture the originally computed vertical path for the remainder of the descent. Unless deleted or modified, all remaining descent constraints will be adhered to.

**OFFPATH DES:** The offpath descent page provides access to “Clean” and speed brake direct descent profiles if the crew does not wish to use the FMC calculated descent path. This page can be access through the <OFFPATH DES prompt in 6L of the DES page or DESCENT FORECASTS page.

**DESCENT FORECASTS Page:** The DESCENT FORECASTS page allows the crew to enter and use forecast values for wind, transition level, anti-ice settings and descent wind direction information. A sample DESCENT FORECASTS page is shown below:
The following information is provided on the DESCENT FORECASTS page:

TRANS LVL: The transition level for the destination airport is displayed in 1L. The transition level can be modified by up-selecting from the scratchpad.

ALT and WIND DIR/SPD: Lines 2 through 5 contain pilot entered wind direction and speed information for specific altitudes. Altitude entries can be entered and up-selected in either the FLAAA or AAAAA format. Wind direction and speed information can be entered and up-selected in a DDD/SSS format.

During the initial data entry, wind speeds must be entered in conjunction with wind direction. For subsequent entries, however, partial entries containing only a direction or only a speed update can be made.

Wind altitude speed and direction entries are made by the crew, and assist the FMC in computing the descent profile as defined in the flight plan.

Descent Profile Logic: The default descent profile logic is to effect an economy descent form cruise altitude to the transition altitude. After passing through the transition altitude, 240 knot descent is commanded. The crew may manually override the default descent profile through the use of speed and/or altitude constraints entered into the RTE LEGS page. The descent profile can also be modified using the MCP speed and/or altitude selector knobs. A combination of RTE LEGS entries and MCP selections can be used to adhere to ATC instructions, or to expedite the descent profile as needed.

During the descent, the aircraft will occasionally reach the descent limit speed regime while attempting to maintain the calculated vertical profile. This can occur as a result of headwinds or tailwinds, or wind forecasts not being entered correctly in the DESCENT FORCASTS page. The DRAG REQUIRED prompt is generally a good indication of a tail wind condition or descent overshoot, while the THRUST REQUIRED prompt generally indicates headwinds, or descent undershoot.

In cases of descent undershoot and overshoot, once the aircraft reaches the limit speeds (upper or lower limits) the vertical guidance function of the FMC will command the aircraft to depart the planned vertical profile while maintaining a descent that most closely follows the planned descent profile.

Adding drag or thrust as required will normally return the aircraft to the planned descent path.

FMC Descent / MCP Altitude Selector Interaction: The process which the FMC uses to process input from both the FMC programmed flight plan and the MCP Altitude Selector is called “Altitude Intervention.” This process allows for deletion of altitude constraints using the MCP knob, as well as level off/resume descent operations.

Constraint Deletion: If the airplane is descending, the pilot may select an altitude in the MCP altitude window that is between the current aircraft altitude and the programmed end of descent altitude. Doing so will delete the next altitude constraint between the aircraft altitude and the MCP selected altitude. Subsequently pressing the MCP altitude knob will delete, one at a time, any additional altitude restrictions between the aircraft and the MCP selected descent altitude.

Level Off/Resume Descent: If the MCP altitude knob is set to an altitude that is between the current airplane altitude and the end of descent altitude constraint, the aircraft will level off at the MCP selected altitude. To resume the descent, a lower altitude should be dialed into the MCP altitude window and the MCP altitude knob should be pressed.
FMC APPROACH PROCEDURES

Overview: The FMC approach initialization process can assist in the effective transition from the descent to the approach and landing phase of flight. The FMC provides the crew with rapid approach calculations for weight/speed data and provides reference information for the touchdown.

APPROACH REF Page: The approach page provides the crew with information directly related to the final approach to landing process. A sample APPROACH REF page is shown below:

The following information is provided on the APPROACH REF page:

GROSS WT: Line 1L provides the current airplane gross weight in thousands of pounds unless the figure has been manually adjusted by the crew. Manual adjustment of the GROSS WT figure is accomplished by up-selecting a manually entered figure from the scratchpad. Valid entries are three digits with an optional decimal point. Crew entered GROSS WT values are used for predictive purposes only, and do not affect aircraft computation of actual gross weight.

Runway Length: Line 4L contains runway reference information to assist the crew in planning the touchdown and stopping phase of flight. The header line in 4L will display the ICAO airport identifier, followed by the runway number and L/C/R designator.

Runway length reference information is provided in large font in 4L, and is displayed in both feet and meters.

FLAPS/VREF: The Vref reference speeds for both the flaps 25 and flaps 30 settings are provided in lines 1R and 2R respectively. These Vref values are directly reported from the aircraft performance database, and will change as the GROSS WT figure in 1L changes.

FLAPS/SPEED: After reviewing the information contained in the APPROACH REF page, the crew can select the desired landing flap setting by down-selecting from either 1R or 2R, then up-selecting this information to 4R.

Additionally, the crew may manually enter a desired flap setting/Vref speed by entering the information into the scratchpad in the format FF/SSS.

If it becomes necessary to update the flap setting/speed entered into 4R, either the flap setting or the speed value may be updated individually. It is necessary, however, to enter them together initially.

The pilot selected flaps setting/Vref speed selector can be deleted by pressing the FMC/CDU DELETE key, the pressing 4R. This will cause the normal speed tape on the primary flight display to show both the flaps 25 and flaps 30 Vref speeds.
**FMC RADIO OPERATIONS**

**Overview:** The radio tuning function is almost entirely managed by the automated logic functions of the FMC. This alleviates the crew from having to manually tune successive radio navigation aids, and allows greater concentration to be placed on terminal navigation procedures, as well as traffic awareness. Understanding what the automated FMC navigation radio function can and cannot do, however, will help the crew to gain the most from the FMC radio tuning system.

**NAV RADIO Page:** The NAV RADIO page, displayed below, provides an overview of how the navigation radios are currently tuned, as well as the ability to manually tune the radios should the crew desire.

- **VOR L/R:** Lines 1L and 1R provide frequency tuning information for the left and right VHF navigation radios. The currently tuned VOR station frequency is displayed in large font, along with the frequency identifier, if the FMC auto-tuning function was able to identify the VHF transmitter.

  - Directly between the frequency and station identifier information, a small font tuning indicator allows the crew to determine what type of tuning mode is currently being employed by each VHF radio.

  - **A:** Auto-selection. The FMC has automatically selected a navaid which will yield the best position and cross radial navigation update information due to its position relative to the path of intended flight.

  - **M:** Manual selection. The displayed station or frequency was tuned manually by up-selecting the frequency from the scratchpad.

  - **P:** Procedure selection. This FMC selected navigation aid was selected because it is required by the active flight plan procedure. (Can be true of SIDs, STARs, Cruise flight or approach.)

  - **R:** Route selection. This FMC selected navigation aid was selected because it is the next VOR on the flight plan within 250 nautical miles of the airplane or the intended path of flight.

  - VOR navigation information can be updated manually in a number of formats.

    - Navaid Identifier Name (NNNN)
    - VOR/DME Frequency (FFF.FF)
    - Frequency/Course (FFF.FF/CCC)
    - Navaid Identifier/Course (NNNN/CCC)

    A manual entry in the above formats will result in the closest matching navaid being tuned. If entered, the corresponding course information will be entered in 2L/R respectively.

    If a manually entered VHF navaid is deleted, the corresponding VHF radio channel will revert to auto-tuning mode.

  - **CRS:** Line 2L and 2R each display the current navigation course information related to manual, procedure or route tuned navigation fixes in lines 1L and 1R respectively. This information is not displayed for autotuned navigation aids.

    - Course information can be updated manually by up-selecting a three digit course from the scratchpad.

  - **RADIAL:** The current radial being received from the navigation fix tuned in either 1L or 1R is displayed in the center of line 2.

    - **ADF L/R:** Line 3L/R displays ADF tuning information. ADF frequencies are displayed in four digit format, and can be manually updated from the scratchpad if desired.
Course information cannot be selected when manually tuning ADF frequencies.

**ILS-MLS:** Line 4L displays the ILS or MLS station tuned by the FMC. When an ILS or MLS station is tuned, but is not currently active, the PARK indicator will be displayed adjacent to the ILS/MLS frequency identifier. The ILS frequency and front course information will be displayed for both manually and auto-tuned stations. This information will be displayed when the airplane is within 200 miles of the top of descent and the approach procedure is selected and entered in the RTE LEGS flight plan.

If an ILS or MLS frequency is manually tuned, auto-tuning capabilities of the ILS-MLS channel will be inhibited until the manually tuned station is deleted.

**PRESELECT:** Using the pre-select prompts at 6L and 6R, the crew may manually enter frequency/identifier/course entry combinations that may be required for use later in flight. This prevents the crew from having to continually re-enter manual navaid selection information to the scratchpad during the busy departure and approach process, but ensures that required navaids can quickly be made available should they be needed.

**FMC Position Updating Logic:** The FMC uses the auto-tuning process to update FMS position data throughout the course of a flight. By auto-tuning navigation fixes which the FMC determines will provide the best cross bearing information, the FMC is able to accurately triangulate the current aircraft position for continual update to the ND and the FMS.

Three different strategies are used by the FMC auto-tuning logic during this process.

**DME/DME Tuning:** (RHO-RHO) DME/DME updating uses the distance values obtained from two DME transmitters who's positions are known to the FMC. The FMC then performs time/range/intercept calculations on the data received from both DME transmitters in order to triangulate the current aircraft position.

**VOR/DME Tuning:** (RHO-THETA) VOR/DME updating uses the distance and bearing information from a single VOR/DME transmitter to update the current aircraft position to the FMS and the ND.
FMC FLIGHT REFERENCE AND CREW SUPPORT

Overview: The FMC is capable of providing the crew with information regarding the performance of the aircraft during flight, as well as supporting information which can help the crew to make informed and accurate decisions.

POS REF Page: The position reference page displays the current computed position and ground speed according to the FMC and each individual IRS flight control computer. The page also displays which navaids are currently being used by the FMC auto-tune system to provide position data to the FMC.

Page 2/3 FMC POS: Line 1L displays the current FMC computed aircraft position and the source of its current position data. In the event the position update capability of the FMC fails or is inhibited, this line will be blanked by the FMC.

Page 3/3 IRS L/C/R: The IRS computed position for each of the three IRS flight control computers is displayed in lines 2L through 4L respectively. If data becomes unreliable from any of the three systems, the associated line will be blanked by the FMC.

RAD UPDATE: Pressing the <PURGE prompt at 5L deletes the current FMC computed position and replaces it with the current IRS computed position data. This may become necessary if it is determined that the FMC computed position has become corrupt or inaccurate. Pressing the <PURGE prompt once will display a <CONFIRM prompt, indicating that the purge sequence is armed and must be confirmed. Leaving the POS REF page before confirming the <PURGE selection will cancel the request.

GS: Lines 1R through 4R display the current computed ground speed according the FMC (1R) and each of the three IRS computers respectively (2R through 4R).

NAV STA: Line 5R displays the navaids which are being used by the FMC for position update and position computation. If the FMC is using VOR/DME or DME/DME stations for position update, the associated fix names will be displayed in 5R, else the display will be blanked.

PROGRESS Pages: The progress display occupies two display pages, and can be called up by pressing the PROG key on the FMC/MCDU.

The first progress display page is shown below. Note that the crew entered flight number, as well as the page reference information is contained in the title line of both pages.
LAST / ALT: Line 1L displays the identifier of the last navigation fix most recently overflown. This line will be blank if there is no active flight plan programmed, the first leg is still being flown, or after flight completion. The ALT indicator in the center of line 1 shows the airplane altitude at the time of fix crossing.

ATA / FUEL: Line 1R displays the actual time of arrival at the last fix in the flight plan in the center of the display line. The right side of the display line shows the FMC computed fuel remaining figure at the time the fix was crossed.

TO / DTG: Lines 2L through 4L display the active navigation fix identifier (2L) the next fix in the programmed flight plan (3L) and the final destination (4L), as well as the FMC computed distance-to-go before reaching each of these respective locations.

ETA / FUEL: Lines 2R through 4R display the estimated time of arrival at the respective navigation points in each line, as well as the expected fuel-on-board when reaching that fix.

DEST: Line 4L can be used to check DTG, ETA and estimated FUEL on board for an alternate destination or an intermediate waypoint by up-selecting the appropriate destination or navigation identifier to 4L from the scratchpad. Alternate values entered to 4L are for informational purposes only and will not change any part of the active flight plan. Leaving the displayed PROGRESS page will return 4L to the flight plan destination.

If no modification has been made to 4L, DEST is displayed, which indicates that the destination shown matches the destination on the RTE page.

If an alternate airport identifier has been added to 4L, the prompt DIR TO ALTERNATE is displayed to indicate that the figures being displayed represent the FMC computed values for a flight directly from current position to the entered destination.

If a navigation fix contained in the active flight plan is entered into 4L, the prompt EN ROUTE WPT is displayed. This indicates that the fix entered is included in the active flight plan, and that the data displayed is the FMC expected values based upon a flight along the active flight plan.

Command Speed Mode: Line 5L shows the active VNAV command speed mode using small font in the header line. The current CAS/Mach number are displayed in large font. Line 5L will display any of the following modes:

- ECON SPD
- SEL SPD
- E/O SPD
- LIM SPD
- MCP SPD
- VREF+80

Next Constraint: Line 5R displays information related to the next constraint expected based on the RTE LEGS page entered flight plan and aircraft performance. This information is displayed in small font using the header line at 5R. Line 5R also displays in large font the estimated time of arrival at the next constraint, as well as the FMC computed distance-to-go to reach the constraint.

Values appearing in header line of 5R identify the type of constrain which will be encountered, and can be any of the following:

- TO STEP CLB: Step climb
- TO T/C Top of Climb
- TO T/D Top of Descent
- TO E/D End of Descent
- LEVEL AT Level flight attained during a VNAV driftdown.
NOW The airplane has passed the most recent constraint.
NONE No constraint active.

The second PROGRESS page is reached by using the NEXT PAGE/PREV PAGE keys, and is displayed below:

Wind: Line 1 contains three wind indicators which display dynamically computed wind values from the FMC. H/WIND displays the aggregate headwind component, WIND displays the actual computed wind direction and speed, and X/WIND displays the crosswind component and direction. Crosswind component is denoted with an L or R for left and right, respectively.

Track Error: Line 2 displays both cross track error (XTK ERROR) and vertical track error (VTK ERROR) in nautical miles and feet.

XTK ERROR is displayed in nautical miles with a L and R designator to indicate that the aircraft has drifted left or right of course respectively. Distance values are displayed up to 99.9 nautical miles.

VTK ERROR is displayed in feet, with a + and – sign to indicate deviation above and below planned flight track. Vertical track error is displayed when the aircraft is in the descent phase of flight.

TAS / FUEL USED / SAT: Line 3 displays the current true air speed, the total fuel used by all four engines, and the current static air temperature.

Individual Fuel Usage by Engine: The header line of line 4 displays an engine number for each engine. Immediately below that number, in large font, is the FMC computed fuel quantity used by each engine respectively.

Fuel Quantity Comparison: Line 6 provides a comparison between the fuel quantity measured using the Fuel Quantity Indicating System, (FQIS) and the FMC computed fuel remaining based on usage. Failure of either the FQIS or the fuel flow sensors will cause these values to be blanked in order to prevent erroneous comparison.

If the fuel values detected by the FQIS differ from the values computed by the FMC by more than 9,000 pounds, the FMC message, FUEL DISAGREE – PROG 2/2 will appear to alert the crew that PROGRESS page 2/2 needs to be examined.

When the page is selected after the FUEL DISAGREE message is displayed, two <use prompts located at 5L and 5R will prompt the crew to choose which fuel value should be used by the FMC to track fuel values for the remainder of the flight. Until a selection is made, the FMC will continue to use FMC calculated numbers.

Both prompts will be blanked if the crew makes a manual fuel quantity entry into the PERF INIT page.

RTE DATA Pages: The RTE DATA page allows the crew access to ETA, computed fuel remaining and wind data for all programmed legs of the active flight plan. The RTE DATA page is displayed by selecting the RTE DATA> prompt from the RTE LEGS page.
The RTE DATA page is divided into four columns. The entire remaining portion of the flight plan can be paged through using the NEXT PAGE / PREV PAGE keys on the FMC/MCDU keypad.

**ETA:** Estimated time of arrival at the associated fix given current flight progress according to the entered flight plan.

**WPT:** Each navigation fix remaining is displayed on a separate line. The name of each fix is displayed in this column in large font.

**FUEL:** The FMC computed fuel remaining upon reaching each associated fix is displayed in small font.

**W>:** Each navigation fix remaining in the flight plan is given its own WINDS page, where the crew can examine wind conditions at the associated fix.

**WINDS Page:** The WINDS page allow for crew review of forecast wind and temperatures aloft at representative altitudes along the route of flight. The WINDS page is accessed using the W> prompt for each associated fix in the RTE DATA pages.

This function is not currently modeled in the PMDG 747-400.