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747-8 Serves  
100th Airport

**ARINC Standards  
Development**

737 Boeing  
Sky Interior

Troubleshooting  
with Interactive  
Fault Isolation  
Manual

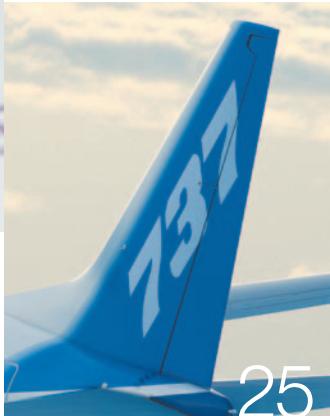
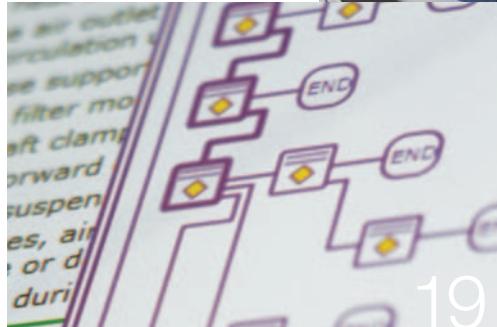
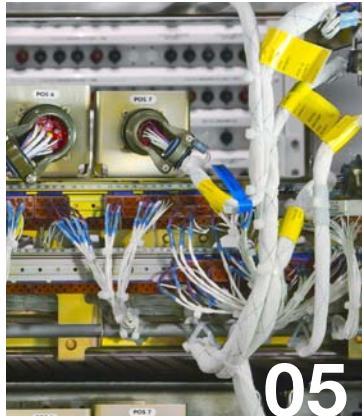
APU-on-Demand  
During ETOPS  
Flights

AERO



# AERO

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# AERO

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[www.boeing.com/boeingedge/aeromagazine](http://www.boeing.com/boeingedge/aeromagazine)

**The Boeing Edge**

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BOEING **EDGE**

AERO magazine is published quarterly by Boeing Commercial Airplanes and is distributed at no cost to operators of Boeing commercial airplanes. AERO provides operators with supplemental technical information to promote continuous safety and efficiency in their daily fleet operations.

The Boeing Edge supports operators during the life of each Boeing commercial airplane. Support includes stationing Field Service representatives in more than 60 countries, furnishing spare parts and engineering support, training flight crews and maintenance personnel, and providing operations and maintenance publications.

Boeing continually communicates with operators through such vehicles as technical meetings, service letters, and service bulletins. This assists operators in addressing regulatory requirements and Air Transport Association specifications.

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# Boeing 747-8 Serves 100th Airport



The new Boeing 747-8 offers a number of operational improvements while preserving key commonalities with the 747-400. One of those commonalities is compatibility with the world's major airports.

In the United States, the Federal Aviation Administration has approved the 747-8 for operations at airports with the same clearances as those required for the 747-400 — and airports around the world are following suit. In March, Hanoi's Noi Bai International Airport became the world's 100th airport to receive the 747-8.

Launch freighter customer Cargolux took delivery of the first 747-8 Freighter in October 2011 and placed the airplane directly into service to its home base in Luxembourg — something we're very proud of. Since then, the fleet has supported revenue service operations at more than 100 airports and has been approved for more than 225 airports around the world. In addition to serving airports around the world, the fleet has seen dispatch reliability and fuel burn better than plan.

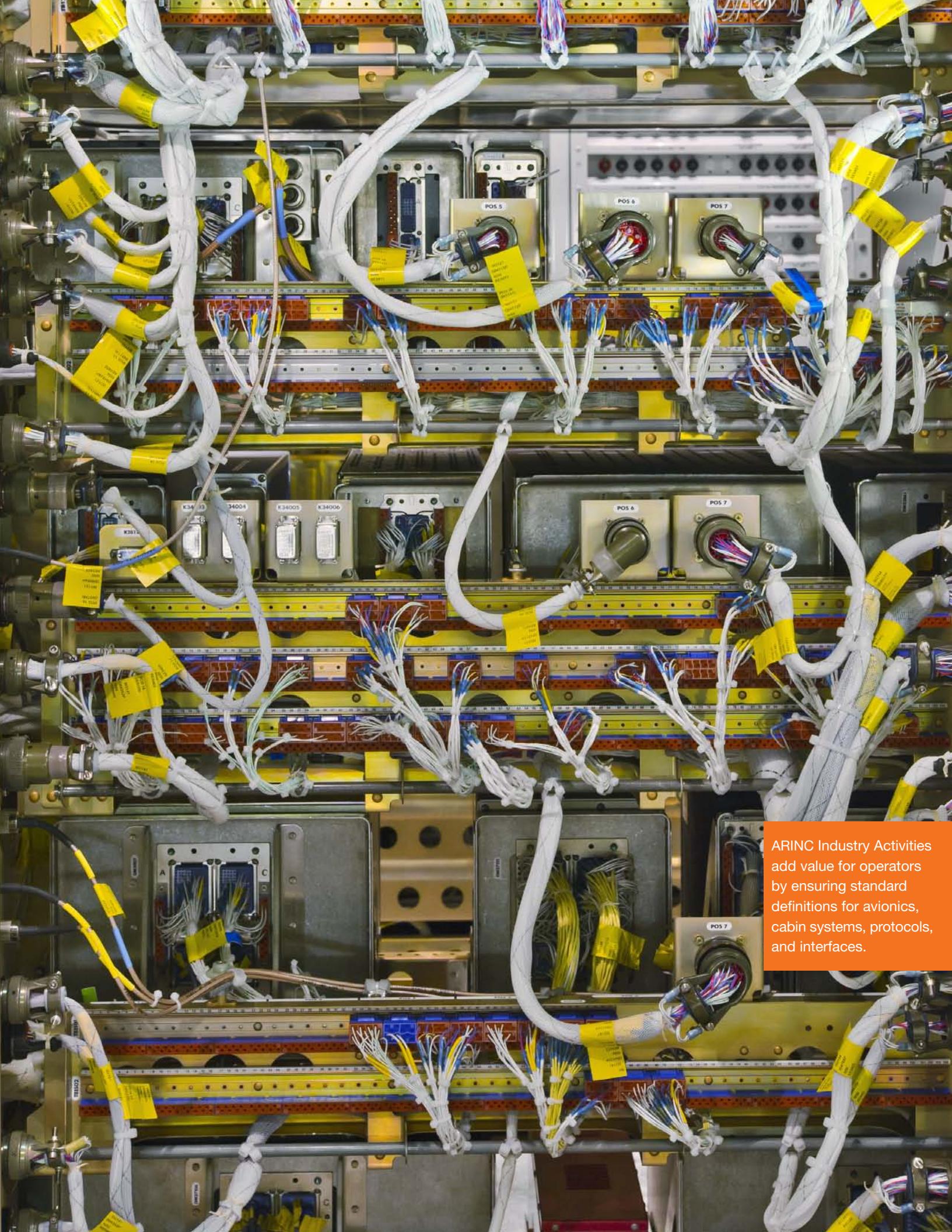
The arrival of the airplane in Hanoi is just another testament to the capabilities and value the 747-8 is providing our customers. It demonstrates that the newest members of the 747 family can operate safely within an airport environment, accounting for regulatory, clearance, pavement loading, and parking requirements. It also exhibits Boeing's commitment to help ensure efficient and effective operations for our customers.

We look forward to continuing to work with our customers as the fleet serves the next 100 airports.

A handwritten signature in black ink, appearing to read "Eric Lindblad".

## ERIC LINDBLAD

Vice President and General Manager  
747 Program  
Boeing Commercial Airplanes



ARINC Industry Activities add value for operators by ensuring standard definitions for avionics, cabin systems, protocols, and interfaces.

# ARINC Standards Development

Aeronautical Radio Inc. (ARINC) Standards define avionics, cabin systems, protocols, and interfaces used by air transport and business airplanes worldwide. Boeing is committed to ARINC Industry Activities because the establishment of appropriate standards adds value for the aviation industry in general and for Boeing customers and products in particular.

By **Kathleen O'Brien**, Associate Technical Fellow, Airplane Electronic Systems, and  
**Brandon Mazzacavollo**, Senior Manager, Simulator Management Services

Members of the aviation industry are working together to establish consensus-based, voluntary aviation technical standards that no single organization could develop independently. This ARINC standardization encourages fair competition among operators, minimizes redundant work, and allows the industry to move forward together. Without standardization, industry cost would increase because avionics components would be highly customized to only interface with one airframe manufacturer's airplane.

This article explains the importance of ARINC Standards and their development.

## ABOUT ARINC

ARINC was formed in 1929 by the airlines of the day at the suggestion of the U.S. Federal Radio Commission (which later became the Federal Communications Commission). For most of its history, ARINC served as the airline industry's single licensee and coordinator of radio communication outside of the government. ARINC has since evolved into a provider of engineering solutions in the aerospace and defense, aviation, airport, government, network, security, and transportation industries, delivering products and services worldwide.

ARINC Industry Activities is the part of ARINC that coordinates and manages three aviation industry activities:

- **Airlines Electronic Engineering Committee (AEEC).** The AEEC develops engineering and technical standards for avionics, networks, and cabin systems. Boeing has a voting seat on the AEEC and is part of the AEEC Executive Committee, along with the world's airlines, Airlines for America, the International Air Transport Association, the U.S. Air Force, general aviation, and a European airplane manufacturer.

One of the most widely known standards is ARINC 429, "Digital Information Transfer System," which

**Figure 1: Standardized hardware and data formats**

Flight decks, like the one on this 747-8, are the nerve centers for communication between electronic systems on an airplane. ARINC Standards are used on all Boeing airplanes and establish hardware and data formats.





## Figure 2: ARINC AEEC subcommittees

AEEC includes a number of subcommittees focused on a variety of aviation topics.



establishes the hardware and data formats for communication between electronic systems on an airplane (see fig. 1).

- **Avionics Maintenance Conference (AMC).** The AMC provides an annual forum for exchanging avionics maintenance and support techniques and attracts more than 700 participants, representing airline maintenance community stakeholders.
- **Flight Simulator Engineering and Maintenance Conference (FSEMC).** The FSEMC provides an annual forum for exchanging cost-effective solutions to simulator operational and maintenance problems and develops technical standards related to simulation and training. Boeing serves on the FSEMC Steering Committee, along with airlines, flight simulator manufacturers, and suppliers.

### HOW ARINC STANDARDS IMPROVE AIRLINE OPERATIONS

ARINC Standards and collaborative solutions improve cost effectiveness, increase productivity, and reduce lifecycle costs for airlines and their industry partners in the avionics, cabin system, maintenance, and flight simulation and training segments. These standards, which define key elements of equipment and systems installed on airplanes around the world, deliver substantial benefits to the aviation industry by cooperatively establishing common technical principles and developing shared technical solutions. An established standard means more product options and flexibility for airline operators in terms of component interchangeability.

The AEEC has formed subcommittees addressing everything from satellite navigation to ground support. Today, 18 active AEEC subcommittees are working to enhance global aviation in a number of ways, ranging from pilot headsets to advanced networking protocols (see fig. 2). Here are specific examples of this work.

The Data Link Systems Subcommittee recently expanded ARINC 631 to include multi-frequency functionality that enables additional data communications capacity in support of airspace modernization efforts.

#### AEEC DATA LINK SYSTEMS SUBCOMMITTEE

In the air traffic management (ATM) context of the U.S. NextGen program and Europe's Single European Sky ATM Research program, additional data link capability is a prerequisite for operators to gain the expected benefits from increased airspace capacity, improved operational efficiency, and further enhanced safety through controller-pilot data link communications and trajectory-based operations in an internationally harmonized manner.

The Data Link Systems Subcommittee recently expanded ARINC 631, "Very High Frequency Digital Link Mode 2 Implementation Provisions," to include multi-frequency functionality that enables additional data communications capacity in support of airspace modernization efforts.

The Data Link Users Forum is also available to help operators improve system performance and maximize the operational and economic benefits of existing air-to-ground data link communication services. Forum discussions include technical issues and the direction and schedule of new air

traffic service data link programs with representatives from airlines, airplane manufacturers, avionics manufacturers, data link service providers, civil aviation authorities, and air traffic service providers.

#### AEEC COCKPIT DISPLAY SYSTEMS

ARINC 661, "Cockpit Display System Interfaces to User System," defines necessary interfaces between airplane systems and cockpit display systems (CDS). This specification provides graphical and interactive services to user applications within the flight deck environment. When combined with data from user applications, the CDS displays graphical images to the flight deck crew.

Prior to ARINC 661, flight deck displays were proprietary solutions for each airplane manufacturer and model, with unique software for displaying a number of interconnected systems, such as the navigation and surveillance systems. This resulted in high certification and upgrade costs, as well as a lack of interchangeability between airplane models.

ARINC 661 emphasizes the need for independence between airplane systems and the CDS and defines interfaces between the CDS and the airplane systems, including the interfaces between avionics equipment and display system graphics generators. Although display look-and-feel graphical requirements are not specified, customization tools are available to provide a flexible and common tool set to flight crew interface designers.

Use of this specification reduces the cost of change associated with systems that drive display interfaces, enables lower cost options and updates for airline customers, increases airline developed or modified application possibilities, and promotes cross-fleet commonality. For example, a cockpit display of traffic applications using automatic dependent surveillance data broadcast from surrounding airplanes is being developed. The surveillance system is adding new display symbology without requiring any changes to the graphics server software.

# Inside ARINC Industry Activities

## Airlines Electronic Engineering Committee:

### *Delivering standards-based avionics*

Today, many avionics and cabin systems installed in commercial and regional jet airplanes around the world are built on the consensus-based, voluntary ARINC Standards developed and approved by AEEC. ARINC Standards are used as the basis for design, development, investment, acquisition, lifecycle support, and other business decisions throughout industry. Additionally, for new airplane and avionics installations, ARINC Standards provide a common baseline for avionics and cabin equipment development and allow manufacturers to pre-wire airplanes, ensuring that cost-effective avionics are available when needed.

## Avionics Maintenance Conference:

### *A forum for industry discussion*

The AMC develops maintenance process and maintenance data standards to improve cost effectiveness, increase productivity, reduce lifecycle costs, and assist with regulatory compliance. AMC working groups address issues such as design maintainability and testability, levels of avionics maintenance, and test equipment guidance.

The AMC also provides industry-specific problem-solving and networking opportunities. It is a forum for operators to interact on a face-to-face basis with airplane manufacturers, suppliers, and other airlines. In addition to the formal question-and-answer format of AMC discussion sessions, symposium topics are added to the sessions to discuss current, significant industrywide issues.

## Flight Simulator Engineering and Maintenance Conference:

### *Enhancing safety through better training equipment*

The FSEMC is a forum specific to aviation training devices. It promotes greater reliability and reduced operating costs in flight simulators by improving engineering, maintenance, and support techniques through the exchange of technical information. In addition to a formal conference with a question-and-answer format, like the AMC, the FSEMC also manages multiple working groups and develops standards covering important topics facing the flight simulator industry. Current working groups include topics such as future concepts for simulators, simulator malfunctions, and how to specify and accept simulator equipment and simulated air traffic environments. The ARINC website ([www.aviation-ia.com](http://www.aviation-ia.com)) provides a complete list of ARINC industry activities.

## AEEC NETWORK INFRASTRUCTURE AND SECURITY

ARINC 842, "Guidance for Usage of Digital Certificates," provides guidance for airline operators in creating, using, and retiring digital certificates and associated public and private keys within an airplane environment. The purpose of these certificates is to provide authentication and security for offboard communication devices, onboard network servers, onboard applications, electronic flight bags (EFBs), and in-flight entertainment equipment. Applying these practices consistently reduces design and support costs for manufacturers, suppliers, and operators.

## EFB

The EFB Subcommittee is currently working on ARINC 759, "Aircraft Interface Device," that connects class 1 and class 2 EFBs to avionics equipment. This specification defines connectivity, connectors, services, and protocols.

## AEEC/AMC SOFTWARE DATA LOADING (SDL) SUBCOMMITTEE

Software data loading (SDL) is an area where the interests of the AEEC engineering community and the AMC maintenance community overlap (see fig. 3). A good example is the situation with looming floppy disk obsolescence. Currently, thousands of airplane software loaders and software loading ground tools will only accept floppy disks.

The SDL Subcommittee is developing several standards, including a standard to convert floppy-based software to a logical media-independent format. The logical format can be used electronically or put on any kind of physical media, allowing operators the option of choosing an electronic or physical media process for distributing software. While many software loaders will still need to be upgraded, the new standard will provide operators with a wider selection

### Figure 3: Regular subcommittee meetings draw large crowds

Meetings like this 2012 AMC gathering held in Anchorage draws airlines, manufacturers, and suppliers to discuss key issues facing the industry.



of interchangeable options. This will avoid the loader suppliers having to create unique solutions which are not interchangeable.

#### **FSEMC SIMULATOR SOFTWARE WORKING GROUP (SSG)**

As modern commercial airplanes become more software intensive, flight simulation devices have also seen a significant increase in the amount and number of software applications required to effectively operate. This has driven a need to standardize the means to control this software among users and operators, original equipment manufacturers, equipment vendors, and training device manufacturers.

With new airplane models often driving far more numerous software modules than legacy models, the management of configuration control, airplane options, and maintaining actual fleet equipment has become and will continue to be a challenging task for operators. SSG aims to identify a minimum data set and standardize the process and deliverable format for software change notices. The working group will

be leveraging previous work based on loadable software airplane parts found on the airplane itself and from ARINC Report 667 as a guide for managing software storage and control.

This is important for operators and the flight simulation industry at large, as a new generation of airplanes accelerate the amount and speed with which data is produced, modified, incorporated, and validated on the airplane — in addition to the complex environment of a flight simulator trying to mimic that very airplane. All of this data must be accurately represented in the flight simulator fleet to ensure delivery of the highest-quality training.

#### **PARTICIPATION OF AVIATION COMMUNITY**

The AEEC, AMC, and FSEMC are important forums for operators to gain insights from industry stakeholders and work cooperatively with suppliers and airframe manufacturers. This direct participation can provide Boeing customers with new approaches that can help increase efficiency and lower costs.

Fundamental to the success of the AEEC, AMC, and FSEMC is cooperation among the members of the aviation community that are involved. More than 2,500 engineers and scientists representing more than 60 airlines and 200 industry suppliers from nearly 40 countries participate in the development of ARINC Standards.

#### **SUMMARY**

ARINC Industry Activities add tremendous value for operators by ensuring standard definitions for avionics, cabin systems, protocols, and interfaces used by commercial airplanes; providing a discussion forum for the airline maintenance community; and promoting reliability and reduced operating cost in flight simulators. Boeing is committed to these activities, maintains involvement with them around the world, and encourages airlines to participate.

For additional information, please visit ARINC on the Web at [www.aviation-ia.com](http://www.aviation-ia.com). 



The new Next-Generation 737 Boeing Sky Interior option offers airlines an improved cabin interior that enhances the flying experience.

# 737 Boeing Sky Interior Enhances Flying Experience

In October 2010, Boeing introduced a new interior option for the Next-Generation 737 called the Boeing Sky Interior. Since the first 737 Boeing Sky Interior was delivered, more than 60 airlines and leasing companies have ordered the new interior and more than 600 airplanes have been delivered with it.

By Brent Walton, 737 Interiors Engineering Manager

The Boeing Sky Interior gives airlines the ability to offer passengers a more comfortable flying experience and use cabin differentiation to increase passenger preference for their airline. This article explains the changes that are incorporated in the new interior and provides examples of its appearance.

## A NEW INTERIOR IN RESPONSE TO PASSENGER REQUESTS

Boeing engineers developed the Boeing Sky Interior following extensive surveys of airline passengers to find out what they prefer on board an airplane.

Featuring similar design elements to the 787 Dreamliner, the Boeing Sky Interior is optional on new Next-Generation 737s and standard on the 737 MAX (see fig. 1). It is weight neutral, compared to the current

interior, and requires limited crew training. Elements of the Boeing Sky Interior:

- Adds an open, bright, and modern look and feel to the cabin.
- Has improved stowage bins to allow for more carry-on bags.
- Introduces a new lighting system.
- Provides enhanced passenger service units (PSUs).
- Incorporates a new attendant control panel.

**Figure 1: The Boeing Sky Interior builds on the standard 737 interior design**

The standard Next-Generation 737 interior (top) continues to deliver comfort to passengers worldwide, while the new Boeing Sky Interior (bottom) incorporates a number of improvements designed to further enhance the flying experience.





**Figure 2: New cove lighting and window reveals**

New cove lighting enhances the airplane's entry. Redesigned, sculpted sidewalls (right) direct passenger attention to windows.

	Standard Interior	Boeing Sky Interior
737-700	Standard Bin Bags	BigBin™ Bags
737-800	52	86
737-900ER	70	114
		90
		118
		121
		125

Typical bag count based on a standard-size carry-on bag, 9x14x22 inches (23x36x56 centimeters).

BigBin™ is 2 inches deeper than a standard bin and allows luggage to be stored inboard to outboard, nearly doubling carry-on bag capacity.

The redesigned cabin features an open look and feel for improved passenger and crew comfort. New cove lighting and curving architecture create a distinctive entryway, while modern, sculpted sidewalls and window reveals draw attention to the airplane's windows, giving passengers a greater connection to the flying experience (see fig. 2). The new redesigned sidewall air grilles have a latching feature that requires a special tool to open, improving security.

**Stowage bins** are larger, providing more room for carry-on bags and enabling more passengers to store their luggage closer to their seats — and with more bags stowed above, there is more leg room under seats (see fig. 3). The bins pivot up and out of the way so they take up less space, and the shape adds to the open feel of the cabin.

A mechanical assist device has been added to the side of the stowage bins and is intended for use by flight attendants as desired to help them close the bins more

**Figure 3: Stowage bins hold more and are easier to close**

Pivot bins are optimized to accommodate more carry-on bags compared to the standard 737 interior. The closing force of the stowage bins is similar to that of current pivot bin designs. However, a bin-assist mechanism reduces the maximum closing force of a fully loaded pivot bin by approximately 40 percent.

easily. The bin-assist mechanism reduces the closing force of a fully loaded pivot bin by approximately 40 percent when activated. The design consists of a simple all-mechanical gas spring that can be engaged by pressing a lever on the aft end panel of the bin bucket. The bin-assist mechanism has been tested to more than 150,000 activation cycles.



**Figure 4: Energy-efficient lighting system offers new color scheme options**

Among the lighting options available with the Boeing Sky Interior are a typical boarding/deplaning scheme (left) and a sunrise/sunset scheme (right). Lighting is controlled with a new touch-screen attendant control panel.



**Figure 5: Passenger service units with integrated speakers**

Boeing Sky Interior PSUs incorporate speakers, LED signage and attendant call lights, and LED reading lights with a life of 40,000 hours, 10 times the life of the previous halogen lights.



**Figure 6: Attendant control panel**

The attendant control panel is a liquid crystal display touch-screen processor-based system with an intuitive controls interface. The control panel accommodates all existing cabin controls.

**A new lighting system** features light-emitting diodes (LEDs) that can portray different color schemes, such as a soft blue sky or sunset colors (see fig. 4). The new lights are also more energy efficient and have a longer life than previous lights, with LEDs lasting an estimated 40,000 hours. This compares with an estimated 10,000 hours for the previous standard fluorescent light bulbs and means less work for maintenance crews and less impact on the environment.

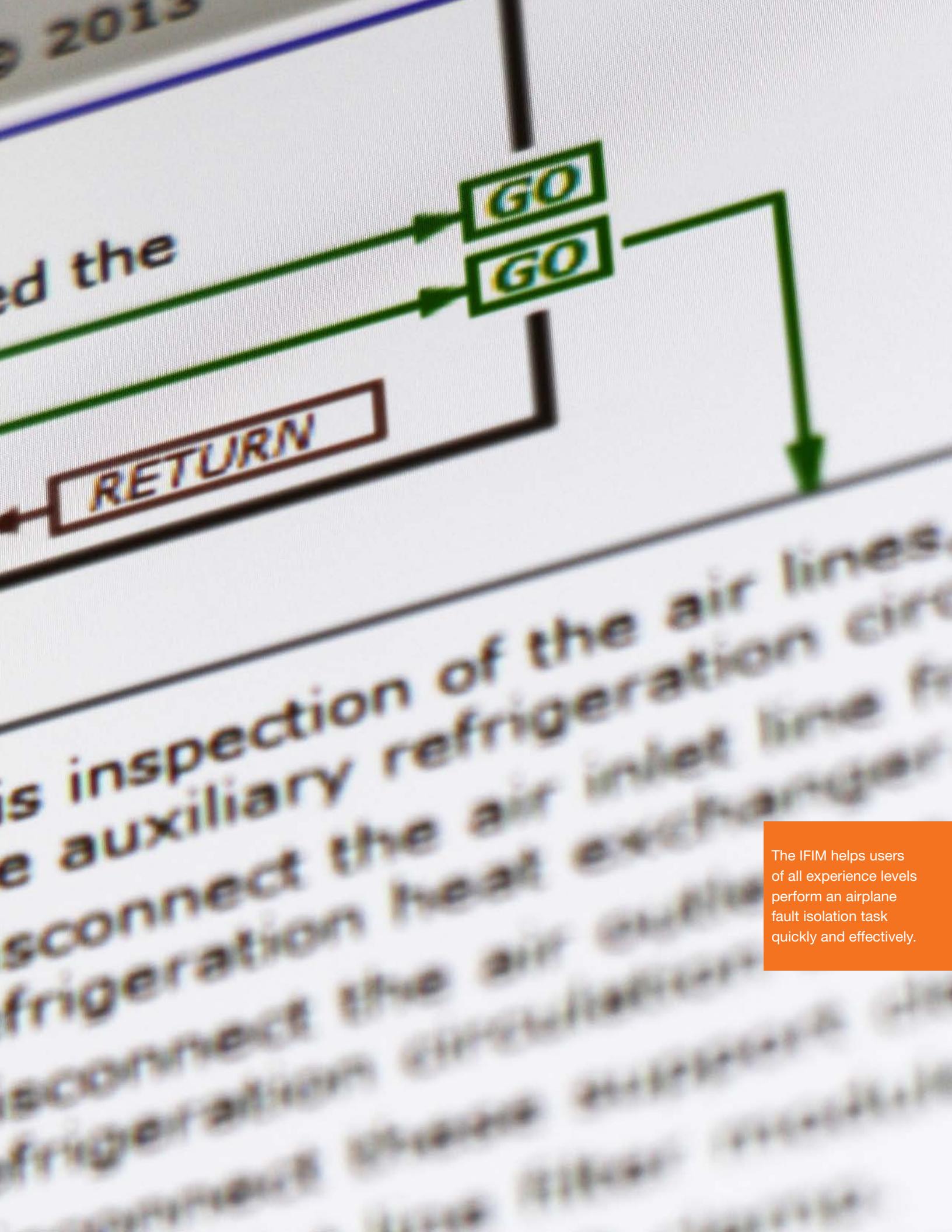
**Improved PSUs** include LED reading lights and redesigned reading-light switches so

passengers can find them more easily and avoid accidentally pressing the flight attendant call button (see fig. 5). Speakers are integrated into each row's PSUs, improving sound and clarity of public address operations. Optionally, life vests can be stored in the PSUs.

**A touch-screen attendant control panel** provides operators with improved flexibility in managing cabin system functions such as lighting scene control, lighting zone control, and optional cabin temperature control (see fig. 6).

#### SUMMARY

The new Next-Generation 737 Boeing Sky Interior option offers airlines an improved cabin that enhances the flying experience for passengers, provides an improved environment for the cabin crew, and reduces maintenance and environmental impact.



The IFIM helps users of all experience levels perform an airplane fault isolation task quickly and effectively.

# Faster Troubleshooting with Interactive Fault Isolation Manual

Airplane systems are more sophisticated and more interconnected than ever before, and airplane system faults are more complex. Boeing has developed an Interactive Fault Isolation Manual (IFIM) that makes it easier to identify and correct faults.

By John Shaw, Senior Engineer, Airplane Maintenance Engineering

Today's airplanes can exhibit a wide range of fault symptoms, usually in the form of visual indications. Some indications are intended for the flight crew, some for the cabin crew, and others for maintenance personnel. Each fault indication must be clear in its meaning, and for each indication there must be a way to correct the underlying cause and return the airplane to a serviceable condition.

Boeing has created the IFIM to speed up the process of resolving airplane faults. The IFIM is a Web-based application that makes it easier to find the right fault isolation task for a fault and then shows the task in a form that is simple to follow. It also provides special navigation tools for experienced airplane troubleshooters. Initially developed for Boeing's newest airplane models, the

IFIM will be available on additional models in the future.

This article describes typical fault conditions and codes, outlines the operation of the IFIM, and provides examples of how the IFIM can be used to identify and correct faults.

## TYPES OF FAULTS

There are many fault conditions that can occur on an airplane, and there are different ways that a fault condition can make itself known. Each new generation of airplanes brings greater detection and consolidation of fault conditions and allows more faults to be displayed in a central location. Airplane faults can be categorized into several types:

- Textual messages on flight deck displays.
- Other indications on the flight deck (for example, lights, warning flags, and colors).
- Nonvisual flight deck symptoms (for example, sounds, odors, and vibrations).
- Cabin symptoms (for example, galleys, passenger seats, and entertainment systems).
- Ground symptoms (for example, servicing, cargo loading, and scheduled tasks).

For indications that are intended only for use in airplane maintenance, there is a special type of fault, called a maintenance message. This can be a textual message displayed by the airplane's onboard maintenance system (OMS) or a diagnostic result from the built-in test equipment of some airplane systems.

## FAULT CODES FOR STANDARDIZED FAULT REPORTING

Boeing creates a textual description and a unique eight-digit fault code for each flight-deck fault, cabin fault, and ground-maintenance fault. These are some examples:

- Flight deck message:  
"REFRIG SYS L..... 219 108 41"
- Potable water indicator:  
"shows water level of zero... 383 922 00"

The Fault Reporting Manual (FRM) is a companion document to the IFIM. The FRM contains all the fault descriptions and their fault codes. It helps the flight crew communicate the precise fault condition to maintenance personnel. The fault code is recorded by certain airplane systems, and it provides a direct entry point to the IFIM.

Maintenance messages are not intended for use by flight crews and do not have fault codes. Maintenance messages have a different numbering format than fault codes, such as "Auxiliary Refrigeration System control power is not available. 21-80367."

## IFIM FAULT FINDER

After a fault has been reported, the airline technician must find the appropriate fault isolation task. Because an airplane can have more than 25,000 different fault indications, the process of finding the right task needs to be fast and definitive. The main page of the IFIM application is the Fault Finder, and

its purpose is to get the user to the task as quickly as possible (see fig. 1).

The Fault Finder has three input boxes. The Fault Code box accepts an eight-digit fault code from the FRM or from certain airplane displays. The Fault Description box accepts a partial or full fault description. The Maintenance Message box accepts maintenance message numbers.

When a fault code is typed in the Fault Code box, its fault description and a link to its fault isolation task will appear at the bottom of the Fault Finder.

When text is typed in the Fault Description box, an alphabetical list of key phrases will appear and scroll to the phrase with the best match. After the user selects a key phrase, secondary lists will appear as necessary to allow the specific fault to be selected. Once selected, the fault description and a link to its fault isolation task will appear (see fig. 2).

When a maintenance message number is typed in the Maintenance Message box, the text of the maintenance message and a link to its fault isolation task will appear.

## MESSAGE CORRELATIONS

Airplanes with an OMS can automatically correlate fault indications on the flight deck to specific maintenance messages. The IFIM recognizes all such correlations and distinguishes between fault isolation tasks for the flight deck indication and tasks for the maintenance message.

Where necessary, the Fault Finder will show a special reminder to the user to read

the task for the flight deck indication first. The Fault Finder will also tell the user when it is acceptable to skip the task for the flight deck indication.

## ALTERNATE LISTS AND EXPORTS

The basic search function for text that is typed in the Fault Description box will match the key phrases exactly as they appear in the FRM. For example, typing the word "brake" will scroll the Fault Finder phrase list to the fault descriptions that start with the word "brake."

In addition, an alternate list of results is simultaneously created that includes the word "brake" found anywhere inside any fault description. Users can choose to view this alternate list. It can be particularly helpful in cases where the FRM was not used.

The Fault Finder has a special function to build and export lists. All the faults, maintenance messages, or task numbers for a specific Air Transport Association chapter number can be displayed instantly and then printed or exported to a spreadsheet.

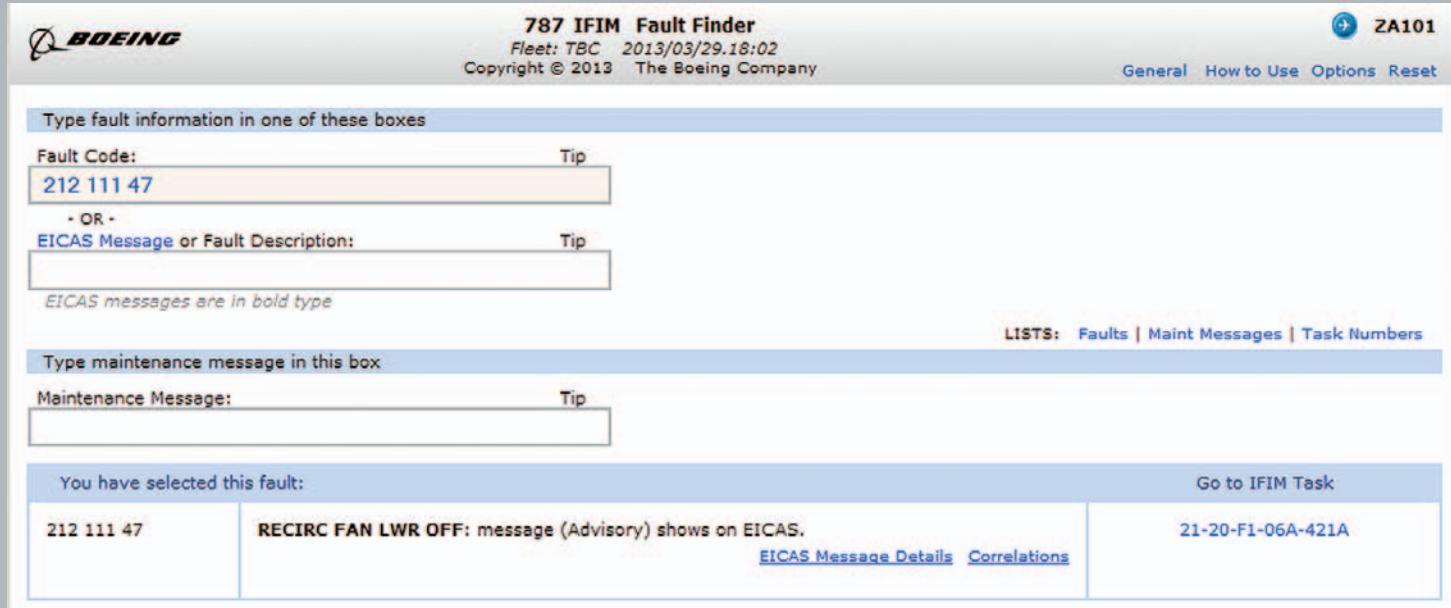
## INTERACTIVE FAULT ISOLATION TASK

When a task link on the Fault Finder is selected, the interactive fault isolation task will appear (see fig. 3). The task display has three parts:

- Blocks of procedure steps.
- A procedure map.
- A corrective action summary.

Figure 1: IFIM Fault Finder with fault code input

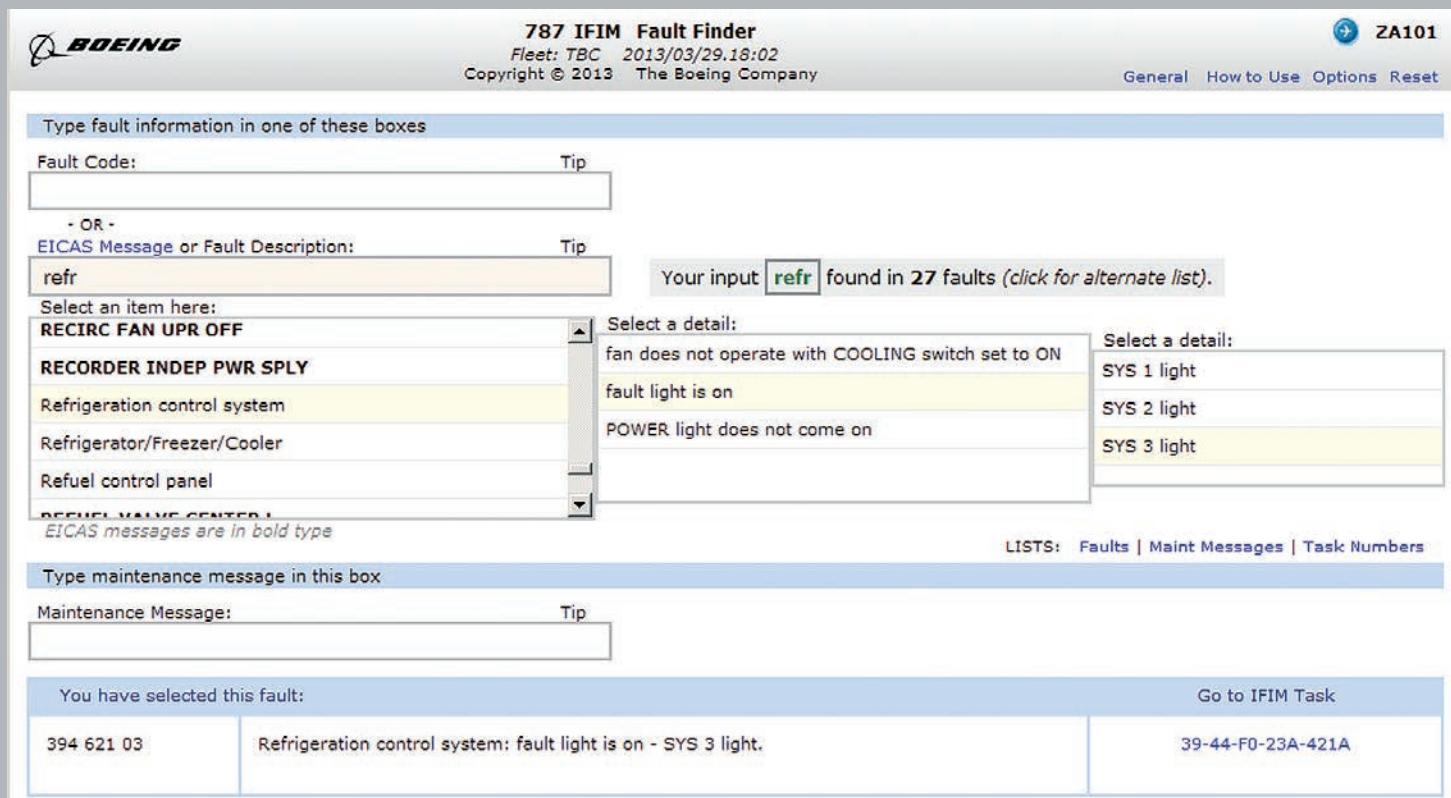
The main page of the IFIM is the Fault Finder. It allows the user to search for any fault code, fault description, or maintenance message. In this example, a fault code has been entered and the results are displayed.



The screenshot shows the Boeing 787 IFIM Fault Finder interface. At the top, the Boeing logo is on the left, the title '787 IFIM Fault Finder' is in the center, and the date 'Fleet: TBC 2013/03/29, 18:02' and 'Copyright © 2013 The Boeing Company' are on the right. A 'ZA101' identifier is in the top right corner. Below the title, a message says 'Type fault information in one of these boxes'. There are two input fields: 'Fault Code:' containing '212 111 47' and 'EICAS Message or Fault Description:' containing 'RECIRC FAN LWR OFF: message (Advisory) shows on EICAS.'. Below these is a note: 'EICAS messages are in bold type'. A 'Tip' link is next to each input field. On the right, a 'LISTS' button with 'Faults | Maint Messages | Task Numbers' is visible. A 'Type maintenance message in this box' input field is below. A 'Maintenance Message:' input field is shown with a 'Tip' link. At the bottom, a summary table shows the selected fault: '212 111 47' (highlighted in blue), 'RECIRC FAN LWR OFF: message (Advisory) shows on EICAS.' (highlighted in blue), and '21-20-F1-06A-421A'. A 'Go to IFIM Task' link is to the right of the fault description.

Figure 2: Fault isolation task with fault description input

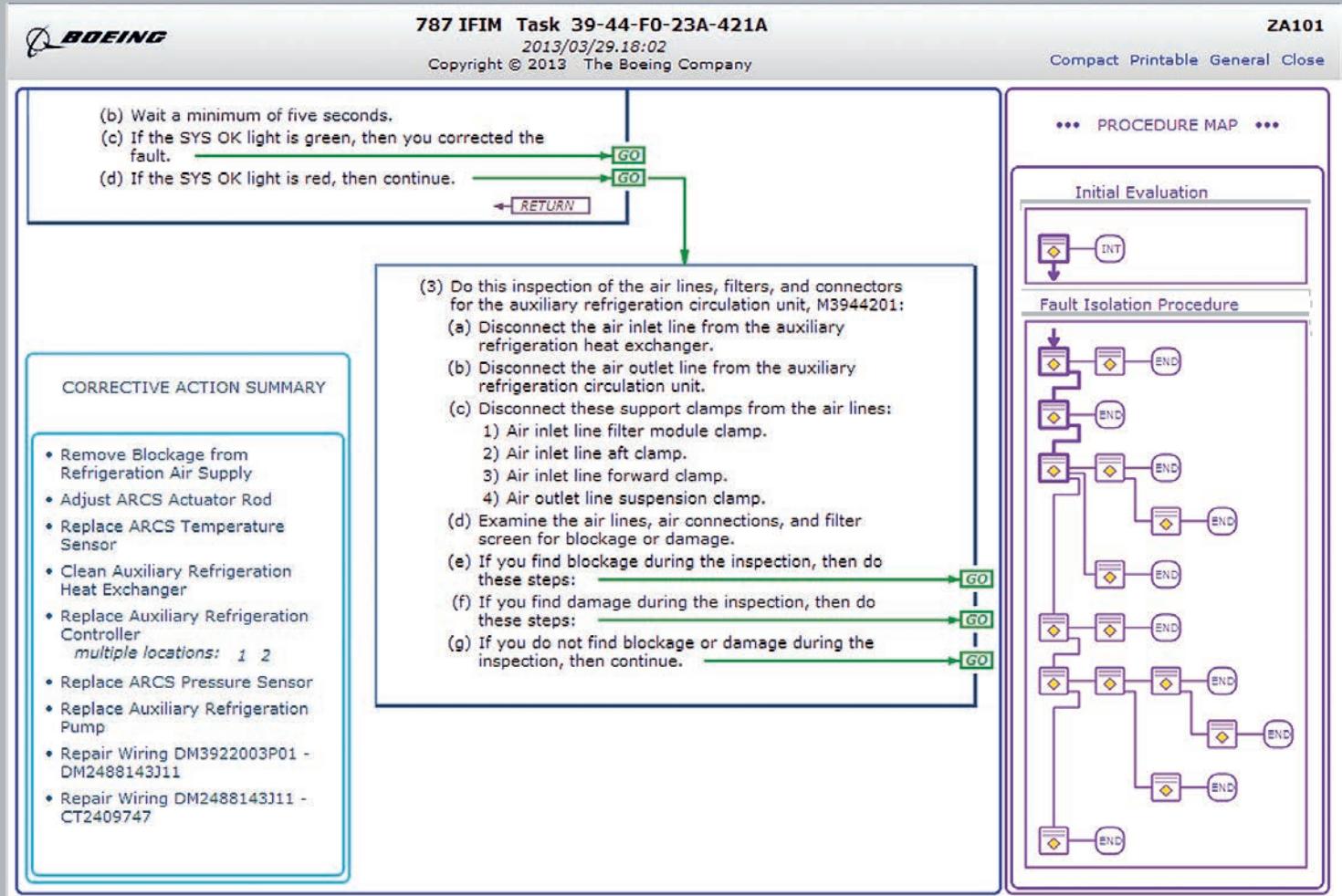
The Fault Finder accepts any fault description text input and will scroll to the closest match. Further selection boxes will appear so that the exact fault can be chosen.



The screenshot shows the Boeing 787 IFIM Fault Finder interface. The layout is similar to Figure 1, with the Boeing logo, title, and date at the top. The 'EICAS Message or Fault Description:' input field now contains 'refr'. A message box says 'Your input **refr** found in 27 faults (click for alternate list.)'. To the right, a 'Select a detail:' dropdown shows 'SYS 1 light', 'SYS 2 light', and 'SYS 3 light', with 'SYS 3 light' highlighted in yellow. Below the input fields, a note says 'EICAS messages are in bold type'. A 'Tip' link is next to the input fields. A 'LISTS' button with 'Faults | Maint Messages | Task Numbers' is on the right. A 'Type maintenance message in this box' input field is below. A 'Maintenance Message:' input field is shown with a 'Tip' link. At the bottom, a summary table shows the selected fault: '394 621 03' (highlighted in blue), 'Refrigeration control system: fault light is on - SYS 3 light.' (highlighted in blue), and '39-44-F0-23A-421A'. A 'Go to IFIM Task' link is to the right of the fault description.

**Figure 3: Interactive fault isolation task**

The interactive fault isolation task shows the blocks of procedure steps, with the blocks separated by decision points. A schematic map gives an overview of the procedure flow, and a summary list shows the possible corrective actions.



Active buttons and links in the task allow the user to quickly navigate through the procedure. The blocks of steps provide detailed, sequential instructions for isolating the cause of the fault. The procedure map and the corrective action summary allow the user to get an immediate overview of the task's full structure and its goals.

#### STEP-BY-STEP PROCEDURE BLOCKS

All fault isolation steps are grouped into blocks. At the end of each block is a decision point at which the user must make a choice by selecting one of the GO buttons.

As each selection is made, the task display will shift to the next block in the decision tree. The shift is seamless, with the previous block traveling upward and away as the newly selected block arrives.

The GO buttons from the previous choice remain visible at the top left of the task, and the user may continue to choose between them without moving the display. The previous block has a RETURN button, which allows the user to go back to view it again.

#### PROCEDURE MAP

On the right side of the task display, a schematic diagram represents all the procedure blocks and shows how they are interconnected. As the user progresses through the procedure, the path taken is continuously highlighted on the map.

All of the block symbols on the procedure map are active. Selecting a block symbol will move the main task display to the corresponding block. This provides a way to instantly jump to any part of a long procedure without the need to pause at the decision point of each of its blocks.

#### END POINTS OF TASK

All paths through the fault isolation task end with a corrective action followed by a final confirmation. The corrective action may be a component replacement, a repair, an adjustment, or some other remedy. The final confirmation verifies that the fault condition no longer exists.

At each end point, the corrective action that was taken is highlighted so that it may be recorded if needed.

#### CORRECTIVE ACTION SUMMARY

On the left side of the task display, a box summarizes all corrective actions present in the task. This gives an advance look at the possible causes for the fault.

Selecting an item on the corrective action summary will move the task display to the corresponding block and highlight the exact step at which that action takes place.

#### DISPLAY FORMATS

If desired, tasks can be displayed in a more compact format (see fig. 4). Selecting the

Compact option at the top of the task hides the corrective action summary and the procedure map. Either of them can be recalled by selecting a tab on the side of the compacted display.

Each fault isolation task can be printed if needed. The printed version uses the traditional format of nested text paragraphs, and its content is identical to the interactive task.

#### LINKS TO GENERAL INFORMATION

Standard practice information that applies to any task can be accessed with the General link at the top of the task. In addition, certain words inside task steps (such as "wiring check" or "intermittent fault") have quick links that open to a detailed explanation in the General information section.

#### SUMMARY

The IFIM gives operators a faster way to troubleshoot airplane system faults. It guides users more directly to the correct fault isolation task and helps users of all experience levels perform an airplane fault isolation task effectively.

For more information, please e-mail [MaintenanceEngineering@boeing.com](mailto:MaintenanceEngineering@boeing.com). 



Improving APU reliability for on-demand operation provides an overall benefit to airplane electrical system reliability.

# Using APU-on-Demand During Next-Generation 737 ETOPS Flights

As a result of accumulated service experience and recent design changes, operators of the Next-Generation 737 are now able to operate the auxiliary power unit (APU) on demand in lieu of running it continuously during the extended range operations (ETOPS) portion of a flight. The historical background of APU use during ETOPS, methods used to substantiate on-demand operation, and benefits to operators are discussed. This change reduces fuel demands and maintenance requirements and complies with regulatory requirements and guidance.

By **David Dummeyer**, Associate Technical Fellow, Boeing Propulsion Engineering

Standard ETOPS operating procedures require the Next-Generation 737 APU to be started and running prior to reaching a point farther than 60 minutes from a suitable alternate airport and kept running for the duration of the ETOPS segment of the flight. A U.S. Federal Aviation Administration (FAA) approval obtained in 2011 permits the APU to be left off and started and used only if conditions require its use.

Running the APU on demand instead of continuously during the ETOPS portion of a flight eliminates the need to include APU fuel as part of the standard mission planning process. An allocation of APU fuel accountability for use during a diversion must still be maintained in accordance with

the latest ETOPS operational standards. This new authorization allows operators to assess their current ETOPS programs that require running the APU and determine the value of using the APU on demand.

This article provides background on the role and use of the APU and explains the benefits of using it on demand.

## BACKGROUND

Historically, for the 737, the APU must be running while the airplane is in the ETOPS phase of its route. As the number of ETOPS flights by Next-Generation 737s continued to increase, operators asked if it would be possible to obtain approval

for APU-on-demand operation for ETOPS (see fig. 1).

The alternating current (AC) power system of all 737 airplane models includes three main sources of AC power: the left generator installed on the left engine, the right generator installed on the right engine, and the APU generator installed on the APU. During a typical ETOPS flight, the electricity generated by the engine generators is used to power the systems on the airplane. The APU runs as a backup source of electricity in case one of the engine sources is lost. This system architecture meets the minimum redundancy standard for ETOPS.

**Figure 1: Global 737 ETOPS routes (as of September 2011)**

The number of ETOPS operations flown by 737 airplanes increased 23 percent from 2010 to 2011.





Other twin-engine airplanes, such as the Boeing 767 or 777, have additional sources of AC power available during a flight. That has allowed the APU on those airplanes to remain off during the ETOPS phase of flight. These APUs are designed or upgraded to start in-flight at cruise altitude and after cold soaking. ETOPS operators regularly conduct APU in-flight starts to confirm continued reliability and availability in case the APU is needed.

During the development of the Next-Generation 737, a new APU was designed and tested to show in-flight, cold-soak start capability similar to what had been done for other twin-engine airplanes. The development and test program was very similar to the 777 APU program, which obtained ETOPS-type design approval at entry into service. The program included cold-soak simulated altitude start tests, a 3,000-cycle endurance demonstration, and airplane cold-soak, in-flight starts. With service experience, improvements have been made to the Next-Generation 737 APU, which has benefited APU reliability for ETOPS operators.

The APU design improvements and demonstrated capabilities allowed Boeing to develop a plan with the FAA to utilize the cold-soak, in-flight start capability of the airplane's APU to satisfy on-demand operation regulatory requirements. The fuel savings from avoiding unnecessary APU operation results in savings to ETOPS operators and, in some cases, allows for more direct routes.

#### **SUBSTANTIATING APU-ON-DEMAND OPERATIONS**

Substantiation for the Next-Generation 737 ETOPS APU-on-demand procedure focused on three areas: APU start capability, with emphasis on cold soaking; APU start reliability and the required level to support ETOPS; and APU run reliability (the ability

to run and carry an electrical load). All three areas were tested extensively during the Next-Generation 737 development program in the mid to late 1990s.

**APU start capability.** The Next-Generation 737 APU was designed and tested to establish in-flight start capability throughout the airplane's flight envelope. This was demonstrated by simulated flight conditions at the APU manufacturer's test facility and by airplane flight test. Early test conditions included cold-soak exposure of the APU prior to attempting to start.

**APU start reliability.** In addition to establishing high-altitude, cold-soak start capability, adequate in-flight reliability must also be established to support ETOPS. ETOPS operators typically demonstrate APU in-flight start reliability per guidance contained in the FAA Advisory Circular 120-42B. This guidance recommends ETOPS operators demonstrate and maintain an APU in-flight start reliability of 95 percent. For Next-Generation 737 APU-on-demand operation, the APU in-flight start sampling program includes more stringent requirements that are conveyed in the airplane's configuration, maintenance, and procedures (CMP) document. Also, design upgrades made to the APU starter-generator intended to improve reliability (see Honeywell service bulletin 28B545-7-24-4220) are now part of the required APU configuration for APU-on-demand operation. In addition to normal oil consumption monitoring per Code of Federal Regulations 14 section 121.374(k)7 and FAA Advisory Circular 120-42B, 301.l, instructions for APU condition monitoring have been added to the CMP document to support APU-on-demand operations. This condition monitoring is intended to support both in-flight start reliability and run reliability. Finally, more effective troubleshooting of APU in-flight start problems is required by the CMP to maintain APU-on-demand operations.

Wear on the APU itself, as a result of running the APU continuously during an ETOPS flight, is reduced with APU-on-demand authorization, extending APU on-wing life and APU maintenance intervals.

**APU run reliability.** The Next-Generation 737 APU run reliability was tested as thoroughly as was APU in-flight starting. The APU ETOPS program completed for the 777 programs was reproduced for the Next-Generation 737 program. With respect to run reliability, the 777 ETOPS special condition requirement for an APU 3,000-cycle test was used to impose the rough equivalent of two years of use on the Next-Generation 737 APU. This endurance test was used to detect any early reliability problems, to expose the APU to a variety of environments, and to assess the maintainability of the APU and installation. In addition, the APU control system (specifically the APU electronic control unit, data memory module, and exhaust gas temperature sensors) includes provisions to track the health of the APU as part of an operator's maintenance program.

#### BENEFITS TO OPERATORS

The ability to operate the APU on demand during ETOPS flights offers several benefits for operators.

APU-on-demand authorization streamlines fuel planning by eliminating the requirement to plan for APU fuel consumption for an ETOPS flight. (APU fuel for diversion planning is still maintained.) For example, using the APU on demand on a daily round-trip flight from Los Angeles to Honolulu, with a 10-hour total APU run time if run continuously, results in savings of more than 54,000 U.S. gallons (204,412 liters) of fuel for that airplane over a full year.

Wear on the APU itself, as a result of running the APU continuously during an ETOPS flight, is reduced with APU-on-demand authorization, extending APU on-wing life and APU maintenance intervals. For example, using the APU on demand instead of continuously on the same daily, round-trip flight from Los Angeles to Honolulu, results in 3,650 fewer APU operating hours per year for that

airplane. This extends the interval between scheduled maintenance for the APU.

The reduced fuel burn associated with on-demand APU operations reduces emissions. With about 21 pounds (9 kilograms) of carbon dioxide (CO<sub>2</sub>) emitted per gallon of fuel, more than 500 tons (453 metric tonnes) of CO<sub>2</sub> emissions per airplane can be eliminated annually by not running the APU continuously on a daily round-trip flight between Los Angeles and Honolulu.

Finally, improving APU reliability for on-demand operation provides an overall benefit to airplane electrical system reliability. Learning from in-service experience has led to design improvements to the APU, thereby benefiting overall airplane reliability.

#### SUMMARY

Using the Next-Generation 737 APU-on-demand during ETOPS flights will save fuel, reduce scheduled maintenance, lower CO<sub>2</sub> emissions, and improve the overall reliability of the airplane electric power system. 



