

GoldCare Service
Expands to Next-
Generation 737

**Airworthiness
Directive
Implementation
and Compliance**

Fire Protection:
Cargo
Compartments

InFlight
Optimization
Services for
Greater Fuel
Efficiency

Human Fatigue
Risk Management
System for
Maintenance

AERO

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03

GoldCare Service Expands to Next-Generation 737

Boeing's service option on the 787 is now being offered to Next-Generation 737 operators.

05

Industry Efforts to Improve Airworthiness Directive Implementation and Compliance

More than 30 changes are being made to processes and procedures affecting regulators, original equipment manufacturers, operators, and maintenance providers.

11

Fire Protection: Cargo Compartments

Cargo compartments on Boeing passenger and freighter airplanes incorporate comprehensive fire protection that includes fire detection and suppression systems.

21

InFlight Optimization Services Offers Airlines More Fuel-Efficient En-Route Operations

Boeing has developed a suite of flight services that enables operators to increase fuel and flight efficiency and reduce costs and carbon emissions.

25

Implementing a Human Fatigue Risk Management System for Maintenance

Maintenance and engineering organizations should develop risk management systems to deal with human fatigue that contributes to maintenance errors.

AERO

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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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GoldCare Service Expands to Next-Generation 737

It is my great pleasure to introduce this edition of *AERO* magazine. In our last issue, my recently named successor, Jay Maloney, explained our 787 service, GoldCare.

GoldCare began in 2004 when we put a small team together to develop a new service around the 787, leveraging capabilities throughout Boeing and our supplier network. We saw the potential to add customer value and began discussions with 787 customers to assess whether they also saw this value.

Responses were far-ranging, but the general opinion was that GoldCare did indeed add value and appeared to be well-aligned with market trends toward airline outsourcing of material management, engineering, and maintenance. Most importantly, customer responses indicated a clear desire for original-equipment-manufacturer services to provide technical, logistical, and regulatory support not available elsewhere in the marketplace. Our goal has been to imbed unique, value-added benefits in the GoldCare service, many of which Jay reviewed in his article.

Since we announced TUI Travel as the GoldCare launch customer, we

have received many customer inquiries. Much of the interest has concerned platforms other than the 787. Given the high level of customer interest, Boeing is now offering the GoldCare service on all Next-Generation 737 airplanes, and the GoldCare team is engaging with several operators. We expect to make a launch customer announcement in the near future. We are also evaluating GoldCare offerings for the 777 and 747-8 models.

If you have ever received an e-mail from me, you may have noticed that I include a quotation by Frances Hodgson Burnett, which I think best describes our journey to bring GoldCare to reality. It reads, "At first, people refuse to believe that a strange new thing can be done, then they begin to hope it can be done, then they see it can be done — then it is done, and all the world wonders why it was not done centuries ago."

Developing a product that provides high value to customers is what Boeing is all about, and it has been personally very rewarding for me to see GoldCare come to market for our customers.

Please enjoy this issue of *AERO* magazine!



BOB AVERY

Vice President
Fleet Management



The Aviation Rulemaking Committee is changing how airworthiness directives are developed and implemented.

Industry Efforts to Improve Airworthiness Directive Implementation and Compliance

The Airworthiness Directive (AD) Implementation Aviation Rulemaking Committee (ARC) was chartered by the U.S. Federal Aviation Administration (FAA) to implement recommendations resulting from an investigation into the grounding of numerous airplanes because of AD noncompliance.

By **Terry McVenes**, Director, Operational Regulatory Affairs, and
Dale Johnson, Senior Program Manager, Regulatory Operations Support

The purpose of the AD ARC was to develop and implement solutions that would improve airline compliance with FAA ADs. Improvements include clearly identifying the critical steps required for AD compliance, adding flexibility and standard practices to reduce the need for alternative methods of compliance (AMOCs), providing FAA inspectors with better tools to determine compliance, and communicating best practices for operators when planning and performing inspections and modifications mandated by an AD. In all, the committee is implementing more than 30 changes to processes and procedures affecting the FAA,

original equipment manufacturers (OEMs), operators, and maintenance providers.

This article highlights these changes and how the success of the AD ARC is expected to improve the current process for developing and implementing ADs.

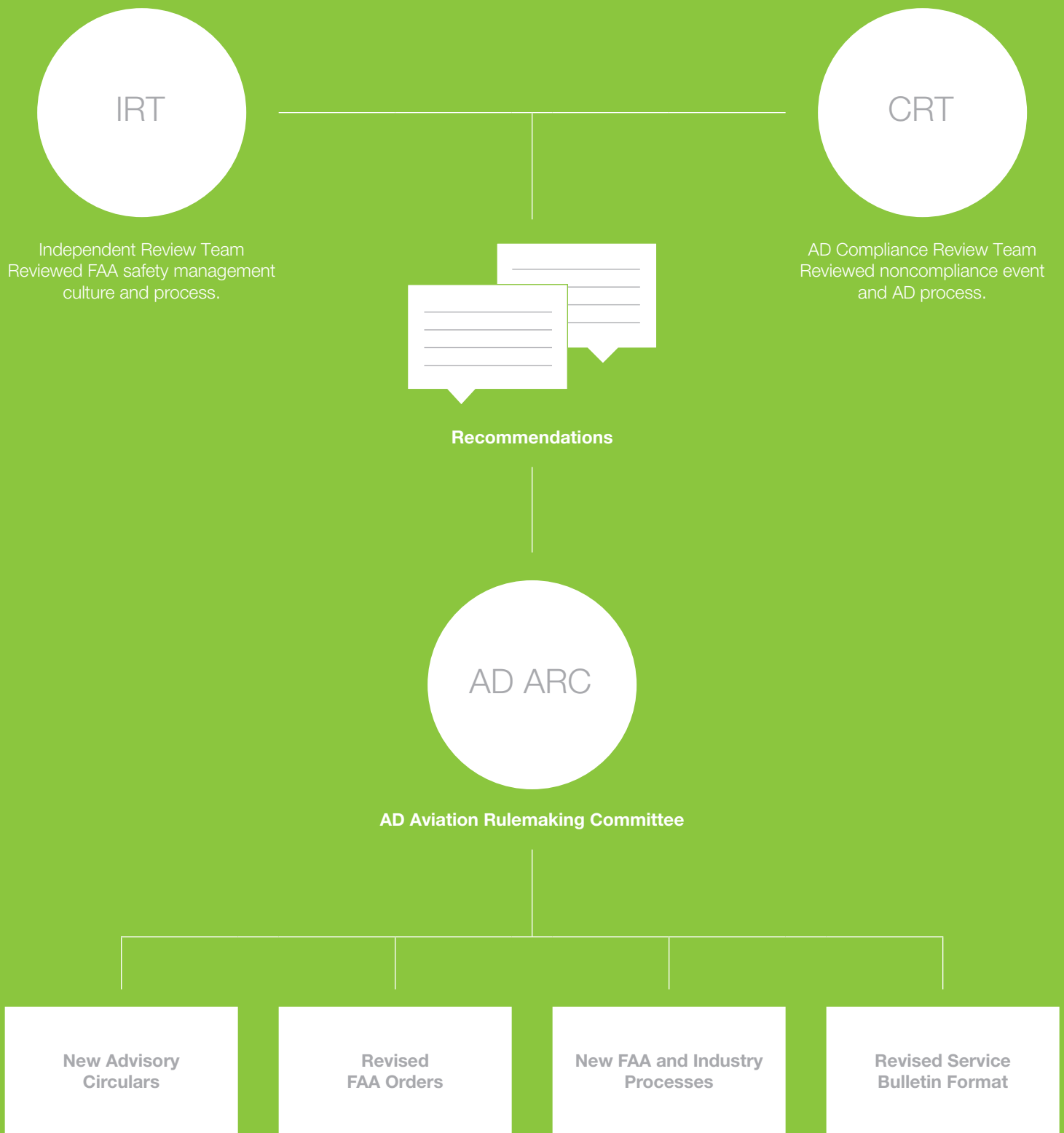
BACKGROUND

During March and April 2008, two cases of potential noncompliance to ADs resulted in hundreds of airplanes being grounded, inconveniencing thousands of passengers. This prompted the U.S. Department of Transportation to establish an Independent

Review Team (IRT) to examine the FAA's safety culture and its implementation of safety management. The IRT consisted of five aviation and safety experts who were tasked with evaluating and making recommendations to improve the FAA's implementation of the aviation safety system and its culture of safety. The IRT issued its final report in September 2008, identifying recommendations related to ADs, the voluntary disclosure program, the culture of the FAA, safety management systems, the air transportation oversight system, and the role of FAA inspectors.

Figure 1: AD ARC process

The U.S. Department of Transportation established an Independent Review Team (IRT) followed by an Airworthiness Directive (AD) Compliance Review Team (CRT) that was established by the FAA. Findings and recommendations for improvements from these two teams were sent to the AD Aviation Rulemaking Committee, which was tasked with implementing the recommendations.



Soon after the IRT was formed, the FAA also established an AD Compliance Review Team (CRT) to review the events that caused the major disruption to some airlines' schedules. This team consisted of eight FAA and industry subject matter experts. The team first reviewed compliance issues related to a model-specific AD and then reviewed the general process for developing and implementing ADs. The team's findings show that the AD processes within the FAA and within the manufacturing and air carrier industry have worked well over the years. However, during this review the team uncovered areas where improvements can be made. The team created two reports (see fig. 1) with findings and recommendations for improvements. These recommendations focus on the areas of service instructions, the FAA Aircraft Evaluation Groups (AEGs), lead airline process (i.e., Air Transportation Association Specification 111), AD process and implementation, mandatory continuing airworthiness information, AMOCs, crisis communication, and Part 39 regulations.

AD IMPLEMENTATION ARC

In August 2009, the FAA chartered the AD ARC to evaluate and address the recommendations of the AD CRT and IRT relating to airworthiness directives. The AD ARC had its first meeting in December 2009 with members including the FAA, various airplane manufacturers, airlines, and industry associations. It was tasked with implementing the recommendations by June 30, 2011.

Working groups. The ARC divided the recommendations into four categories and created four associated working groups: service information, AD development, AD implementation, and FAA organization/procedures. Working group members

included people from various airlines, design approval holders, the FAA, and industry associations. The objectives of the working groups were:

- **Service information.** Revise the way service bulletins (SBs) are written to avoid mandating actions that are not required to meet the safety intent of the AD.
- **AD development.** Ensure that the AD development process is effective and efficient.
- **AD implementation.** Identify and develop guiding principles, processes, procedures, and best practices for implementing and maintaining compliance with ADs to ensure a safe product.
- **FAA organization/procedures.** Define decision-making processes for compliance versus noncompliance that can be used by the FAA and industry in any situation.

SERVICE INFORMATION WORKING GROUP

The Service Information Working Group was co-led by Boeing and a major U.S. airline. This group's efforts will result in significant changes to the way Boeing SBs are written, especially those associated with ADs. These changes and best practices are being written into an FAA advisory circular (AC) with strong encouragement for all design approval holders to make similar changes. These changes include:

- **Writing SBs to clearly identify which accomplishment steps are required to correct the unsafe condition that prompted the AD and which steps can be performed using acceptable procedures.** This will allow airlines to use their own accepted practices for steps

such as access and close-up. It should also reduce the need for AMOCs for work done during a heavy visit when the airplane is already opened up, and other similar situations.

- **Adding notes to SBs that allow flexibility in using acceptable equivalent alternate materials, parts, and procedures where allowed.** General notes have been used in SBs for years, but this effort is creating new notes and expanding existing notes to allow for the maximum amount of flexibility when accomplishing the SB instructions. For example, this may eliminate the need for AMOCs to use alternate fasteners or change the sequence of steps in a procedure, or when gaining and restoring access to accomplish a modification.
- In addition to adding general notes, SBs will be written using standard industry practices whenever possible, instead of unique materials or processes. This will make it less likely for work to be accidentally undone during normal maintenance.
- Figures and illustrations will be identified as either "authoritative" or "reference only," communicating more clearly when the airplane configuration must match the illustration.
- Best practices are being shared among the design approval holders serving on the working group to help streamline the processes for developing and revising SBs.
- The lead airline process is being enhanced to improve the coordination of corrective action necessary to correct an unsafe condition before the SB and AD are released.

The Service Information and AD Development Working Groups are working jointly to document in the AD what is necessary after accomplishment of the AD to either maintain the exact configuration defined by the AD or whether standard maintenance practices can be used.

AD DEVELOPMENT WORKING GROUP

This working group was led by the FAA and was tasked with making the AD process more effective and efficient. Changes that either already have been completed or are being implemented include:

- FAA Notice 8110.112, which discusses the FAA posting of service information that is “incorporated by reference” in ADs onto the Federal Docket Management System (FDMS) at the final rule stage. This gives public access to bulletins containing work instructions mandated by ADs. It also allows the FAA to post service information onto the FDMS at the Notice of Proposed Rulemaking (NPRM) stage with permission from the design approval holders. Boeing has granted the FAA permission so that during the NPRM comment period, commenters will have the appropriate information needed to review the requirements before commenting. This will apply to new ADs only; it is not retroactive.
- A process developed by the FAA and OEMs for tracking and managing multiple AD-related SBs that may conflict or overlap. This will help to avoid potential confusion, inadvertent noncompliance, or reversal of previous AD actions.

- A formalized process for documenting within the AD whether credit is given for accomplishing earlier versions of the related service information. This will help reduce the number of AMOCs.
- The FAA has clarified in the AD manual what is meant by *ex parte* (“one-sided”) communications and how it relates to commenting on rule changes. This will provide awareness of the proper documentation during rulemaking.

The Service Information and AD Development Working Groups are working jointly to document in the AD what is necessary after accomplishment of the AD to either maintain the exact configuration defined by the AD or whether standard maintenance practices can be used. This effort was an add-on from the IRT and CRT recommendations and may take additional time to work through the details of the implementation.

AD IMPLEMENTATION WORKING GROUP

A major U.S. airline headed up this working group. It took the best practices from all the groups’ participants and is including them into an FAA AC so that all operators can adopt them. The AC will include the following guidance related to best practices

for air carrier AD compliance planning, implementation, and monitoring:

- FAA aviation safety inspector (ASI) involvement in air carrier AD management processes.
- Air carrier prototyping of AD documentation prior to implementation in order to ensure work efficiency and AD compliance.
- Periodic audits of AD compliance by air carriers with a focus on ADs with a high risk of inadvertent alteration during normal maintenance.
- Training on AD processes and wiring best practices.
- Air carrier skill-specific training for particular ADs.
- OEM and air carrier best practices when requesting AMOCs.
- Identification of opportunities to make more AMOCs global when appropriate and posting of these AMOCs on OEM websites.
- 24/7 crisis communication process among air carriers and FAA Flight Standards Service field offices to prevent potential grounding situations.

Incorporation of these best practices will help to improve the overall process for AD implementation and reduce noncompliance findings and the need for AMOCs.

FAA ORGANIZATION/PROCEDURES WORKING GROUP

This team was led by the FAA and focused on making changes to the way the FAA manages ADs. This team's functions included:

- **Strengthening the role of the FAA AEG by:**
 - Clarifying AEG roles and responsibilities in FAA Order 8900.1 (Flight Standards Information Management System). The AEG specialist will be involved earlier in the AD process, which will help the AEG determine when an outreach program to the principal inspector is needed.
 - Developing new AEG classroom and Web-based training regarding AEG roles and responsibilities and their interfaces with the Aircraft Certification Office (ACO). The training program would define the communication protocol and elaborate on the responsibilities and positions of each group (e.g., ASI, AEG, aviation safety engineer, etc.).
 - Ensuring that FAA field personnel understand that the AEG is a key resource for technical issues and continued operational safety.
 - Developing new 24/7 and AMOC support process Web-based training. The 24/7 AMOC support process will help prevent grounding of a large number of airplanes.
 - Conducting briefings to the FAA regional field offices on the new 24/7 AMOC support process.
- Increasing staff at the AEG.
- Improving compliance planning through:
 - Providing new guidance in FAA Order 8900.1 and AC for AD management. This is the AC being worked by the AD Implementation Working Group that will address the six elements of an effective AD management process:
 - Planning
 - Support
 - Provisioning
 - Implementing
 - Recording
 - Auditing
 - Revising the AD management and foundations for principal inspector courses to bring them up to speed on the new AD management processes.
- **Enhancing ASI decision making by:**
 - Providing new guidance in FAA Order 8900.1 for ASIs for addressing situations in which the compliance of a single airplane or fleet of airplanes is in question, as well as how and when to determine coordination with AEG and ACO.
 - Providing new guidance in FAA Order 8900.1 for principal inspectors' role in the AMOC process (e.g., roles, responsibilities, and 24/7 interface).
 - Providing a new logic flowchart that illustrates step-by-step procedures that can be followed to eliminate single-person determination and to elevate concerns regarding AD compliance.

- Revising FAA orders 8100.15 and 8110.37 to include expansion of structural AMOC delegations in limited situations to allow approval of alternative inspection methods, thresholds, and intervals, and certain global AMOCs.

SUMMARY

Formed by the FAA following an investigation into the grounding of hundreds of airplanes owing to AD noncompliance, the AD ARC is implementing a number of recommendations to more clearly identify the steps airlines and maintenance, repair, and overhaul organizations must take to ensure compliance with ADs and making numerous changes to the way the FAA manages ADs. The AD ARC has proven that when the FAA and industry come together to work on a common cause, many good things can happen. The changes that are being implemented, along with the collaborative attitude that has formed between all those involved in this effort, will result in a significant reduction in the number of AMOCs needed, a much better understanding of the steps that are required to correct the unsafe condition identified by ADs, and fewer instances of grounded airplanes.

For more information, please contact Dale Johnson at dale.r.johnson2@boeing.com. 



Boeing designs cargo compartments to prevent fire and to provide passive and active protection systems should a fire occur.

Fire Protection: Cargo Compartments

Cargo compartments on Boeing passenger and freighter airplanes incorporate comprehensive fire protection that includes fire detection and suppression systems.

By **Carol Hipsher**, Senior Manager, Flight Safety and Design Office, Technical Customer Support, and **Douglas E. Ferguson**, Technical Safety Chief, Fire Protection, Technical Services and Modifications

This article is the second in a series exploring the implementation of fire protection on transport category airplanes.

Fire protection is given one of the highest considerations at Boeing in airplane design, testing, and certification. In designing an airplane's fire protection features, Boeing uses the principles of prevention, separation, isolation, and control.

Prevention is the first order of the day, as it is better to prevent a fire than to have to contend with one in flight. The principles also involve separating the three essentials for creating a fire (i.e., fuel, ignition source, and oxygen), isolating potential fires from

spreading to other parts of the airplane, and controlling a fire should one occur.

To effect this prevention, separation, isolation, and control, Boeing uses both passive and active features. Passive features include the use of noncombustible or self-extinguishing materials; separation by routing, compartmentalization, isolation, ventilation, and drainage; and bonding and grounding. Active features include fire and overheat detection systems, fire-suppression systems, temperature sensing, air shut-off means, and automatic shutdown of nonflight critical systems. Fire protection systems on Boeing airplanes meet all aviation regulatory requirements as well as internal Boeing design requirements.

This article describes how Boeing designs fire protection into the cargo compartments of passenger and freighter airplanes.

CARGO COMPARTMENT CLASSIFICATIONS

The Federal Aviation Regulations classify cargo compartments into four categories:

Class A. The presence of a fire would be easily discovered by a crewmember while at his or her station and each part of the compartment is easily accessible in flight.

Figure 1: Class C lower cargo compartment

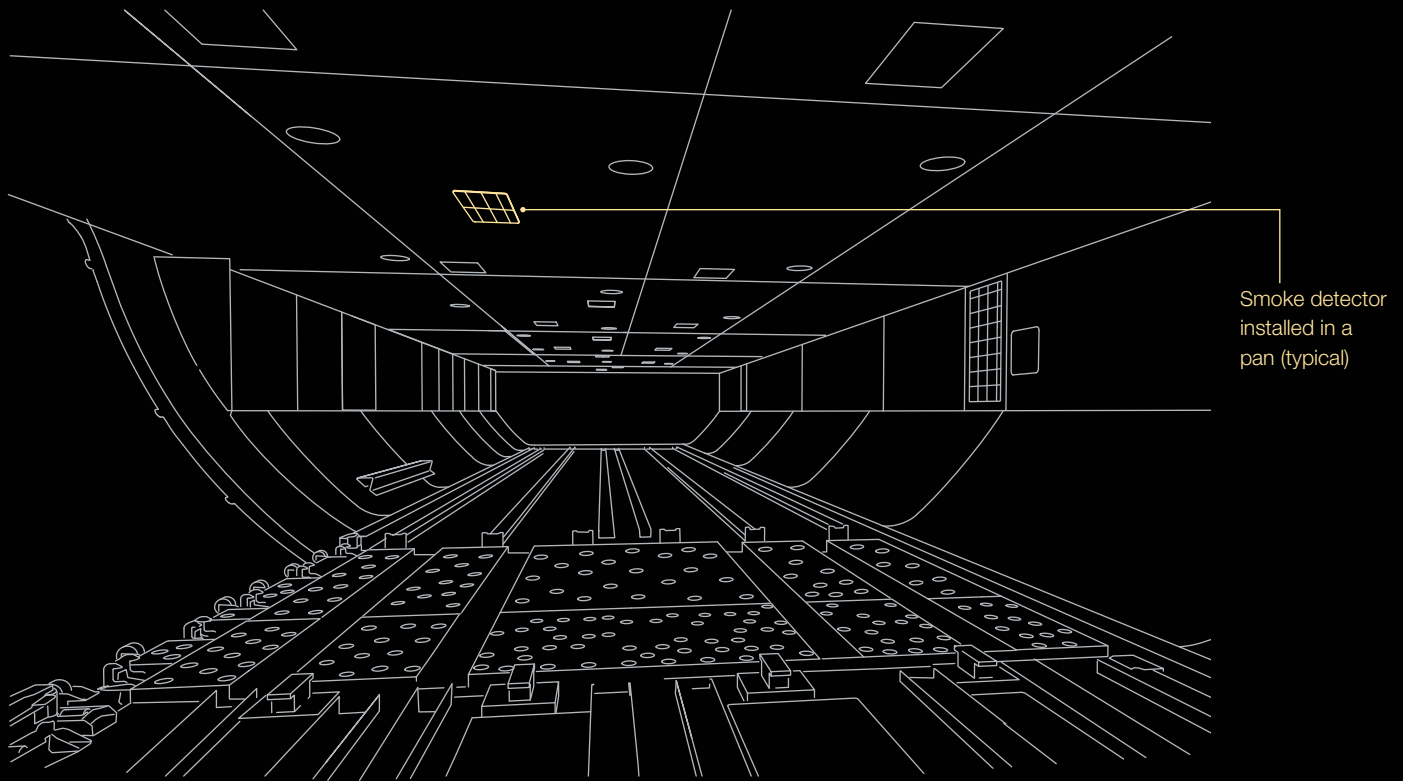


Figure 2: Class E main deck cargo compartment



Figure 3: Fire protection in a typical cargo compartment

This main deck cargo compartment illustrates two types of fire protection: liners on the sidewalls and smoke detectors running overhead.



Class B. There is a separate approved smoke detector or fire detector system to give warning at the pilot or flight engineer station. There is sufficient access in flight to enable a crewmember to effectively reach any part of the compartment with the contents of a hand fire extinguisher. When access provisions are being used, no hazardous quantity of smoke, flames, or suppression agent can enter any compartment occupied by the crew or passengers. There are means to control ventilation and drafts within the compartment.

Class C. There is a separate approved smoke detector or fire detector system to give warning at the pilot or flight engineer station. There is an approved built-in fire extinguishing or suppression system controllable from the flight deck. There are means to exclude hazardous quantities of smoke, flames, or suppression agent from any compartment occupied by the crew or passengers. There are means to control ventilation and drafts within the compartment so that the suppression agent used can control any fire that may start within the compartment (see fig. 1).

Class E (allowed only on airplanes used strictly for carrying cargo). There is a separate approved smoke or fire detector system to give warning at the pilot or flight engineer station. There are means to shut off the ventilating airflow to, or within, the compartment, and the controls for these means are accessible to the flight crew in the crew compartment. There are means to exclude hazardous quantities of smoke, flames, or noxious gasses from the flight crew compartment. The required crew emergency exits are accessible under any cargo loading condition (see fig. 2).

ADDITIONAL REQUIREMENTS FOR CARGO COMPARTMENT FIRE PROTECTION

In addition, the following are required by the regulations:

Liners. The liner must be separate from (but may be attached to) the airplane structure (see fig. 3). Ceiling and sidewall liner panels of Class C compartments must meet fire test requirements.

Construction materials. All materials used in the construction of the cargo compartment besides the liners must meet applicable test criteria that include fire tests as required.

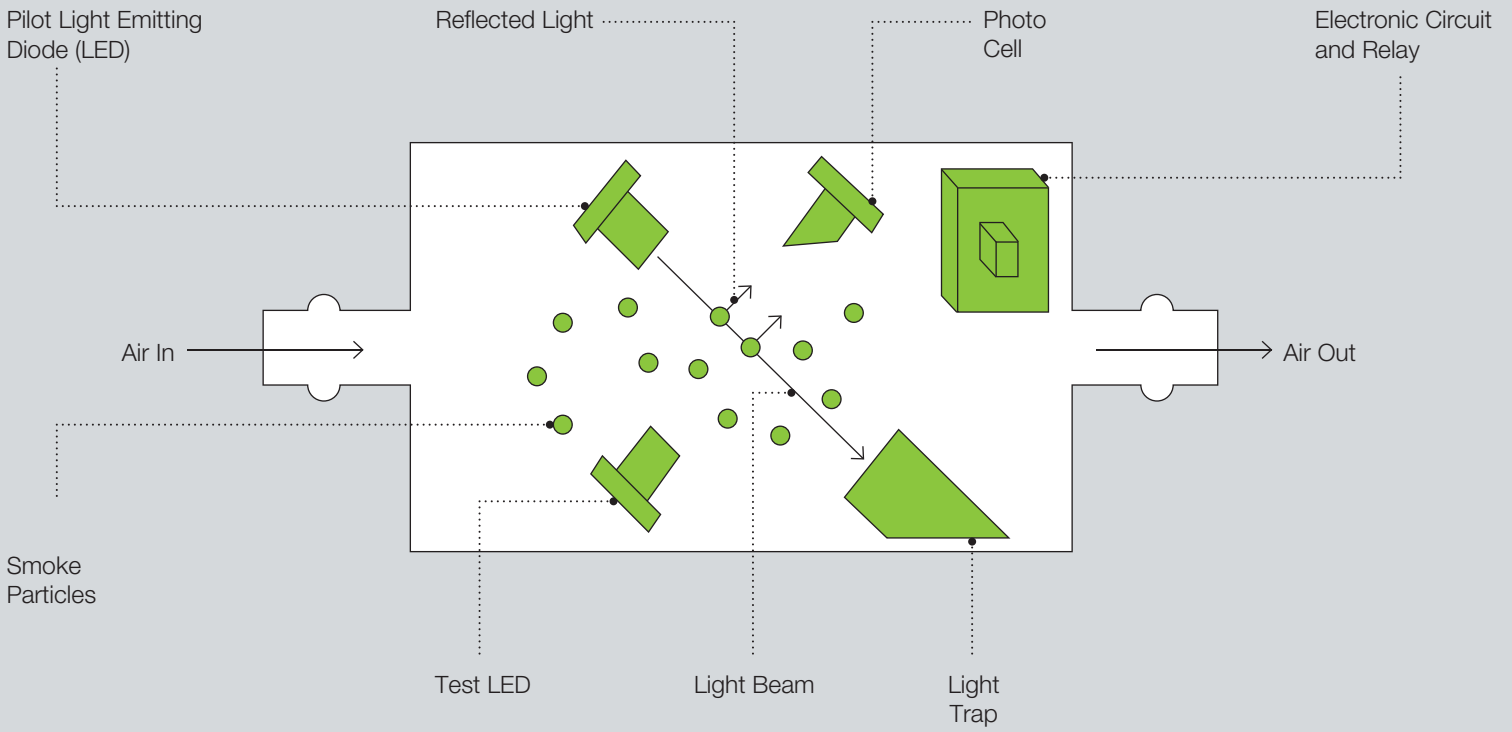
Controls. No cargo compartment may contain any controls, lines (wires, tubing, cables), equipment, or accessories whose damage or failure would affect safe operation, unless those items are protected so that they cannot be damaged by the movement of cargo in the compartment and their breakage or failure will not create a fire hazard.

Cargo/baggage restraint. There must be means to prevent cargo or baggage from interfering with the functioning of the fire protective features of the compartment.

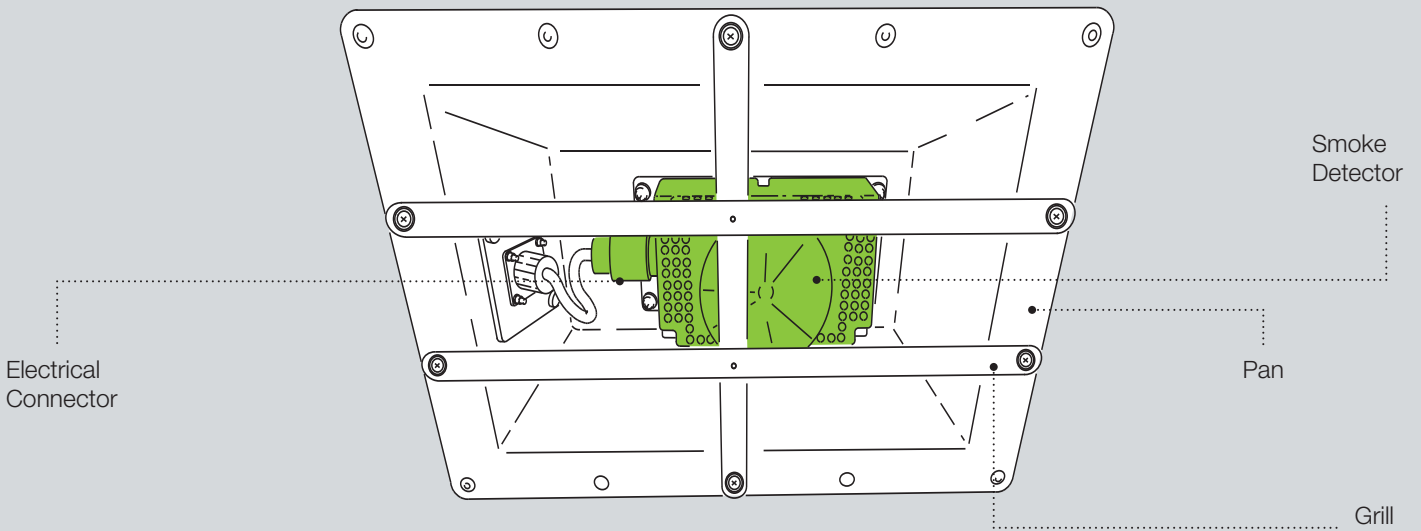
Heat sources. Sources of heat within the compartment (i.e., from lights, control panels) must be shielded and insulated to prevent igniting the cargo or baggage.

Figure 4: Types of smoke detectors

A smoke detector can be described by how the smoke enters the sensing chamber.



Draw-Through Type Smoke Detector



Open-Area Type Smoke Detector

Almost all cargo compartment smoke detectors are based on photoelectric sensing. Smoke particles interfere with a light beam inside the detector, causing the light to scatter onto a photosensitive diode, which increases the photodiode's current output and generates an alarm.

Wiring. Cargo compartment electrical wiring interconnection system components must meet installation requirements, such as wire separation, and component qualification tests.

Tests. Certification ground and flight tests must be conducted to demonstrate various requirements. These include:

- In-flight access to cargo compartments for Class A, B, and E cargo compartments.
- The prevention of hazardous quantities of smoke or suppression agent from entering into compartments occupied by the crew or passengers.
- Demonstration of the smoke detection system is performed to show compliance to all requirements, including flight testing to show that the system performs its intended function at all foreseeable operating conditions.
- Concentration measurements for the suppression agent in Class C compartments.

During these flight tests, it must also be shown that no inadvertent operation of smoke or fire detectors in any compartment would occur as a result of fire contained in any other compartment, either during or after extinguishment. (Although *fire extinguishing* is the term used by the regulatory authorities, the more realistic term is *fire suppression*. A fire in a cargo compartment is required to be suppressed long enough for an airplane

to land and evacuate passengers and crew safely. Both terms are used interchangeably in this article.)

CARGO COMPARTMENT LINERS

Liners are a passive fire protection feature. The primary purpose of a cargo liner is to prevent a fire originating in a cargo compartment from spreading to other parts of the airplane before it can be brought under control by the fire suppression system.

In Class C cargo compartments — which include the lower cargo compartments of all passenger airplanes and the lower cargo compartments for most freighters — the cargo compartment sidewall and ceiling liner panel installations are fire tested to determine flame penetration resistance. Test requirements specify that a minimum of three specimens must be tested; there must be no flame penetration of any specimen within five minutes after application of the 1,700 degrees F (927 degrees C) flame source; and for ceiling liners, the peak temperature measured at four inches above the upper surface of the horizontal test panel must not exceed 400 degrees F (202.4 degrees C). All other materials must be self-extinguishing.

Many Boeing-certified freighter airplanes' main deck Class E cargo compartments also incorporate cargo liners made from the same material that meets Class C compartment liner requirements.

SMOKE DETECTION

Class B, C, and E cargo compartments have smoke detection systems that provide active fire protection. These systems are designed to provide an aural and visual indication to the flight crew in the early, smoldering phase of a fire prior to it breaking out into a large fire. In older model airplanes, the time to detect a fire was not quantified by the regulators. Smoke detection systems of that era typically met a five-minute detection time. Using newer technology, smoke detection systems can provide an indication in a shorter time. Based on a simulated smoke source representing a smoldering fire, all newer airplanes can detect a fire within one minute. In all cases, the smoke detection systems can detect a fire at a temperature significantly below that at which the structural integrity of the airplane could be adversely affected.

Almost all cargo compartment smoke detectors are based on photoelectric sensing. Smoke particles interfere with a light beam inside the detector, causing the light to scatter onto a photosensitive diode, which increases the photodiode's current output and generates an alarm. A smoke detector can be described by how the smoke enters the sensing chamber: draw-through or open-area type (see fig. 4).

Figure 5: Draw-through cargo smoke detection system

Many Boeing airplanes utilize draw-through smoke detectors in the cargo compartment smoke detection systems.

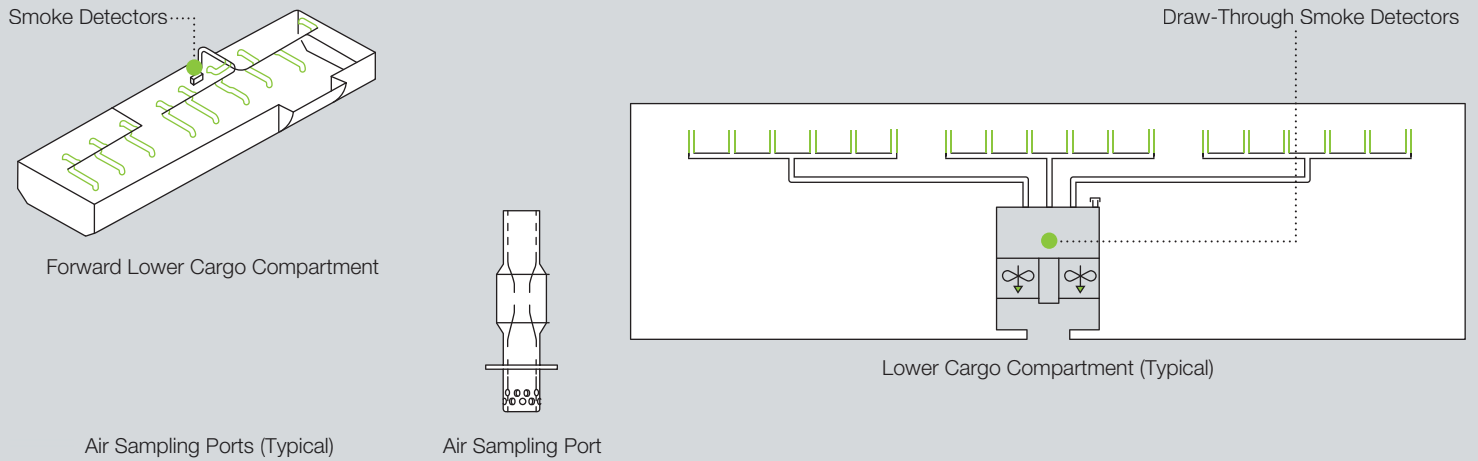
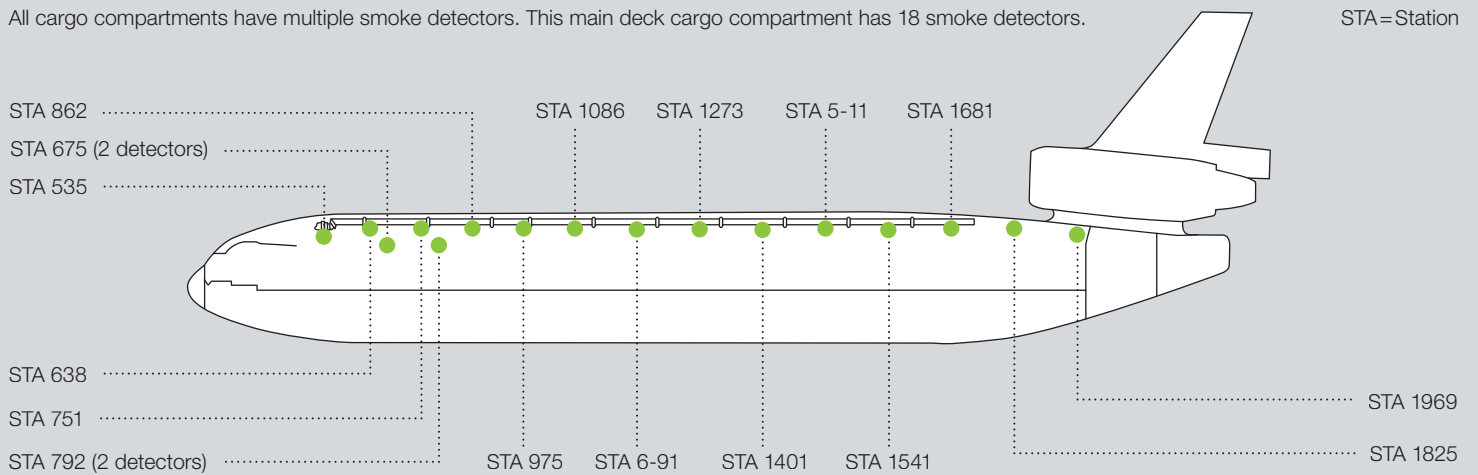


Figure 6: Cargo compartment smoke detectors

All cargo compartments have multiple smoke detectors. This main deck cargo compartment has 18 smoke detectors.



Draw-through type detectors, also known as active smoke detectors, continuously monitor a sample of air drawn from the cargo compartment for the presence of smoke — an indication of a fire condition. A draw-through detection system consists of a distributed network of sampling tubes (see fig. 5) that bring air sampled through various ports located in the cargo compartment ceiling to the smoke detectors located outside the cargo compartment. The air is also exhausted outside the compartment.

Open-area type detectors, also known as passive smoke detectors, are installed inside the compartment, usually in the ceiling, and directly exposed to the smoke (see figs. 1 and 2).

In addition, there are means to allow the crew to perform in-flight system testing of each fire detector circuit to ensure proper function. The effectiveness of the detection system must be shown for all approved operating configurations and conditions.

The cargo compartments of all Boeing airplanes are equipped with multiple smoke detectors. For example, the MD-11 freighter main deck cargo compartment has 18 area smoke detectors; 14 distributed axially along the compartment overhead centerline and four located in the forward area of the cargo compartment (see fig. 6). A smoke signal from any smoke detector will trigger a fire alarm at the flight deck. This is a “single loop” system because any single detector can set off the fire alarm.

The smoke detection systems in each cargo compartment can also be designed in a dual-loop (two single-loops) configuration. The smoke detectors are organized with one or more detectors associated with each single-loop. In a dual-loop system, two separate smoke signals are required to generate a fire alarm at the flight deck. Most Boeing airplanes use a dual-loop configuration for cargo smoke detection systems. For both dual-loop and single-loop systems, there is guidance provided through the master minimum equipment list to allow dispatch if a smoke detector is inoperative.

When smoke is detected in the cargo compartment, visual and aural warnings are provided at the flight deck (see fig. 7). Two

Figure 7: Typical flight deck indications and control

When smoke is detected in a cargo compartment, visual and aural warning indications are provided at the flight deck, which also has controls for the cargo compartment fire suppression system.



red master warning lights are located on the glare-shield, one in front of the pilot and one in front of the first officer. In addition, on airplanes with engine indicating and crew alerting systems (EICAS), the message FIRE CARGO FWD or FIRE CARGO AFT is displayed on the upper EICAS display located on the main panel to identify the affected lower compartment. On all airplanes and on older airplanes without the EICAS system, individual red lights for the cargo compartment with the fire will light (e.g., FWD CARGO FIRE or AFT CARGO FIRE).

For the main deck compartment on the Boeing 747-400F, the message FIRE MN DK FWD, FIRE MN DK MID, or FIRE MN DK

AFT will be displayed on the EICAS to identify the affected area within the main deck compartment. The EICAS warning message FIRE MAIN DECK is displayed if smoke is detected in more than one zone of the main deck cargo compartment.

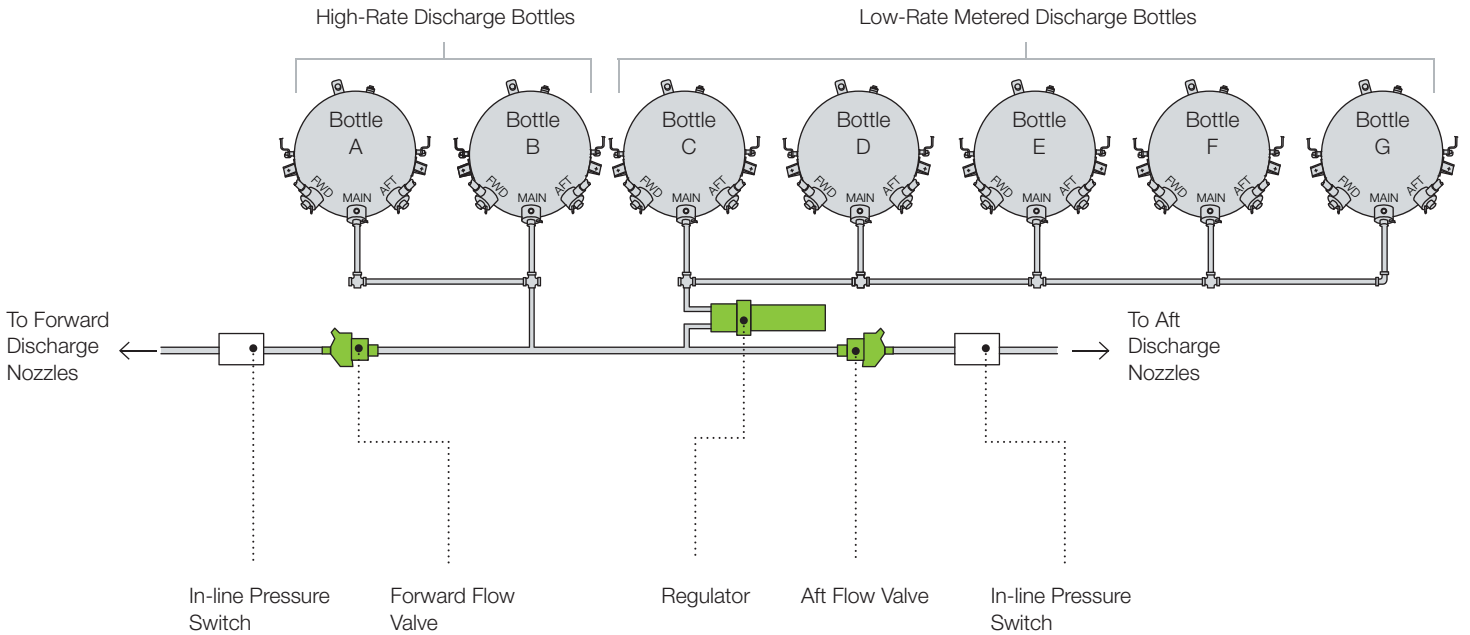
A fire bell or aural warning will sound in conjunction with the visual fire warning, lights, and messages.

FIRE SUPPRESSION

The first step in controlling and suppressing a fire (after turning off the aural warning) is shutting down the airflow to the cargo compartment. All ventilated cargo compartments have a means for shutting off

the airflow from the flight deck. Following airflow shutdown, Boeing-designed Class C cargo compartment fire suppression systems provide minimum Halon 1301 concentration coverage for one hour or more, depending on the airplane model, sufficient to suppress the fire until the airplane lands at the nearest suitable airport. The flight crew commands the discharge of the cargo fire suppression system from the flight deck (see Engine/Auxiliary Power Unit/Cargo Fire Control Panel in fig. 7). This initiates the discharge of halon from fire suppression bottles, which are generally located next to the cargo compartment. Additional fire suppression capability is designed into

Figure 8: Typical metered fire extinguishing system with a flow regulator



the airplane as required for Extended Operations and is dependent on airline customer option configuration.

Typically, cargo fire suppression systems have an initial high-rate knockdown discharge, followed by a low-rate metered discharge of Halon 1301, designed to keep the fire suppressed for continued safe flight and landing at the nearest suitable airport.

Halon can be discharged into the forward or aft cargo compartment. The probability of a cargo fire in any compartment is very low, and the likelihood of two simultaneous fires in two cargo compartments is even lower. Because of this, it is not required to have separate halon bottles for each compartment. One set of bottles provides suppression capability to either cargo compartment.

In all models, once a fire is detected and the halon discharged, minimum halon concentrations are required for the remaining duration of flight. Compliance to these requirements is demonstrated by measuring suppression agent concentration at key locations in the compartment during a certification flight test.

The initial knockdown fire suppression systems installed in all Boeing airplane cargo compartments consist of Halon 1301 bottles discharged through a distribution tubing system to discharge nozzles in the respective cargo compartment ceiling. This initial discharge knocks down the flames and suppresses a fire with a minimum of 5 percent Halon 1301 concentration by volume. The system is sized as a function of compartment volume, temperature, and cabin altitude and typically takes one to two minutes to reach maximum concentrations.

A second discharge, a metered system with a flow regulator (see fig. 8), is either discharged at the same time as the initial knockdown or after a specified time delay and provides a steady-state halon flow rate to maintain compartment halon concentrations above 3 percent for a specified duration. The required metered flow is a function of compartment leakage. The higher the compartment leakage rate, the higher the halon flow rate must be to compensate. Cargo compartments are designed to minimize compartment leakage

during a fire to maximize halon retention and to reduce smoke penetration effects.

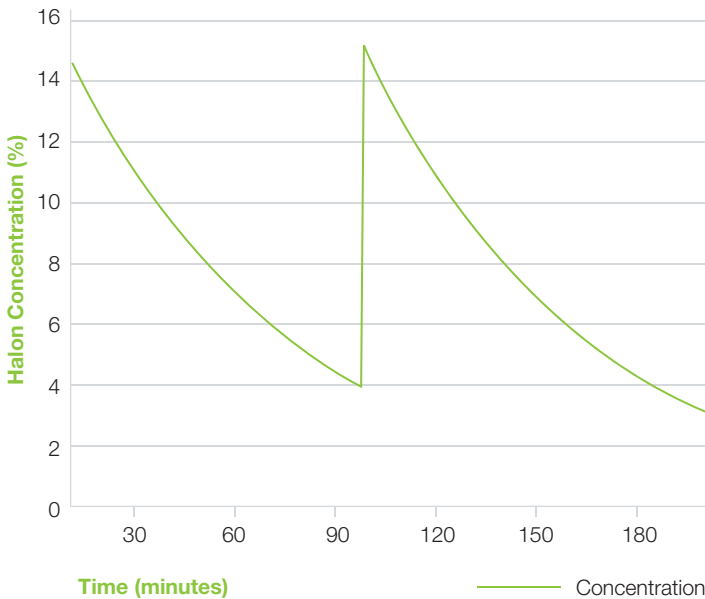
An alternate method for maintaining the minimum required halon concentration is the high-rate discharge fire suppression system. As the concentration of agent from the initial knockdown decays and approaches 3 percent, a subsequent bottle is discharged; the concentration increases and again begins to decay. Depending on system design, additional bottles may be discharged to maintain concentration levels above 3 percent until the airplane has landed safely and the passengers and crew evacuated (see fig. 9). An airplane timer is turned on when the first discharge occurs and subsequent discharges are made manually by the flight crew. The time delay for discharging the additional high-rate bottles is defined in the airplane flight manual and is also usually incorporated into the alert messaging logic.

Firefighting in a Class E cargo compartment is accomplished by shutting down the airflow to the compartment, depressurizing the airplane, and (depending on airplane) descending to just below

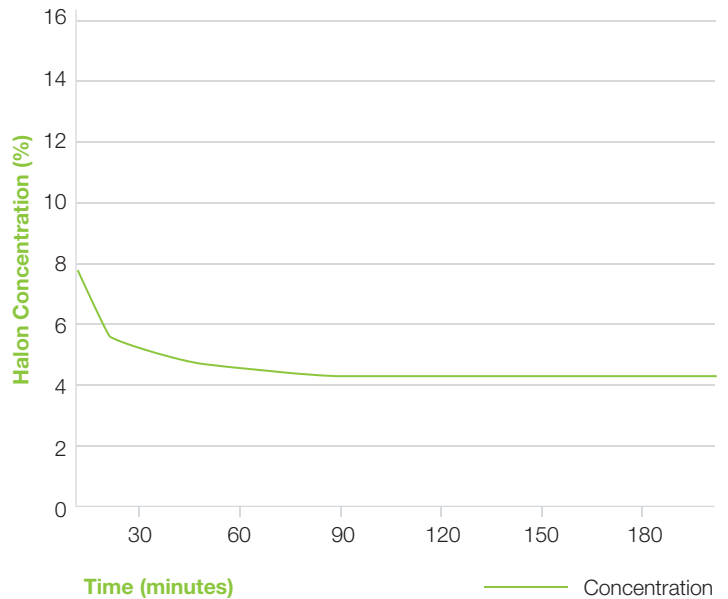
Figure 9: Cargo fire suppression performance by type of system

Cargo fire suppression systems typically have an initial knockdown concentration discharge of Halon 1301 followed by an additional high-rate discharge (left) or a low-rate metered discharge (right).

Halon Concentration Curve for a Two-Bottle High-Rate Discharge Fire Suppression System



Halon Concentration Curve for a Metered Fire Suppression System



25,000 feet as conditions permit. If it is not possible to immediately land at a suitable airport, the depressurized airplane is maintained at approximately 25,000 feet to minimize the oxygen available to the fire. Supplemental oxygen is provided to the flight crew and any supernumeraries via oxygen masks when the cabin altitude exceeds 10,000 feet.

CONTROLLING SMOKE PENETRATION

Boeing uses a two-pronged approach to exclude hazardous quantities of smoke and noxious gases from entering the flight deck or other occupied compartments.

First, the flight deck and passenger compartments are maintained at a slightly higher pressure relative to adjacent compartments that may contain smoke or noxious gases during Class C or E compartment fire suppression.

In Class E compartments, one air-conditioning pack remains on a low-flow setting. This airflow provides air to the flight deck and exits via the electrical equipment cooling system and through

air return paths into the forward lower cheek areas. In addition to acting as a pressure source, the fresh air entering the flight deck also serves to sweep away trace amounts of smoke that may enter the compartment. Smoke within the flight deck is self-clearing and hazardous accumulations are prevented.

Air pathways in and out of occupied areas, including the flight deck, are controlled to ensure that the pressure differential produced is effective in preventing smoke migration into the compartment. In addition, other methods are also used, such as sealing of bulkheads, e.g., rigid cargo barriers on freighters, to minimize smoke penetration.


Second, the individual cargo compartments have liners and barriers designed to minimize the amount of smoke leakage out of the compartment into occupied areas. On different airplanes, these compartment closeouts and seals take different forms, but the integrity of the liners and other smoke barriers is important in establishing and maintaining the fire protection capability of the airplane.

Component tests and certification tests.

All components specified for the fire protection, smoke detection, and fire suppression systems are qualification tested to the requirements specified by Boeing. Certification ground and flight tests are conducted on the smoke detection and fire suppression systems. In addition, smoke penetration tests are also conducted to comply with Boeing and regulatory requirements.

SUMMARY

Boeing designs cargo compartments in passenger and freighter airplanes to prevent a fire and to provide passive and active fire protection systems to control a fire should one occur. Boeing gives the highest considerations to the safety of passengers and crew.

For more information, please contact Carol Hipsher at carol-sue.c.hipsher@boeing.com. 



A new suite of applications helps airlines optimize their postdeparture flight operations.

InFlight Optimization Services Offers Airlines More Fuel-Efficient En-Route Operations

Boeing has developed a new type of flight services that enables operators to increase fuel and flight efficiency and reduce costs and carbon emissions.

By Mike Durham, Product Manager, Airline Efficiency Services, Flight Services

Boeing InFlight Optimization Services (InFlight) is a suite of applications that continuously checks an array of real-time air traffic, weather, and airplane data to uncover postdeparture opportunities for individual flights to save fuel and improve operational performance.

This article describes the development of InFlight by Boeing Flight Services, how it works, and how airlines can benefit from its use.

DEVELOPMENT OF INFLIGHT OPTIMIZATION SERVICES

With fuel expenses representing up to 30 percent of an airline's annual operating budget, reducing fuel use remains one of

the best ways for airlines to cut costs. Airlines typically use roughly 10 percent more fuel than necessary due to flight and air traffic inefficiencies. So implementing even small per-flight efficiency improvements can deliver significant fleetwide savings during the course of a year.

Capturing these savings was the impetus for developing InFlight. This suite of products provides live, actionable flight-specific airline advisories, resulting in efficiency improvements for postdeparture operations. InFlight, which is offered as a subscription service, is available for an airline's modern fleet, including non-Boeing airplanes.

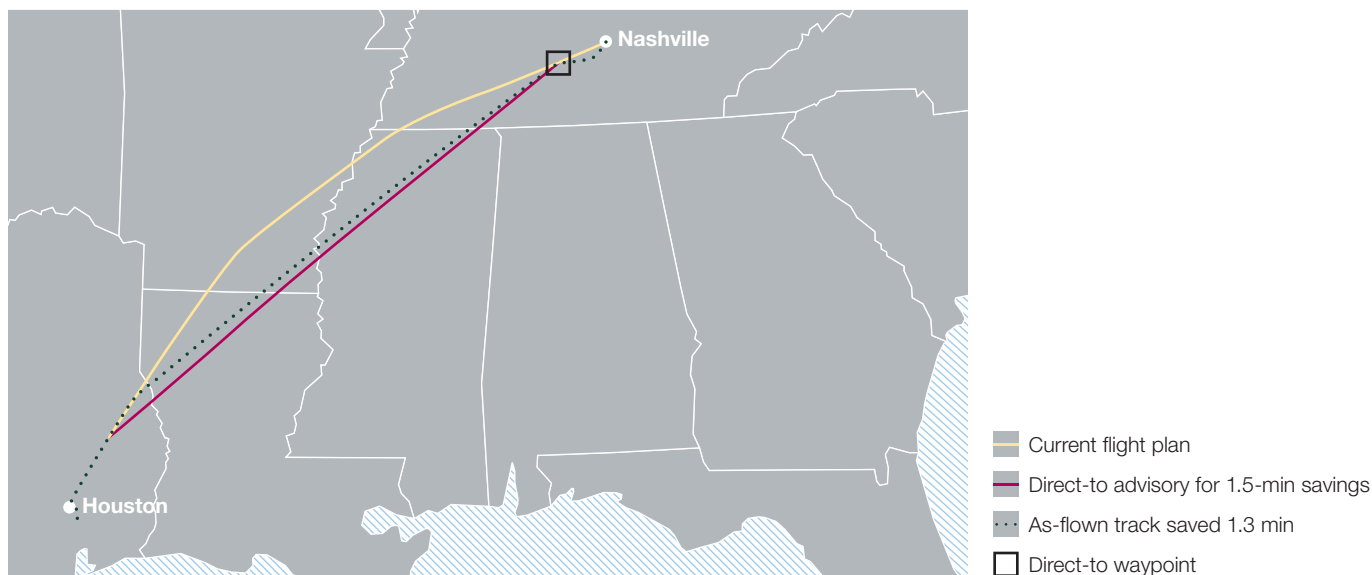
HOW INFLIGHT WORKS

InFlight continuously monitors each flight's progress to identify emerging efficiency opportunities — configured to airline specifications — and automatically sends advisories to the airline. The ground-based service optimizes individual flights by addressing real-time air traffic control (ATC) system variables, the airplane's current flight trajectory, flight management computer (FMC) data, weather conditions, and other factors. The information is up to date to within seconds.

InFlight communicates flight-specific advisories to an airline's operations center or directly to the flight deck in a format that can be immediately loaded into the FMC or

Figure 1: Direct Routes flight optimization

InFlight Direct Routes provides simple, ATC conflict-checked, wind-optimal reroute opportunities with at least one minute of time savings within the next hour of flight.



acted upon by flight crews. It was developed with a common infrastructure to accommodate growth of new flight optimization service applications. The software is designed with common core services and functionality while enabling data sharing across multiple products.

InFlight services are implemented within current air traffic and airline operating procedures using existing communication channels. No regulatory changes and little or no new equipment or training are required, so airline savings begin immediately.

InFlight currently comprises two services: Direct Routes and Wind Updates. Each service provides up-to-the-minute information to airline operation centers and flight crews, enabling adjustments en route to account for weather and ATC status. The Direct Routes service is currently available in the continental United States while the Wind Updates service is being implemented worldwide.

DIRECT ROUTES: AUTOMATIC FLIGHT-OPTIMIZING ALERTS

Airlines always aim to develop and file the most efficient flight plans possible. However, these predeparture filed flight plans are constrained to procedurally separated jet routes and en-route transitions to and from standard departure and arrival routes. Currently, after airplane departure and with traffic permitting, pilots can make a verbal request to ATC for direct-to routings to downstream waypoints in the current flight plan, eliminating inefficient dog-legs in the en-route phase of flight.

InFlight Direct Routes automates this process. Direct Routes software continuously searches for simple, ATC conflict-checked, wind-optimal reroute opportunities that offer at least one minute of time savings within the next hour of flight (see fig. 1).

Direct Routes alerts an airline's operations center or flight crew when a more fuel-efficient path that could be approved by the controller opens up along the route of flight. To increase the likelihood of ATC approval and to keep air traffic controller workload to a minimum, the advisories are prechecked for traffic

conflicts, convective weather, established airspace constraints, and other factors. Finally, the pilot must contact ATC to request the direct-to clearance for the more fuel-efficient flight path.

The current Direct Routes system only covers airline operations within the continental United States. The U.S. Federal Aviation Administration (FAA) is providing the live high-update rate surveillance data necessary to monitor the airline's operation and check for ATC conflicts on any proposed Direct Routes advisories. Boeing has shared details of the project and findings from Direct Route trials with the FAA to ensure the advisories are compatible with airspace procedures and constraints, and are complementary to ATC services. Operational testing of Direct Routes has been completed, and this service is available to customers.

Initial Boeing projections show that Direct Routes can save more than 40,000 minutes of flight time per year for a medium-sized U.S. airline — the equivalent of operating hundreds of flights that use no fuel and produce no emissions.

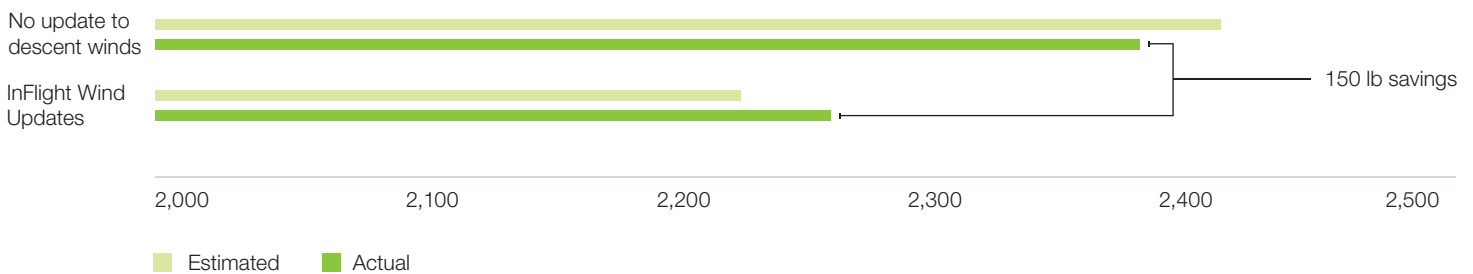
Figure 2: Wind Updates flight optimization

InFlight Wind Updates continuously monitors airline operations and proactively uploads descent winds when beneficial.



Figure 3: InFlight Wind Updates benefits

In this example, which assumes a net increase in tailwind (or decrease in headwind) since the flight plan was generated, the airplane can save 150 pounds of fuel using InFlight Wind Updates to optimize the FMS from top of descent to landing. Fuel saving data is based on analytical models, simulator sessions, and flight trials.



WIND UPDATES: REAL-TIME FMC WIND UPDATES

Historically, flight crews have received weather forecasts and flight plan weather information prior to a flight and manually entered the en-route and descent winds data into the FMC before departure. The forecast information can be several hours old by the time an airplane pushes back from the gate. And, although these weather reports provide general forecasts of winds, temperature, and pressure within a region, they do not include FMC inputs precisely tailored for current as-amended flight paths.

The InFlight Wind Updates system calculates the most accurate FMC input to best represent the updated wind and temperature for the flight trajectory and for the unique capabilities of the FMC on that airplane. The system utilizes the number of weather bands available on the FMC and determines the flight levels for the weather bands based on the specific wind and temperature profile. Currently, descent wind updates are available for the Next-Generation 737, 777, MD-11, and A330. Wind Updates for

the 747, 757, 767, 787, and A320 family will be available soon.

The use of old, inaccurate, and limited weather data — especially wind and temperature data — can prevent airplanes from operating at their most efficient flight-management-system settings and prevent them from meeting precisely established arrival times (increasing fuel burn through additional use of speed brakes and descent level offs). Correcting even small inefficiencies in postdeparture wind updates adds up to significant fleetwide savings during the course of a year.

InFlight Wind Updates identifies optimal input settings while the airplane is in flight and proposes updates to specific FMC weather parameters when there is a sufficient net economic benefit (see fig. 2). After review and acceptance by the flight crew, the wind updates are autoloading into the FMC. This updated weather information in the airplane FMC enables a more efficient and effective trajectory prediction as a component of en-route and descent flight planning, such as improved computation of step climb decisions, speed schedules, and the top of descent point. Boeing

projects that Wind Updates users will experience potential savings of 100 to 200 pounds (15 to 30 gallons or 55 to 110 liters) of fuel for just the descent portion of a typical single-aisle airplane flight (see fig. 3). Boeing is currently conducting operational trials with two major airlines to further expand the capabilities of this service.

SUMMARY

Most airlines are not fully optimizing their postdeparture flight operations. There are several new approaches to optimize in-flight trajectories, including updating the FMC with an intelligent selection of the most current and accurate wind information, and continuously monitoring each flight for wind-optimal “direct-to” opportunities to shorten flight paths. Boeing InFlight Optimization Services is a suite of applications that automate these processes, offering postdeparture opportunities for individual flights to save fuel and improve operational performance.

For more information, please contact Mike Durham at michael.h.durham@boeing.com or airlineefficiencyservices@boeing.com.



A fatigue risk management system can help airplane maintenance organizations reduce the hazards associated with fatigued workers.

Implementing a Human Fatigue Risk Management System for Maintenance

Aviation maintenance technicians (AMTs) often work extended hours and through the night. The result can be a lack of adequate sleep and a fatigued state that can contribute to errors. There is a growing realization that maintenance and engineering organizations should develop their own fatigue risk management systems (FRMS) to deal with these issues.

By William L. Rankin, Ph.D., Boeing Technical Fellow, Maintenance Human Factors

Numerous studies have highlighted the need for aviation maintenance and engineering organizations to implement an FRMS. The International Civil Aviation Organization and the major national aviation authorities also encourage an FRMS for maintenance workers — some even require this type of system.

This article outlines the need for an FRMS, describes the main elements of an implementation, and provides Web site information where airlines and maintenance, repair, and overhaul (MRO) organizations can access materials to use in their FRMS programs.

THE DANGERS OF FATIGUE

Between 1998 and 2000, the U.S. Federal Aviation Administration (FAA) conducted a significant study on the sleeping habits of AMTs in the United States. The FAA collected some 50,000 hours worth of sleep data using a watchlike accelerometer to determine how long an individual was sleeping. The study concluded that the technicians slept an average of just five hours and five minutes per day compared to the recommended eight hours per day for the average person (Hall, S., Johnson, W. B., and Watson, J. [2001] *Evaluation of Aviation Maintenance Working Environments, Fatigue, and Human Performance:*

Phase III, Washington, D.C.: FAA Office of Aviation Medicine. <http://hfskyway.faa.gov>).

This lack of sleep is believed to be an important contributor to errors made by AMTs. For example, the Aviation Safety Reporting System — an incident reporting service for pilots, mechanics, and flight attendants in the United States that is administered by the National Aeronautics and Space Administration — included 77 AMT fatigue-related reports from 1990 to 2009. Fatigue contributes to both errors of commission (i.e., the AMT did something, but did it incorrectly) and errors of omission (i.e., the AMT forgot to do something that should have been done) (see fig. 1).

Figure 1: Fatigue-related errors reported to the Aviation Safety Reporting System

Errors of Commission	Errors of Omission
Damaged ram air turbine blade on functional test.	Taxiing airplane and forgot to stop at an active runway.
Installed flap control knob incorrectly.	Failed to remove tape covering a pitot tube.
Replaced incorrect oxygen bottle.	Failed to reinstall flap screws.
Locked out wrong valve.	Failed to enter information into computer after task completion.
Entered incorrect logbook entry.	Failed to install top-of-wing access panel.
Installed fan blades in wrong order.	Failed to disarm door before opening.
Incorrectly evaluated nose-landing-gear door delamination.	Failed to torque and safety a nut.

ADDRESSING FATIGUE IN MAINTENANCE ORGANIZATIONS

There are two primary ways to address fatigue in maintenance organizations: duty time limitations or an FRMS. However, there is general agreement that duty time limitations are not the best approach in maintenance because they do not deal with the root problem of fatigue; even an AMT observing duty time limitations can be affected by fatigue if he or she has not had adequate rest. For example, in a study

conducted by the FAA, 25 percent of respondents reported feeling fatigued or exhausted.

As a result, most experts agree that the best way to address fatigue is by training AMTs on strategies to get sufficient sleep and on what they should do when they are working while fatigued, including:

- Exercising/stretching at frequent intervals.
- Talking to coworkers.
- Drinking plenty of liquids.

- Working with somebody else so you can catch each other's errors.
- Going back and checking your own work.

DEVELOPING AN FRMS

Airlines and MROs interested in developing an FRMS can use the guidelines on page 27. Additionally, high-quality FRMS materials can be accessed easily on the Web. Both the FAA and Transport Canada have FRMS materials on their Web

Implementing a Fatigue Risk Management System

These general guidelines can help airlines and maintenance, repair, and overhaul organizations develop and implement an effective fatigue risk management system (FRMS). Additional tools are available online at the U.S. Federal Aviation Administration and Transport Canada Web sites.

1. Policies and Procedures

- Outline the commitment of high-level organizational management to manage fatigue-related risk.
- Write detailed procedures for managing fatigue at the operational level.

2. Responsibilities

- List personnel responsible for FRMS design, implementation, and maintenance.
- Document organizational responsibilities.
 - Comply with any regulations or legislation.
 - Develop policies.
 - Provide training and education.
 - Develop error and incident reporting systems.
 - Assess work schedules and tasks for fatigue-related risk.
- Document individual responsibilities.
 - Use time away from work to get adequate sleep—“fit for duty.”
 - Report potential risks to manager if feeling fatigued.
 - Report fatigue-related errors and incidents.

3. Training and Education

- Train employees on the organization's fatigue management policies and procedures.
- Train employees on how to identify and manage risks associated with fatigue at both a personal and an organizational level.
- Train managers and employees on their responsibilities in managing fatigue.

- Train managers on their responsibilities and how to implement appropriate fatigue-reduction strategies where necessary.

4. Controls

- Provide sufficient sleep opportunity.
 - Assess work schedules for adequate sleep opportunity.
 - Use fatigue modeling to help develop schedules.
 - Consider options to maximize sleep opportunity.
 - Limit night shifts.
 - Restrict shift length to 12 or fewer hours.
 - Limit early morning starts.
 - Limit extended duty/overtime.
 - Ensure appropriate breaks.
 - Create a napping policy and napping facilities.
- Assess actual sleep.
 - Provide employees with methods for assessing whether they have gotten adequate sleep before coming to work.
 - Assess whether policies to provide adequate sleep are working.
- Assess symptoms of fatigue.
 - Include fatigue-related symptom checklists within the FRMS.
 - Assess employees for fatigue-related symptoms.
 - Counsel employees regarding major sleep disorders.
 - Insomnia.
 - Sleep apnea.
 - Restless leg syndrome.
 - Narcolepsy.
- Fatigue-proofing.
 - Target the areas of highest fatigue in the schedule with fatigue-proofing strategies.
 - Double-checking to increase probability of finding errors.
 - Close supervision.
 - Task rotation.
 - Checklists.
 - Work in pairs.
- Work environment.
 - Self-selected breaks.
 - Appropriate break facilities and healthy snacks.
 - Good lighting.
 - Temperature control.
 - Carpooling.
 - Stretching or exercise.
- Scheduling less complex or less safety-critical tasks.
 - High risk/highly complex activities done during the day.
 - Rotate tasks.
 - Avoid boring tasks at night.
- Training programs.
 - Fatigue awareness.
 - How to maximize sleep and alertness.
 - Information for families on facilitating sleep at home.
 - Impact of food and water on alertness.
 - Appropriate use of stimulants like caffeine, NO-DOZ®, and energy drinks.
- Incident investigation.
 - Develop incident investigation process that includes fatigue-related questions.
 - Length of duty time prior to work task.
 - Length of time awake since last major sleep period (more than two hours) prior to work task.
 - Length of last major sleep period (more than two hours).
 - Total length of any nap(s) since last major sleep period.
 - Total amount of sleep in the 24 hours prior to the work task (including naps).
 - Total amount of sleep in the 48 hours prior to the work task (including naps).
 - Time periods worked two days prior to day of task.

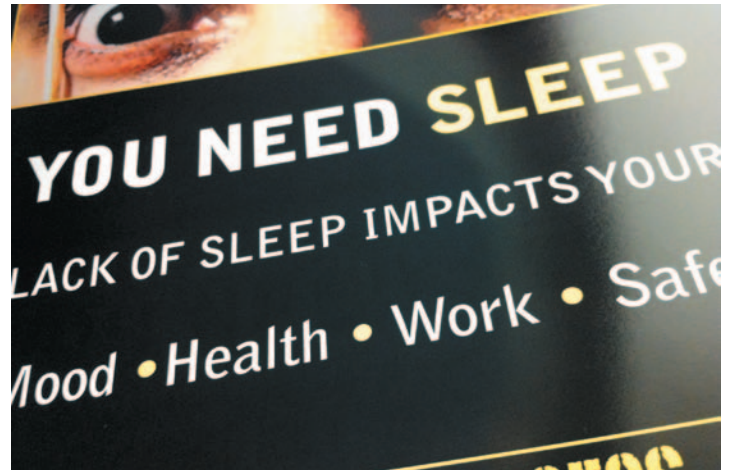
Figure 2: The maintenance fatigue section of the FAA Web site

The FAA and Transport Canada offer a number of fatigue management resources on their Web sites, including complete fatigue management toolboxes.



Figure 3: Fatigue-awareness posters from the FAA

The FAA has produced a series of educational posters designed to bring awareness to human fatigue in aviation maintenance.



sites at www.mxfatigue.com and www.tc.gc.ca/eng/civilaviation/standards/sms-frms-menu-634.htm, respectively (see fig. 2). These materials include:

- **Fatigue awareness materials**, such as newsletters and posters (see fig. 3).
- **Training and education programs** that can provide mechanics with the training necessary to adequately combat fatigue both on and off the job.
- **Fatigue awareness video** entitled *Grounded*.
- **Training assessment tools** that can be used by trainers to evaluate the fatigue management training program for both mechanics and supervisors.
- **Implementation guide** for companies interested in implementing a systematic fatigue management system.
- **Return-on-investment calculator** to determine the risk, cost, and benefit associated with fatigue and fatigue management in an organization.

SUMMARY

When aviation maintenance technicians are fatigued, they are more likely to make mistakes in their work. Implementing an FRMS can help airlines and MROs reduce the hazards associated with fatigued workers. Materials for creating an FRMS are available online.

For more information, please contact William Rankin at william.l.rankin@boeing.com. 