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Boeing 787 Family Grows with 787-9 Deliveries

737 MAX Advanced Onboard Network System

Performing Safe Go-Around Maneuvers

Protecting Airline Personnel from Falls

AERO

Cover photo: *787 Engine*

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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 787 Family Grows with 787-9 Deliveries

Boeing is proud to have delivered the first 787-9 Dreamliner to our valued partner and launch customer Air New Zealand in June.

As they say in New Zealand, the delivery was "good as gold," with some 1,000 Boeing employees representing the 787 program joining Air New Zealand executives and guests in July at a unique celebration of the milestone.

Our delivery of the first 787-9 is a tribute to our partnership with Air New Zealand and all of our 787-9 customers and the hard work and dedication of the entire global 787 team, which worked tirelessly to achieve development, testing, and certification milestones for the 787-9 throughout the development process.

The delivery also marks an exciting new phase for the 787 family as we continue to ramp up 787-9 production and deliveries to you, our customers. Boeing delivered the first 787-9 powered by General Electric GEnx engines to United Airlines earlier this month and recently began production of the 13th 787-9.

With its outstanding fuel performance, lower environmental emissions, and preferred passenger experience, the 787-9 leverages the visionary design of the 787-8 and additional innovations to bring a new level of efficiency to the market.

For starters, the 787-9 offers the flexibility to accommodate up to 40 percent more passengers, 23 percent more cargo, or 450 more nautical miles in range. Yet the 787-9 also offers the same exceptional environmental performance as the 787-8: 20 percent less fuel use and 20 percent fewer emissions than the airplanes it replaces. It's the perfect complement to grow routes first opened by the 787-8.

As we work closely with operators to introduce the 787-9 into operations and to passengers around the world, we thank you for your continued partnership.

LARRY LOFTIS
Vice President and General Manager,
787 Program
Boeing Commercial Airplanes

The 737 MAX features an advanced ONS with components developed and tested on the Next-Generation 737 with 737 MAX features.

737 MAX Advanced Onboard Network System

The new 737 MAX is designed to enhance and extend the Next-Generation 737 while maintaining commonality with the previous models. One of the ways Boeing is advancing the data capabilities of the 737 MAX is by providing an onboard network system (ONS) architecture that securely connects airline operations and maintenance with key airplane data and software parts. Some ONS capabilities also will be made available on Next-Generation 737 airplanes via selectable options. This system increases data available to the airline and provides that data to the crew and the airline's ground infrastructure.

By Victoria Wilk, Manager, 737 Network Systems and Connectivity, and
Tri M. Phan, Associate Technical Fellow, Network Systems and Connectivity

Boeing is improving the 737 by adding a new onboard network system (ONS) to connect airline operations and maintenance with airplane data and software parts. ONS vastly increases data available to the airline, and the ONS connectivity systems provide that data and airplane software to the flight, cabin, and maintenance crews, and the ground. The systems meet stringent U.S. Federal Aviation Administration (FAA) requirements for a safe and secure airborne network.

Together, ONS and ONS connectivity systems consolidate functions typically performed by multiple line replaceable units (LRUs). Basic and optional components make ONS scalable to current operational demand as well as flexible enough to grow for future operational needs. Many ONS components are being introduced on the Next-Generation 737, prior to the first 737 MAX delivery.

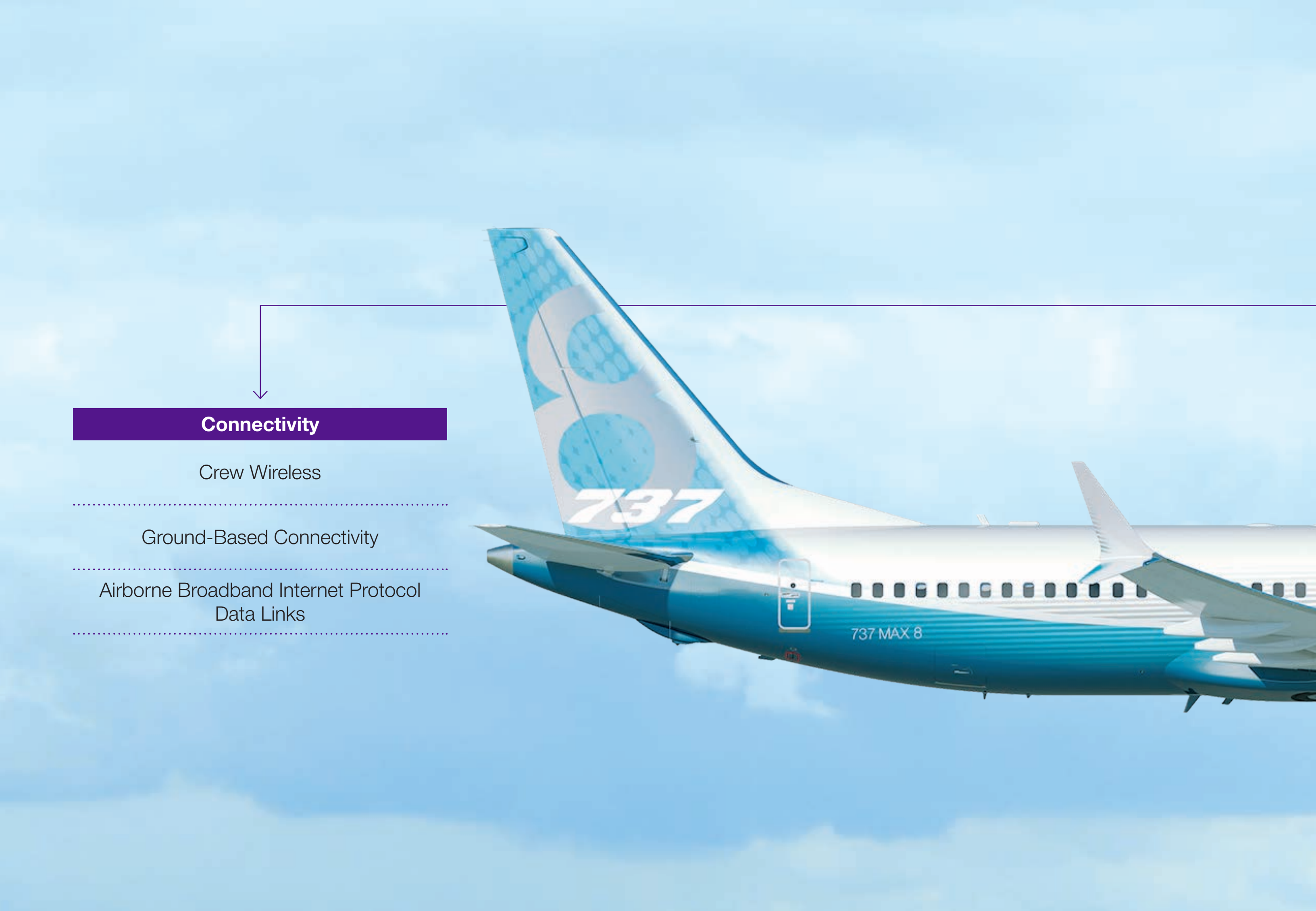
This article describes the architecture and the advantages of the ONS on the 737 MAX and Next-Generation 737.

DESIGNING FOR ADVANCED OPERATIONS AND MAINTENANCE

An integral part of Boeing's continuous improvement of the 737 family of products is listening to and responding to customer needs. Many operators have asked that the 737 MAX include access to additional airplane data, and that data be securely made available to flight, cabin, and maintenance teams during flight or while on the ground.

Figure 1: Enhanced capabilities of airplane systems

The onboard network system integrates data-rich airplane systems with optional connectivity systems to make the 737 MAX a node on the airline's data network.

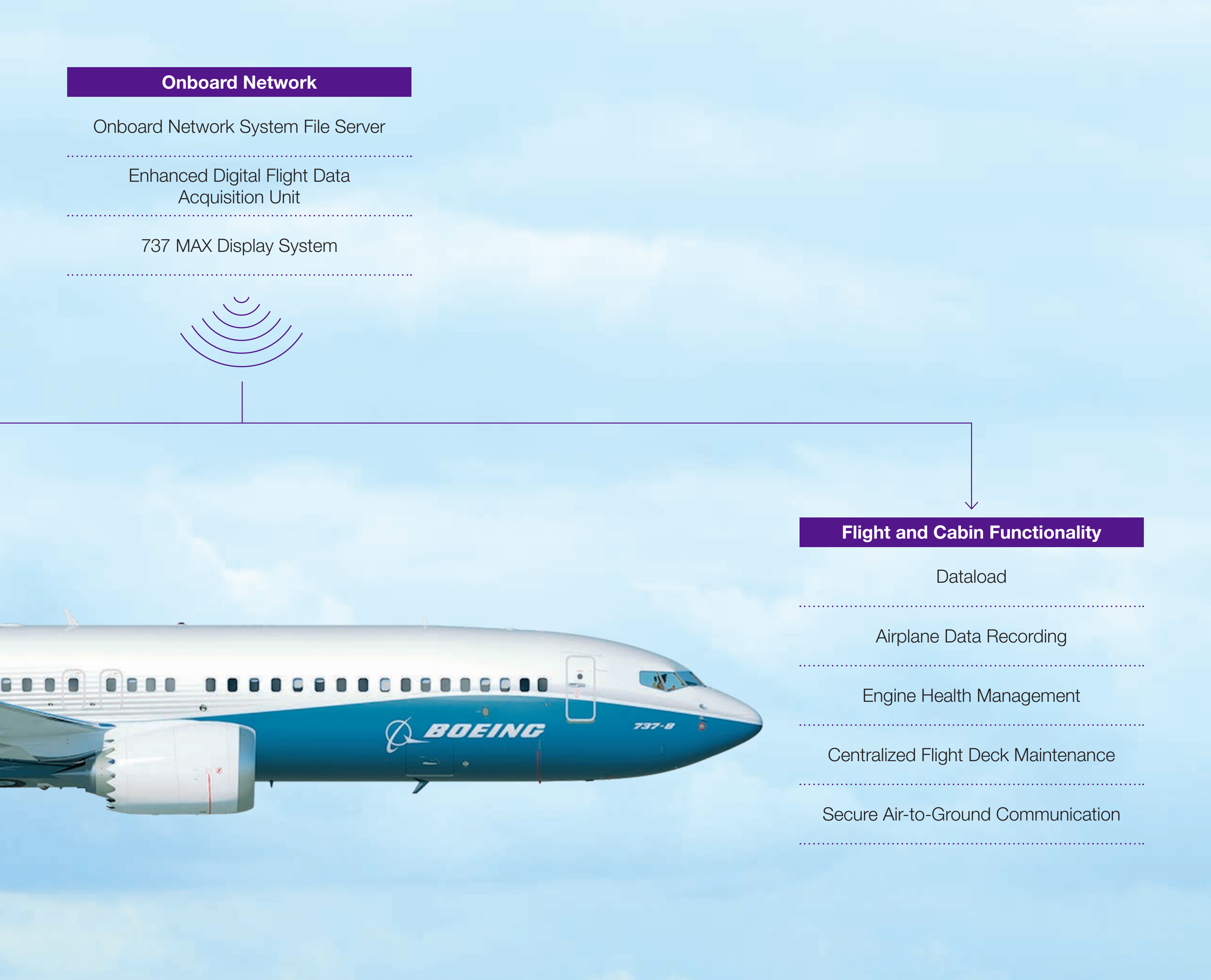


Boeing has responded with ONS: a network of on-airplane systems that collects a high volume of airplane data and makes that data available to the airline. ONS integrates data-rich airplane systems with optional connectivity systems to make the 737 MAX a node on the airline's network. 737 MAX airplanes equipped with ONS allow an airline to seamlessly support more efficient maintenance tasks and operational procedures.

In addition, ONS consolidates existing functions typically performed by several optional systems and expands capability. ONS integrates dataload, airplane data recording, and system troubleshooting onto a single system, and enables integration of operations functions typically performed by the crew on mobile or electronic flight bag (EFB) devices (see fig. 1).

ONS is a scalable architecture. Optional connectivity systems and software applications that further leverage the capability of ONS may be selected to evolve a 737 fleet on the airline's timeline.

ONS may also be combined with Boeing services to leverage an airplane's large volume of data for advanced maintenance planning. ONS enables expansion of many currently offered capabilities and new capabilities. How airlines may maximize ONS using Boeing service offerings will be the focus of an upcoming issue of *AERO*.



THE ONBOARD NETWORK

On the 737 MAX, the hardware most central to the ONS is a part of the basic airplane.

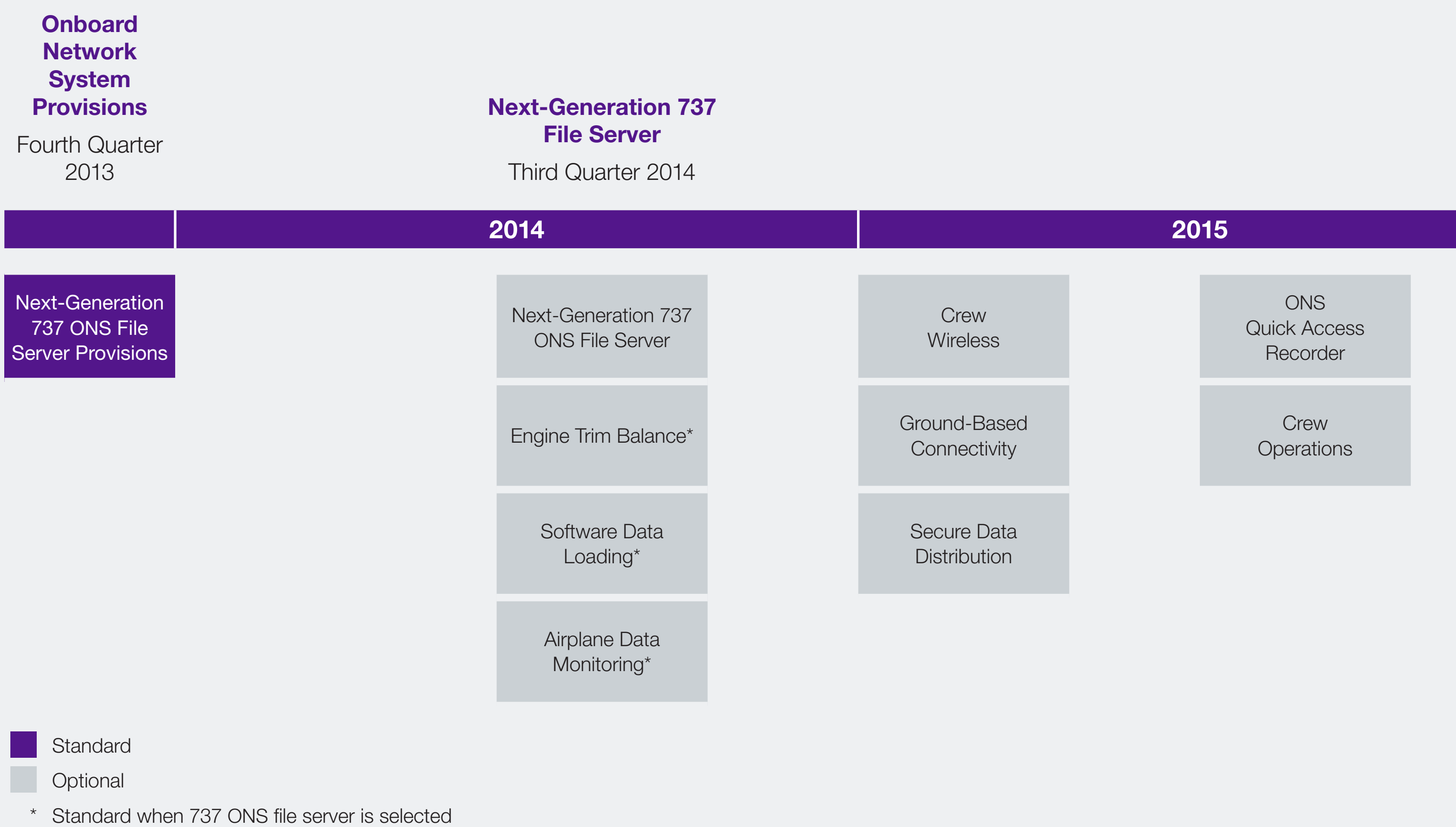
- ONS file server. The ONS file server is the hub of the 737 MAX onboard network. Housed in the electronics equipment bay, the ONS file server connects to a large set of data-rich 737 systems, houses hundreds of gigabytes of mass data storage, sends maintenance data to flight deck displays, and hosts onboard and offboard data processing functions. Direct connection to the ONS file server via the airline's maintenance device is provided by a flight deck Ethernet port or by optional connectivity systems. The ONS file server is available on the Next-Generation 737.
- Enhanced digital flight data acquisition unit (DFDAU). A new DFDAU greatly increases the availability of airplane data to be used for onboard functions and offboard analytics. This DFDAU makes 100 times more data available than the legacy equipment it replaces.
- 737 MAX display system. The 737 MAX display system will be connected to the ONS file server to further increase data availability and to enable flight deck display of maintenance information on the 737 MAX large-format displays. This system is basic hardware that in the future will enable display of operational information data, such as EFB data.

CONNECTING TO THE CREW AND THE GROUND

Several connectivity systems are available on the 737 MAX to connect the onboard network to the crew and to the airline ground infrastructure.

Figure 2: Onboard network system availability timeline

To maximize common operations, the system available on the Next-Generation 737 is equipped with connections to the same or equivalent data-rich systems as the 737 MAX ONS.



- Crew wireless. This connectivity system provides a secure on-airplane WiFi network for crew and ground/maintenance use, both in-flight and at the gate. This system may integrate with crew mobile devices to leverage the ONS for paperless operational and maintenance procedures.
- Ground-based connectivity. This broadband Internet protocol (IP) connectivity system makes the airplane capable of wireless transfer of airplane data or software parts between the ONS file server and the airline's ground-based offices using secure WiFi or cellular connections while the airplane is on the ground.
- Airborne broadband IP data links. The ONS is capable of integration with IP-based satellite connectivity systems, such as L-band, Ku, and Ka satellite communication systems, to allow secure high-speed data transfer during flight.

FUNCTIONALITY CONSOLIDATION

In addition to collecting and connecting more data to the airline's network, the ONS hosts software applications that enhance functions hosted by multiple systems on current Next-Generation 737 models, as well as applications that perform new capabilities. Particularly when paired with connectivity, ONS consolidates a powerful set of capabilities including dataload, airplane data recording, system fault reporting, and health management onto a single integrated system.

COMMONALITY WITH NEXT-GENERATION 737 FLEET

To maximize common operations between the Next-Generation 737 and 737 MAX fleets, many components of ONS will be offered and available for retrofit on the Next-Generation 737. The system available on the Next-Generation 737 is equipped with connections to the same or equivalent

data-rich systems as the 737 MAX ONS, and most of the same capabilities are supported. Centralized flight deck maintenance and engine health management are exclusive to the 737 MAX. See Figure 2 for a roadmap of production availability of systems on the Next-Generation 737 and the 737 MAX.

Functionality coming to the Next-Generation 737 and the 737 MAX

- Software data loading. The ONS file server is connected to all data-loadable systems on the 737 MAX. ONS is unique in its capability to load software parts over high-speed Ethernet, greatly decreasing the time required to load Ethernet-enabled systems such as the display system.
- Airplane data recording. More than 75 flight hours of operational data for onboard and offboard analytics, including legacy quick access recorder data, may be collected on the ONS file server mass storage. This ONS file server-hosted functionality is called ONS Quick Access Recorder (ONS QAR).
- Secure data and software distribution. ONS enables the distribution of airplane data or software parts between the airplane and airline (e.g., software part staging to the airplane from the airline). When paired with a connectivity system and ground-based system integration software, ONS may perform secure wireless electronic distribution of software and airplane data between the airplane and airline.
- Crew operations. Crew applications running on portable maintenance devices, such as tablets, may connect to the ONS file server for services such as onboard storage, printing, airplane data, and offboard connectivity. An ONS software development kit will allow airlines to build custom software applications tailored to specific operational needs. Custom software applications may be hosted on an airline tablet that connects to the ONS data and connectivity network.

Figure 3: Centralized flight deck maintenance

The onboard maintenance function will help reduce no-fault-found events.

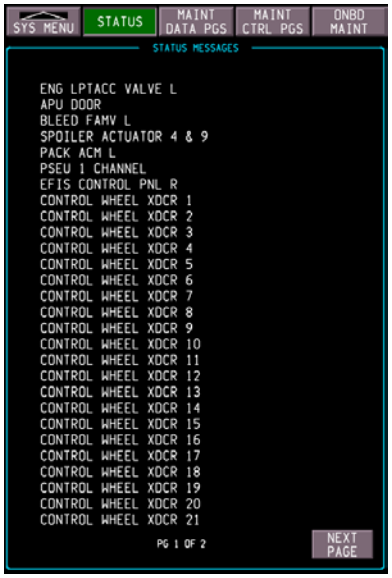
Functionality available exclusively on the 737 MAX

- Centralized flight deck maintenance. The ONS and the MAX display system integrate airplane data collected during flight with a new onboard maintenance function that consolidates maintenance data for view on the flight deck displays and on portable maintenance devices, such as tablets. Data displayed in the flight deck includes system dispatch status, existing faults, initiated tests, configuration reporting, and maintenance page information (see fig. 3).

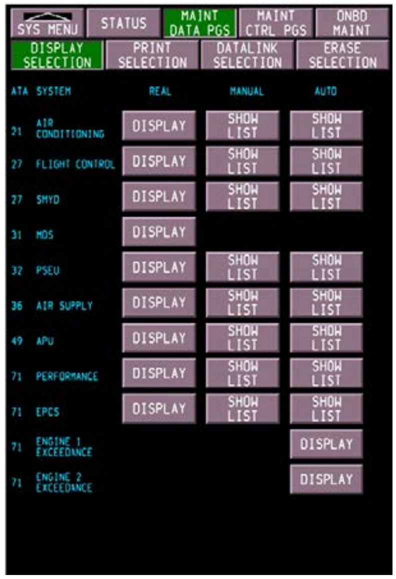
The onboard maintenance function will be capable of reducing no-fault-found events by correlating system status indications to detailed system and equipment faults and will also allow for fault forwarding downlinks. Centralizing the display of this information allows the creation of common maintenance procedures and allows mechanics to perform maintenance and fault isolation tasks for each of the 737 MAX systems without accessing them individually in the electronics equipment bay. Centralized flight deck maintenance combines with the 737 MAX displays system upgrade and upgrades in other systems to create an advanced flight deck environment that is flexible enough to manage maintenance tasks formerly limited to the electronics equipment bay and enables more focused maintenance troubleshooting.

- Engine health monitoring. On the 737 MAX, the functions of the airborne vibration monitor and engine electronic control will be integrated into a single LRU. ONS integration with the engine electronic control will bring advanced engine health management functions to the 737 MAX, including enhanced trim balance, prognostics reports, and

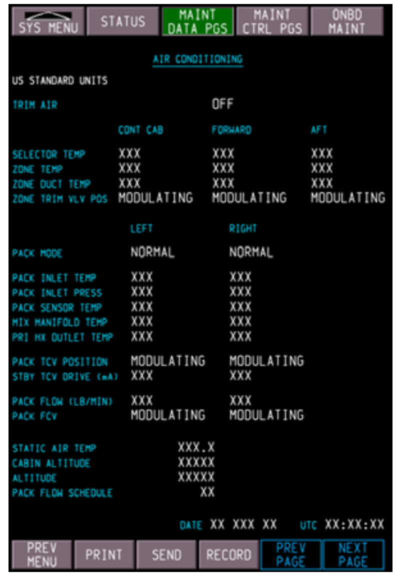
Status Messages



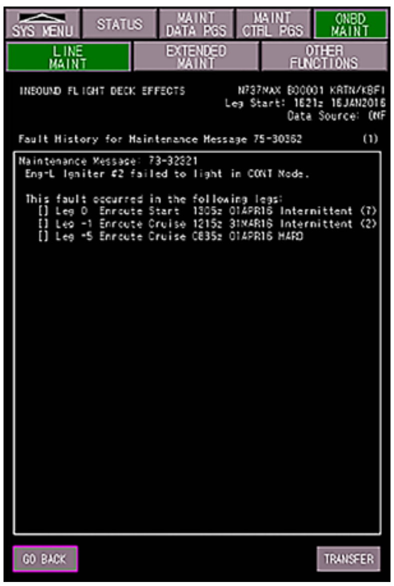
Maintenance Page Menu



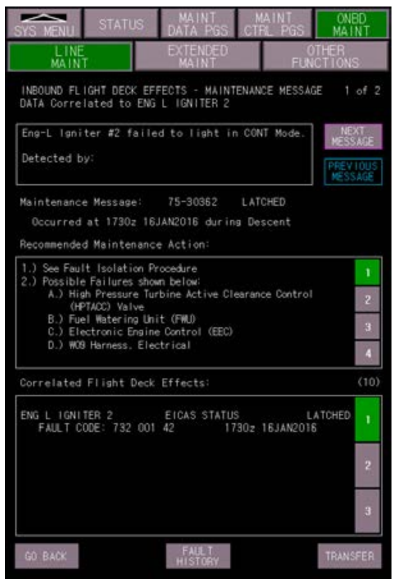
Air Conditioning Maintenance Page



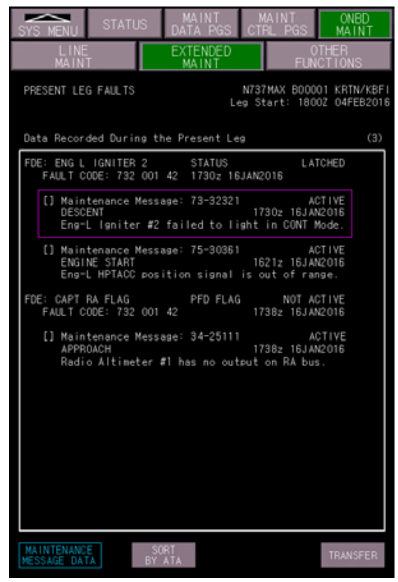
Inbound Flight Deck Effects



Maintenance Message Details



Present Leg Faults



increased engine data collection for in-service maintenance support and performance analysis.

A SECURE NETWORK

As connected airspace evolves, the 737 MAX will be equipped with security measures to protect airplane and passenger information that is transferred on and off the airplane. The 737 MAX ONS will meet FAA data security guidances to create a safe and secure airborne network.

LEVERAGING BOEING COMMERCIAL AVIATION SERVICES

The quantity of data made available by the 737 MAX ONS facilitates advances in all aspects of operations, including maintenance, engineering, and ground operations. For example, an airline maintenance team may leverage data collected across the 737 MAX fleet for predictive maintenance analytics. An ONS-connected airplane will be able to take advantage of services from Boeing that can further optimize airplane operations. How airlines can maximize ONS capability will be the focus of an upcoming issue of *AERO*.

SUMMARY

The new 737 MAX features an advanced ONS that combines components developed and tested on the Next-Generation 737. The new ONS is a secure, scalable, and integrated architecture that enables significant operational and maintenance efficiencies by connecting critical airplane data with the airline and its ground infrastructure. A

A go-around maneuver performed according to standard operating procedures by crews can be effective and safe.

Performing Safe Go-Around Maneuvers

A go-around maneuver may be performed in a number of situations, including when requested by air traffic control (ATC) or when an airplane is making an unstabilized approach. Once a go-around decision has been made, flight crews must focus on ensuring that the maneuver is flown correctly by being aware of the difficulties that can occur and following the appropriate procedures to address those difficulties. A go-around maneuver can be both effective and safe when performed according to standard operating procedures by crews who are alerted to possible hazards.

By David Carbaugh, Chief Pilot, Flight Operations Safety, and
Bertrand de Courville, Captain, Air France, Retired, and Co-Chair, European Commercial Aviation Safety Team

Performing a go-around is the best decision to make whenever the safety of an approach or a landing appears to be compromised. While the go-around maneuver should be a normal and well-trained procedure, difficulties can occur. This article focuses on some of the problems flight crews can experience when executing a go-around maneuver and how they can address these problems to make the maneuver safer.

THE NATURE OF GO-AROUND MANEUVERS

Although only 3 percent of commercial airplane landing approaches meet the criteria for being considered unstabilized, 97 percent of these unstabilized approaches are continued to a landing, contrary to airline standard operating procedures. (See *AERO* second-quarter 2014.) In many of these cases, a go-around maneuver should have been performed.

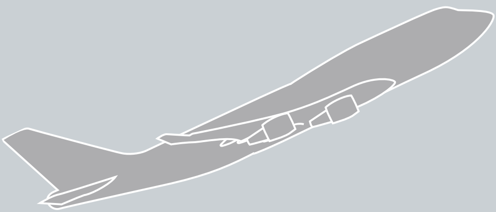
Go-around maneuvers are often performed at low altitude, low speed, and sometimes very close to the ground. A significant number of actions must be performed in a short period of time, and all of them are related to important changes of attitude, thrust, flight path, airplane configuration (i.e., flaps and gear), and pitch trim. Each of these actions must be carefully monitored and cross-checked.

Automation has brought additional checks related to autopilot, flight director, and autothrottle modes, all of which need to be read, checked, and announced by pilots during the go-around. At the same time, ATC can add to the flight crew's workload by requesting information about the cause of the go-around, crew intentions, and sometimes issuing frequency changes. Even without being asked by ATC, a pilot may feel the need to communicate immediately with ATC. The capacities of both the pilot flying (PF) and pilot monitoring (PM) to manage priorities during this phase follow the safety adage of "aviate, navigate, communicate — in that order."

All of these factors explain why the go-around maneuver needs to be approached with care. Airlines should also use data

Handling extreme nose-up incidents

Boeing, in concert with the aviation industry, has developed a nose-high upset recovery procedure that pilots should perform if they encounter this situation.



Pilot Flying

- Recognize and confirm the situation.
- Disconnect autopilot and autothrottle.
- Apply as much as full nose-down elevator.
- Apply appropriate nose-down stabilizer trim.
- Reduce thrust.
- Roll (adjust bank angle) to obtain a nose-down pitch rate.
- Complete the recovery: when approaching the horizon, roll to wings level, check airspeed, and adjust thrust. Establish pitch attitude.

Pilot Monitoring

- Recognize and confirm the situation.
- Call out attitude, airspeed, and altitude throughout the recovery.
- Verify all required actions have been completed and call out any omissions.

monitoring programs to better detect and analyze such events.

TWO PRIMARY ISSUES RELATED TO GO-AROUND MANEUVERS

When there are incidents related to go-around maneuvers, they are usually the result of excessive pitch-up or pitch-down attitude.

Extreme nose-up attitude. These events, which typically result from a particular combination of go-around thrust, speed, and nose-up trim, are characterized by a lack of pitch-down control authority at the beginning of the go-around. They account for a number of scenarios in which a go-around is initiated after a speed excursion well below the approach speed, long enough to have a trim moving into an unusual nose-up setting. The increase of thrust combined with the nose-up trim may result in loss of control. The Airplane Upset Recovery Training Aid (Rev. 2) has been developed by manufacturers to address these situations. (See "Handling extreme nose-up incidents" above.)

One example occurred in the United Kingdom. On final approach, the airplane slowed to near the stall speed. Because the autopilot was still engaged, the stabilizer trim was very nose up to compensate for the reduced speed on approach. When the crew noticed the slow speed and decided to do a go-around, the combination of pitch-up contributions of the engines, stabilizer, and slow speed made the nose pitch up, and the crew was unable to arrest the pitch-up with elevator only until the airplane stalled. Fortunately, the nose fell straight ahead and the airplane recovered; it would have pitched up again except that the crew intervened with nose-down stabilizer input.

Extreme nose-down attitude. Since 2000, several incidents have involved extreme nose-down attitudes during the go-around maneuver on different types of airplanes from different manufacturers. These incidents often result from a breakdown in correct cockpit instrument scanning. Here are some examples:

- After the PF initiated a manual go-around at night over the sea, at 1,000 feet (305 meters), the PF kept a prolonged pitch-down input resulting in a 15-degree nose-down attitude and a dive that was not recovered before the impact with the sea. The amplitude and duration of the initial reaction by the PF to the "pull-up" warning from the ground proximity warning system (GPWS) was insufficient (i.e., a full back stick input was required).
- After the PF initiated a manual go-around in instrument conditions, and approaching 2,500 feet (762 meters), the flight director altitude capture mode was activated earlier than expected by the crew because of a high rate of climb. The PF manually initiated a level-off but kept a prolonged pitch-down input that resulted in a dive that reached an extreme negative attitude (minus 40 degrees). The PF recovered from the dive at about 400 feet (122 meters) above the ground with a vertical acceleration of 3.6 g-force (g).

Handling extreme nose-down incidents

Boeing, in concert with the aviation industry, has developed a nose-down upset recovery procedure that pilots should perform if they encounter this situation.

Pilot Flying

- Recognize and confirm the situation.
- Disconnect autopilot and autothrottle.
- Recover from stall, if required.
- Roll in shortest direction to wings level (unload and roll if bank angle is more than 90 degrees).
- Recover to level flight.
- Apply nose-up elevator.
- Apply nose-up trim, if required.

Pilot Monitoring

- Recognize and confirm the situation.
- Call out attitude, airspeed, and altitude throughout the recovery.
- Verify all required actions have been completed and call out any omissions.

Source: From the flight maneuvers section of the quick reference handbook flight manual and adapted from the Airplane Upset Recovery Training Aid (Rev. 2)

- After the PF initiated a manual go-around at night over the sea, the altitude acquisition mode activated while approaching the selected altitude and the PF pitched down to level off. The indicated airspeed increased toward the maximum for the configuration. Instead of leveling off, the PF kept a prolonged pitch-down input. The attitude quickly decreased and reached a negative 9-degree pitch with a vertical speed of 4,000 feet (1,219 meters) per minute. When the GPWS activated, the PF reacted by pitching the airplane up. The minimum altitude was 600 feet (183 meters) over the sea. The total duration of the event was about 15 seconds. Neither pilot could explain the reason for the upset.

In all of these examples, pilots reacted very late to extreme negative attitudes displayed on both attitude director indicator (ADI) instruments. All of these events happened at night over a dark area or in instrument meteorological conditions. At the time of the upset, in the absence of visual reference, the only attitude information was provided by the ADIs. When flying manually or when monitoring the autopilot, the ADIs are at the center of a control process in which pilots must detect and then quickly and accurately correct deviations from targeted values. (See "Handling extreme nose-down incidents" above.)

A reasonable explanation for this initial lack of pilot reaction is that both pilots become distracted from monitoring the ADIs at the time of a pilot nose-down input. When pilots are distracted, an airplane could change its flight path from a normal go-around climb to a steep dive in fewer than 10 seconds.

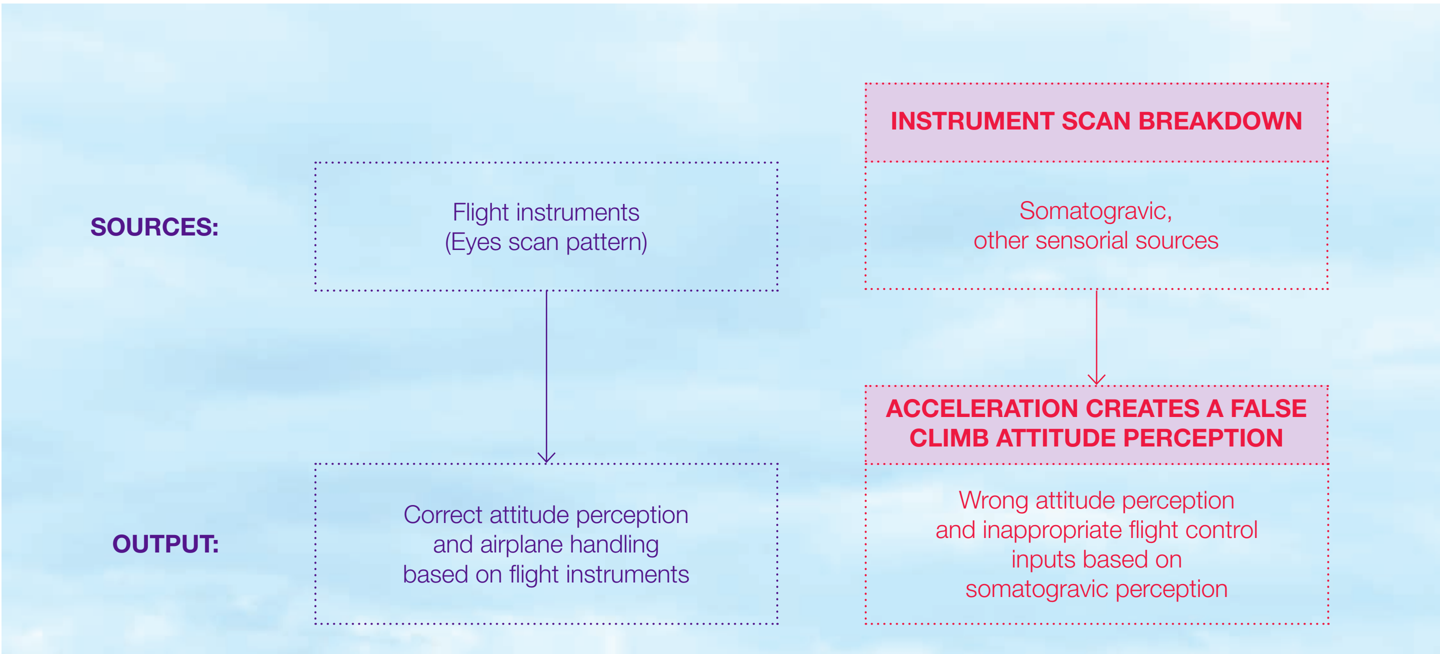
It may appear that such a deep dive would be perceived physically by the flight crew, without need of instruments. However, at constant thrust, any significant nose-down attitude reduction will create acceleration. The physical effect of the resulting acceleration corresponds exactly to the perception of attitude change. Both pilots, unless they look at their instruments, will believe they are climbing while their airplane has entered a deep dive (i.e., the pilots' mental picture is becoming inaccurate) (see fig. 1). When the pilots return to their instruments, what they read will conflict with their mental picture of the airplane attitude. This causes cognitive confusion and potentially severe spatial disorientations. Poor or disrupted pilot instrument scannings may lead to a somatogravic illusion, which is present during high accelerations or decelerations when a pilot has no clear visual reference. A somatogravic illusion is when the human senses of the pilot cause spatial disorientation about the actual airplane movement.

THE NORMAL AND ESSENTIAL INSTRUMENT SCAN

All pilots trained on instrument flight rules learn the T-shape principle of basic instruments scan (see fig. 2). The attitude indication (i.e., pitch and roll information) is at the center of the instrument flying or monitoring process during dynamic phases. From the center of the ADI, the pilot's focus moves successively to speed, altitude, vertical speed, and heading indication — all of which are directly dependent on the airplane attitude presented by the ADI.

Figure 1: Spatial disorientation can confuse pilots

A situation known as somatogravic illusion can occur when an airplane accelerates. If the pilots lose track of visual references and are not looking at instruments, they perceive that the airplane is nosing up, when in fact, it is entering a deep dive.



Modern primary-flight-display design makes the instruments scan easier, but a very common misperception is that the classic T-type eye-scan pattern is no longer needed. Because all basic flight instruments are gathered on the same screen, many pilots erroneously believe that these instruments can be embraced and processed at the same time. However, a T-type eye-scan pattern is still necessary for several reasons:

- The use of central vision is still needed to read digital values.
- Pilots need to focus attention in a sequential manner to monitor and control flight parameters.
- Human cognitive performance does not allow pilots to process speed, heading, altitude, vertical speed, and pitch and roll values simultaneously and accurately.
- The T-type eye-scan pattern forces a sequential method that has been proved to provide more accurate and reliable readings.

FACTORS THAT COULD DEGRADE THE ESSENTIAL EYE-SCAN PATTERN

During a significant pitch reduction, the indicated airspeed increases quickly toward the maximum speed red band (see fig. 3). This has a powerful attraction effect and could capture the attention of both pilots to the point that the instrument scan is slowed down or even suspended. Simultaneously, somatogravic effects, due to longitudinal acceleration, remove the perception of descent while maintaining the feeling of a climb or a level flight path. As a consequence, an extreme nose-down attitude could develop without being noticed, causing the pilots to lose situational awareness.

Similarly, flight management annunciation (FMA) information must be read through central vision. An unexpected FMA display during a go-around maneuver could capture attention and distract pilots from the basic instrument scan long enough to lead to the same consequences.

The PM may be distracted from tasks during the go-around by getting involved with ATC communications at a critical moment. This could happen when the PM feels obliged to call or answer ATC at the precise time that the PF is deviating from the correct course.

PERFORMING SAFER GO-AROUNDS

A flight crew can successfully avoid the hazards that may be present in a go-around maneuver in a number of ways:

- Both pilots should keep a robust instrument eye-scan pattern for the duration of the go-around maneuver until the end of the level-off phase.
- Both pilots should be aware of the consequences of failing to closely monitor the pitch indication of the ADI.

Figure 2: The T-shape instrument scan of the attitude director indicator

The T-shape principle of basic instruments scan provides a quick assessment of speed, altitude, vertical speed, heading, and airplane attitude.

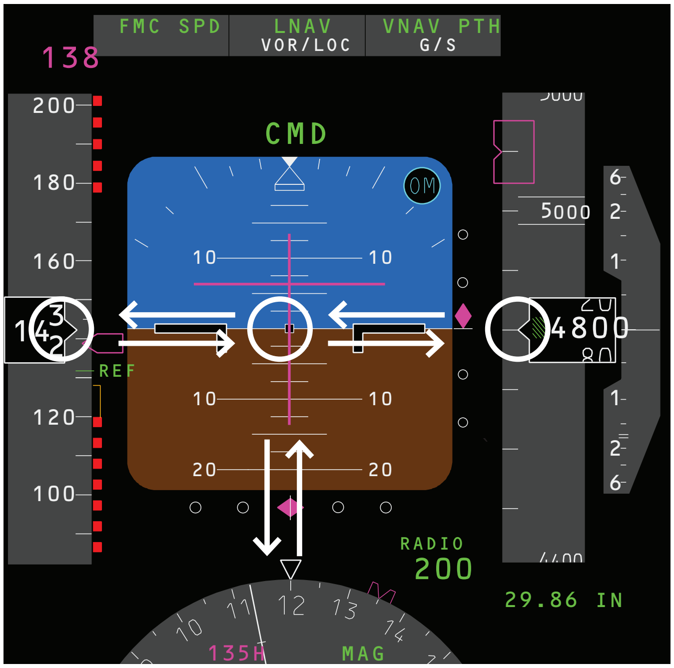
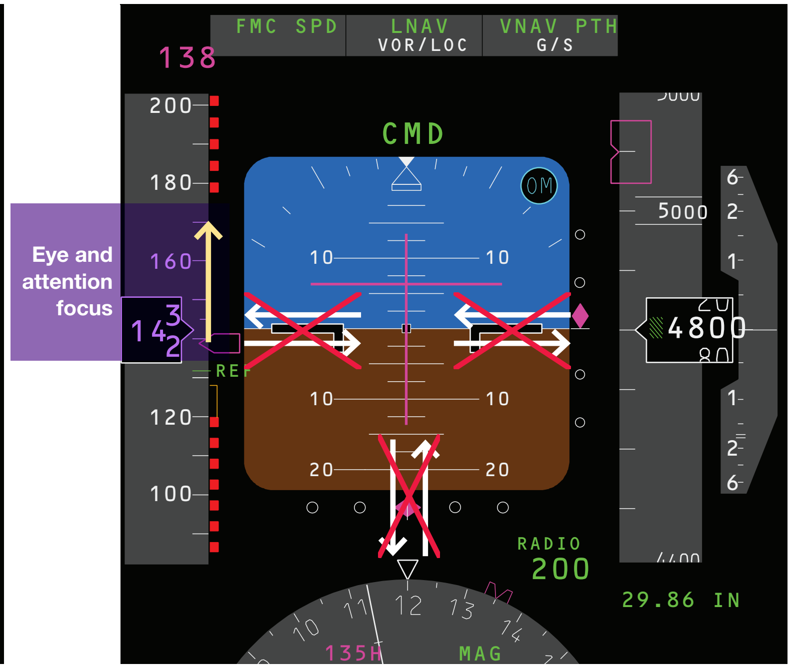


Figure 3: The danger of distraction

As the airspeed increases toward the red band, indicating maximum speed, both pilots may see this to the exclusion of noticing the attitude shown on the instruments.



At night or in instrument meteorological conditions, an extreme nose-down attitude could develop in fewer than 10 seconds without being felt by the pilots.

- Flying the pitch and monitoring the pitch during attitude changes have priority over any other tasks, including communication with ATC. The PM could answer "Stand by, I will call you back" while monitoring and coordinating the maneuver with the PF.
- Pilots should understand automation and mode changes that occur during go-arounds. Many of these features are designed to aid pilot performance.
- Pilots should train for and understand the issues involved in go-arounds conducted at other than minimum approach altitudes. These present different challenges that, combined with the issues already addressed, can be difficult.

HOW AIRLINES CAN CONTRIBUTE TO SAFER GO-AROUNDS

Airlines can enhance the success of go-around maneuvers by closely monitoring them:

- Are flight crews encouraged to choose to go around in the event of an unstabilized approach?
- Are crews performing the go-around maneuver correctly?
- Are serious go-around upsets visible enough?

A robust internal reporting and flight-data monitoring program can help answer these questions. The airline's air safety reports and dedicated surveys can provide an operator's safety or training department with relevant qualitative feedback regarding go-around maneuvers.

In addition, a flight operational quality-assurance program, incorporating flight-data monitoring, can provide important quantitative information and make it possible to track statistics and trends. This data can be shared anonymously with the industry through safety sharing programs.

Airlines can also develop safety performance indicators for go-around maneuvers to capture rate and trends, including attitude exceedances (i.e., pitch or roll), speed exceedances (i.e., too fast or too slow), and automation-mode mismanagement.

SUMMARY

Once a go-around decision has been made, flight crews need to ensure the go-around maneuver is flown correctly through concentrated effort. Difficulties can occur in both nose-high and nose-low situations. It's important that flight crews be aware of the appropriate procedures for those situations. A go-around maneuver performed according to standard operating procedures by crews mindful of possible hazards associated with the maneuver will be effective and safe.

Falls through open doors, panels, and hatches can be prevented by consistent use of barriers and following airline policies and procedures.

Protecting Airline Personnel from Falls

During standard turn-around and line-maintenance activities, open doors, access panels, and hatches on parked airplanes can be potential safety hazards for airline personnel unaware of the openings. Cabin crew and servicing staff have suffered injuries as a result of falls through these openings. Investigations of these incidents by Boeing indicate that they are preventable by proper and consistent use of barriers and following airline policies and procedures.

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Cabin crew and servicing staff have suffered injuries by falling through open panels, hatches, and doors in several airplane models. Open internal access panels in various models that were unprotected have been a significant source of personnel injury. On 747, 767, 777, and 787 models, the internal access panel is known as the internal electrical/electronics (E/E) bay access panel. On DC/MD-10 and MD-11 models, this internal access panel, located about mid-cabin, is known as the center accessory compartment access door. Injuries can also result from tripping on open floor panels, hatches, and doors.

This article updates a fourth-quarter 2007 *AERO* article on fall hazards during standard turn-around and line-maintenance activities in the interior of airplanes. It explains these situations, recommends ways to guard against injuries, describes equipment available to operators to address issues, and discusses the role of airline policies and procedures in helping to prevent falls.

THE DANGER OF FALLS

Falls are a leading cause of occupational deaths and serious injuries. For example, in the United States, falls are the second leading cause of work-related deaths after motor vehicle crashes, according to the U.S. Bureau of Labor Statistics. In the United States in 2009, 605 workers were killed and an estimated 212,760 workers were seriously injured by falls. The most prevalent form of injury resulted from workers falling to a lower level from ladders,

Figure 1: Self-closing internal electrical/ electronics (E/E) bay access panel

All 747-8s, 777s, and 787s currently being delivered include hinged, self-closing E/E bay access panels.

scaffolds, buildings, or other elevations. A fall of 20 feet (6 meters) usually results in death.

In a fall of 6 feet (1.8 meters), it takes only 0.6 of a second for a person to strike the ground with a speed of more than 13 miles per hour (6 meters per second). A 220-pound (100-kg) person develops 1,784 Joules (1,784 Newton meters) of kinetic energy in a fall from this distance.

THE DANGERS OF OPEN PANELS, HATCHES, AND DOORS

Cabin crew and servicing personnel have been injured on airplanes prior to departure by falling through unprotected internal E/E bay access panel openings on 747, 767, and 777 airplanes. (There is no such access panel on the 737 or 757 or on McDonnell Douglas airplanes.) In those cases, the panel was removed from the cabin floor and set aside by a technician while the opening was left unprotected. To date, there have been no reported falls through an internal E/E bay access panel opening for the 787 model, which has a hinged, self-closing access panel door.

Open, unprotected cabin entry doors on all models present another hazard. Many times during servicing of airplanes between flights, cabin entry doors are left open to allow access by caterers and servicing personnel. The danger occurs when a catering vehicle or air stairs move away while the door is still open. Doors are also left open in hot weather to cool an airplane's interior. In these situations, there is nothing to stop someone onboard the airplane from falling to the ground through the open door. (See "Controlling fall hazards" on page 21.)

PREVENTING FALLS ASSOCIATED WITH THE INTERNAL E/E BAY ACCESS PANEL

Accidents involving the internal E/E bay access panel can be prevented by following correct procedures. According to Boeing aircraft maintenance manuals (AMM), the internal E/E bay access panel is to be used for "access to the E/E bay while in flight." This access may be needed for extreme emergencies, such as by the cabin crew to fight an E/E bay fire. During hangar maintenance, the internal access panel may be used by operators to accommodate extensive airplane maintenance or modification activity.

However, the internal access panel was never intended for the purpose of line maintenance in which flight crew, cabin crew, catering personnel, and passengers might be endangered if the access panel were to be removed and left unguarded. The Boeing AMM never specifies opening the internal E/E bay access panel for the purpose of maintenance in the E/E bay. To reduce the fall hazard during line maintenance, technicians should enter the E/E bay via the external access door.

To help prevent accidents and injuries related to this panel, all 747-8s, 777s, and 787s now being delivered have a hinged, self-closing access panel (see fig. 1). For retrofitting purposes, hinged, self-closing

Controlling fall hazards

Maintenance and inspection activities require technicians and inspectors to work from the wing/stabilizer surface, fuselage crown, engine strut, and work scaffolding with open sides and floor holes and incomplete cabin floors — all of which present fall hazards. There are several options for controlling these hazards, including engineering out fall hazards, fixed safety guarding, and fall protection harness and lanyard systems.

- Engineering out hazards requires designing work processes without fall hazards or reducing potential falls to less than 4 feet (1.2 meters).
- Safety guards against fall hazards include various types of railings, barriers, and floor hole covers.
- Fall protection harness and lanyard systems include fall restraint and fall arrest. Fall restraint is more desirable because it prevents falls from the work surface. However, it may limit access to certain work areas. In contrast, a fall arrest harness and lanyard system may improve access and will stop (i.e., arrest) a fall if it occurs, but maintenance technicians can still sustain injuries from contacting objects to the side and below during the fall.

Some maintenance tasks and positions are particularly challenging, such as engine work when engine cowling or thrust reversers are in place, wheel wells adjacent to routine inspection and serviceable equipment (e.g., lubrication fittings), and the auxiliary power unit compartment. For those tasks, ladders, work stands, and lifts do not always provide safe access to the routine maintenance positions.

Boeing offers a wide array of ground support equipment for various airplane models to guard against fall hazards. Such fall protection equipment is specified in the aircraft maintenance manual. In addition, Boeing has taken proactive approaches to minimize fall hazards through product design. For instance, some airplane models incorporate steps and footholds, and no-skid surfaces are included in wheel wells adjacent to equipment requiring routine inspection or service. Other design changes include moving equipment requiring routine inspection or service to a location where it can be accessed without the risk of a fall. One example of this is relocating the hydraulic fluid reservoir fill tube for the engine cowling power-door opening system at ground level instead of on top of the engine pylon.

Figure 2.1: Example of floor guard

This view looks down at the internal E/E bay access panel from within the cabin compartment.

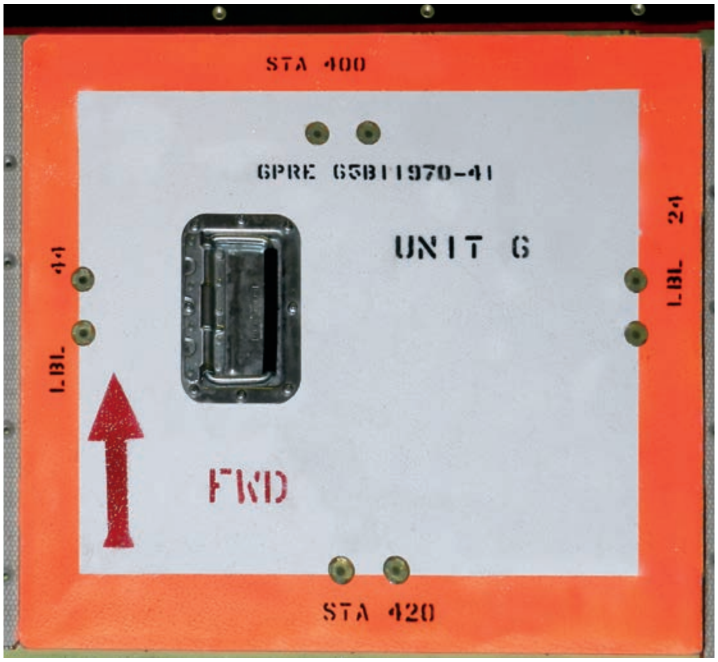


Figure 2.2: Example of personnel barrier

Personnel barriers can be overlooked or ignored and do not stop falls.

access panels are available for 747, 767, and 777 models, and personnel barriers are available for the 747 and 767 models. Since 1982, Boeing has released service bulletins 747-53-2434, 767-53-0092, and 777-53-0021 regarding these barriers. No service bulletin has been issued for 787 models because no retrofit is needed.

If an operator elects not to install a self-closing access panel, Boeing recommends the installation of an E/E bay access opening safety guard around the exposed opening in the floor (see fig. 2.1) or the installation of a personnel barrier in the cabin across the access door panel whenever the panel is removed (see fig. 2.2). The latter is considered a passive type of defense because personnel barriers can be overlooked or ignored and do not stop falls.

During line maintenance on 747, 767, 777, and 787 airplanes, Boeing recommends the use of the external access door at the bottom of the fuselage instead of the internal E/E bay access panel to gain access to the E/E bay. External access doors and stabilizer compartment access doors may also present a fall hazard to technicians during line maintenance (see fig. 3). Extra caution is required when accessing and working in the E/E bay.

FLOOR HATCHES AND PANELS ON DC/MD-10, MD-11 AIRPLANES

Operators have reported instances of cabin crew inadvertently stepping into an open and unguarded floor hatch. In response, warning placards have been installed adjacent to main deck floor access hatches.

Boeing recommends that operators further protect the safety of their personnel by erecting a barricade (see fig. 2.2) around any open floor access hatch or panel.

BLOCKING OPEN CABIN AND CARGO DOORS

Cabin and cargo doors should be closed when access to the airplane cabin or cargo compartment is no longer needed. Many airlines state this explicitly in their policies and procedures. On occasions when a door is deliberately left open, such as to air out an airplane during cleaning, steps should be taken to block the door. Some operators use a simple strap to provide a visual signal that the door is open. However, the strap is not designed to stop a fall, which could result in serious injury or death. For example, if a technician were to fall, the distance from an open 777 cabin door is approximately 16 feet (5 meters) to a landing on a hard concrete surface.

Boeing recommends the use of a fitted personnel barrier that is attached to anchor points any time a cabin door is left open

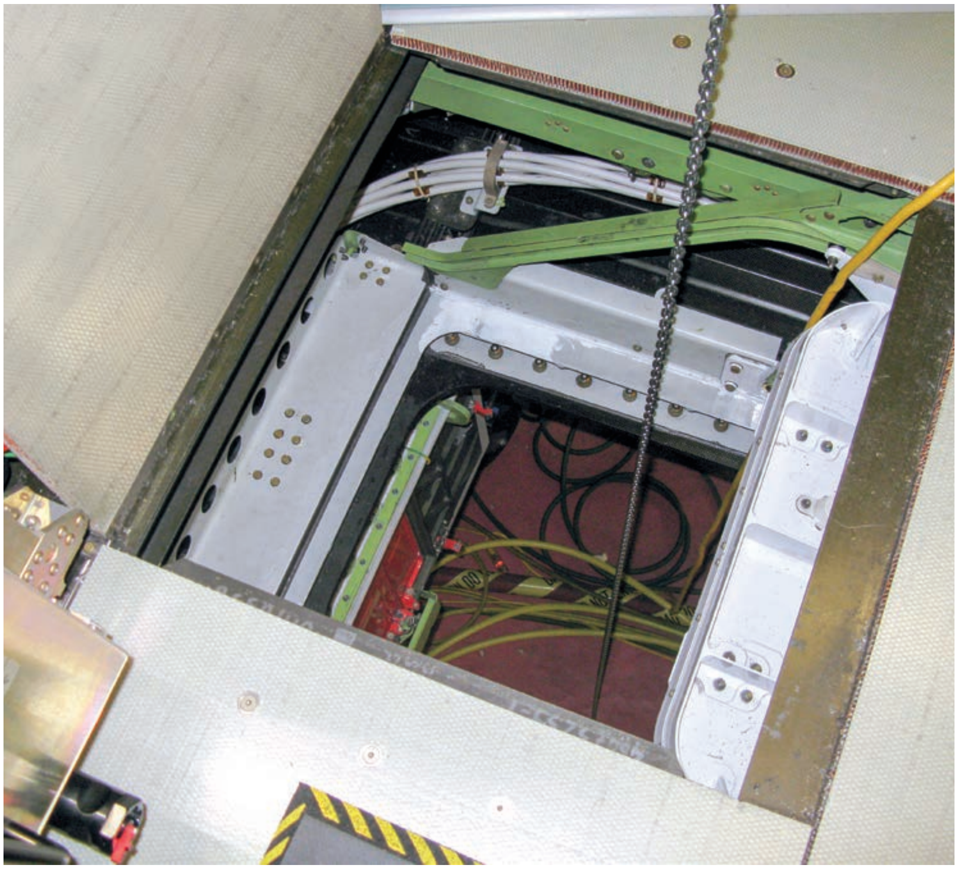


Figure 3: External E/E bay access doors

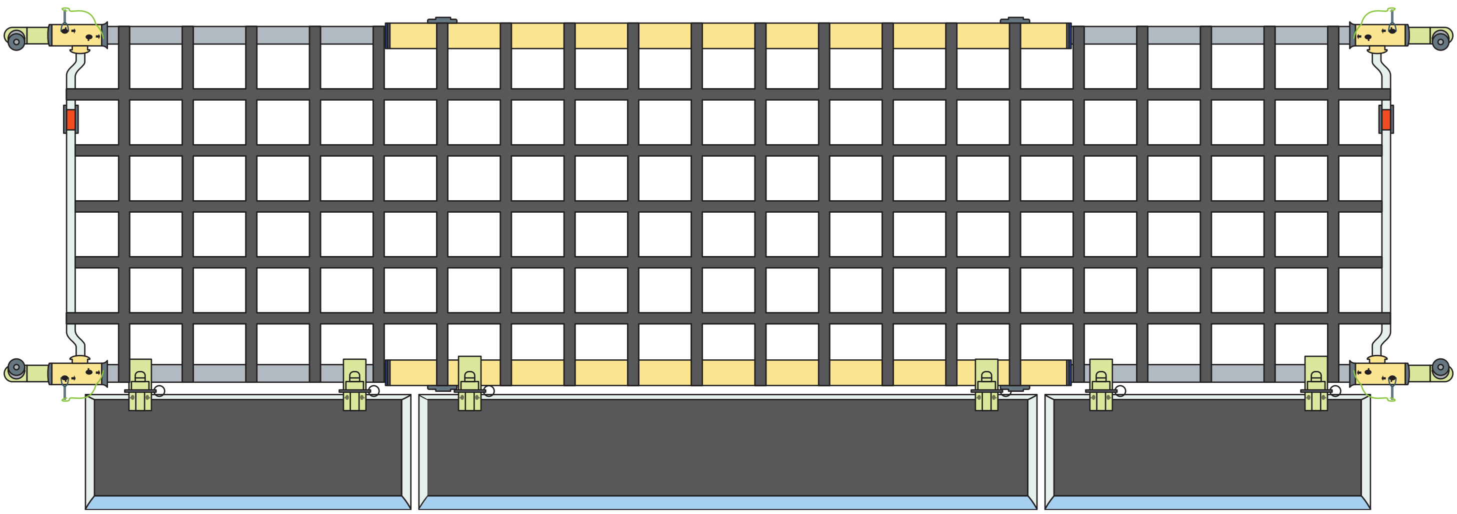
Boeing recommends the use of the external access door at the bottom of the fuselage instead of the internal access door to gain access to the E/E bay during line maintenance on 747, 767, 777, and 787 airplanes. (This view looks down at the external E/E bay access panel from within the E/E bay.)

Figure 4: Personnel barrier for cabin entry door

Boeing recommends the use of a fitted personnel barrier any time a cabin door is left open and unprotected.

Figure 5: Personnel barrier for main deck cargo door

A personnel barrier should be fitted when the cargo door is open but the loading equipment is not in position.



and unprotected while the air stairs or the cabin boarding bridge is not in position (see fig. 4). This recommendation is also included in the 34th edition of the International Air Transport Association's Airport Handling Manual, which became effective Jan. 1, 2014. Boeing ground-support-equipment personnel barriers are available for use in cases in which the cabin door must be open while the air stairs or the cabin boarding bridge is not in position or whenever a cabin door is being replaced. Personnel barriers are designed to safely restrain people from falling. For cargo doors, the personnel barrier should be fitted when the cargo door is open but the loading equipment is not in position (see fig. 5).

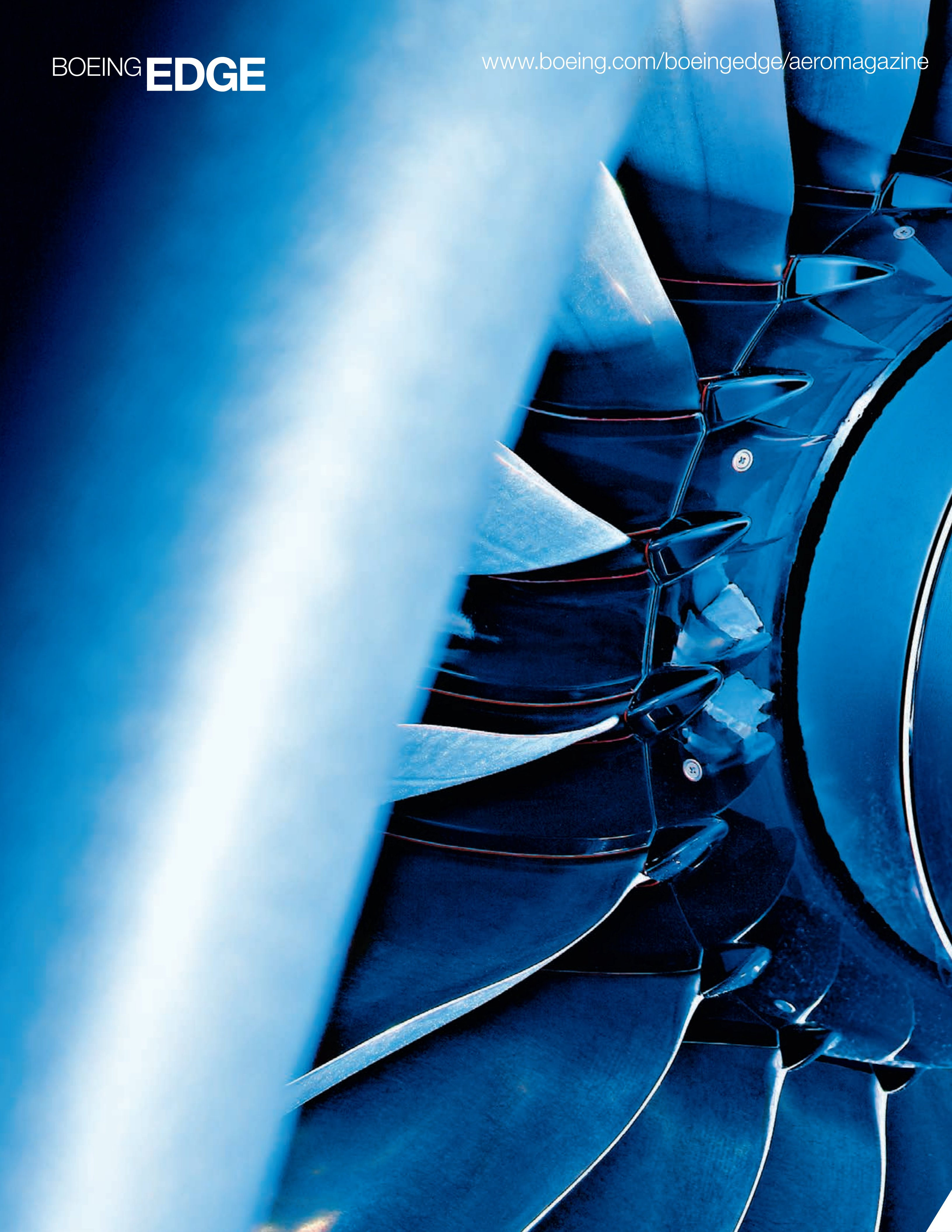
THE ROLE OF AIRLINE POLICIES

If operators elect not to purchase and install the recommended hinged access panels or personnel barriers, or choose not to use the recommended safety barriers, they should use local procedures to provide for the safety of the cabin crew and servicing personnel. These procedures should include specific policies dictating how open floor panels, hatches, and doors should be protected. For example, an employee can be assigned to guard the panel or door while it is open.

SUMMARY

Open doors, access panels, and hatches can present safety hazards, but falls through them can be prevented by proper and consistent use of barriers and following airline policies and procedures.

For more information, e-mail Boeing Maintenance Human Factors at MHF@boeing.com.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