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Cover photo: *Section of the 777 tail prior to fuselage assembly.*

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contents

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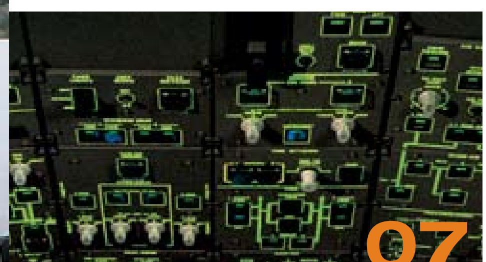

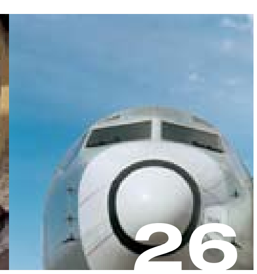

AERO

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***AERO* Online:**
boeing.com/commercial/aeromagazine

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 Company 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.

Print copies of *AERO* are not available by subscription, but the publication may be viewed on the Web at boeing.com/commercial/aeromagazine.

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Working Together to Ensure Safe and Efficient Airplane Operations

PETER WEERTMAN
Vice President, Technical Customer Support
Boeing Commercial Aviation Services

Seven years ago, Boeing and airplane fleet operators developed a new process for resolving significant in-service issues more efficiently and effectively, called FLEET TEAM™. Today, FLEET TEAM tools – available via the Web portal MyBoeingFleet.com – keep you, our valued airline customers, informed about emerging technical issues and fleetwide safety enhancements and economic improvements.

The FLEET TEAM tools allow us to work together better as an industry to develop compliance recommendations for safety-related concerns, share best practices, and understand fleet priorities for economic-related issues.

If you're not already using FLEET TEAM for research and collaboration, I encourage you to become more familiar with it. You'll be joining a virtual team that draws on the talents and experience of Boeing and airlines that operate Boeing airplanes. It is like being a part of the world's largest engineering and maintenance department. To date, more than 500 airlines worldwide regularly work together using the FLEET TEAM tools described on the following pages. The tools are one of the most frequently accessed applications on MyBoeingFleet.com. To join FLEET TEAM, please contact your Boeing Field Service representative or your Boeing electronic access focal.

FLEET TEAM RESOLUTION PROCESS

FLEET TEAM DIGEST
Stay up-to-date on in-service issues

This FLEET TEAM resource delivers the latest status and information regarding in-service issues and upcoming fleet improvements to your desktop. Currently, more than 5,600 articles are posted on significant issues, in-service events, and the status of major projects. Every economic and safety-related issue under investigation has an article posted on FLEET TEAM Digest, with almost 100 new or updated articles posted each week.

An advanced search tool allows you to easily find the article you are seeking. Want to receive an e-mail when a particular article is updated? That's easy with the MyBoeingFleet.com notification system. The FLEET TEAM Digest has replaced previous paper editions of Boeing publications, including the Fleet Issue Summary Reports, In-Service Activity Reports, Technical Focus Reports, In-Service Occurrence Reports, and Configuration Change Support Documents.

FLEET TEAM EMERGING ISSUES
Be ahead of mandatory engineering changes

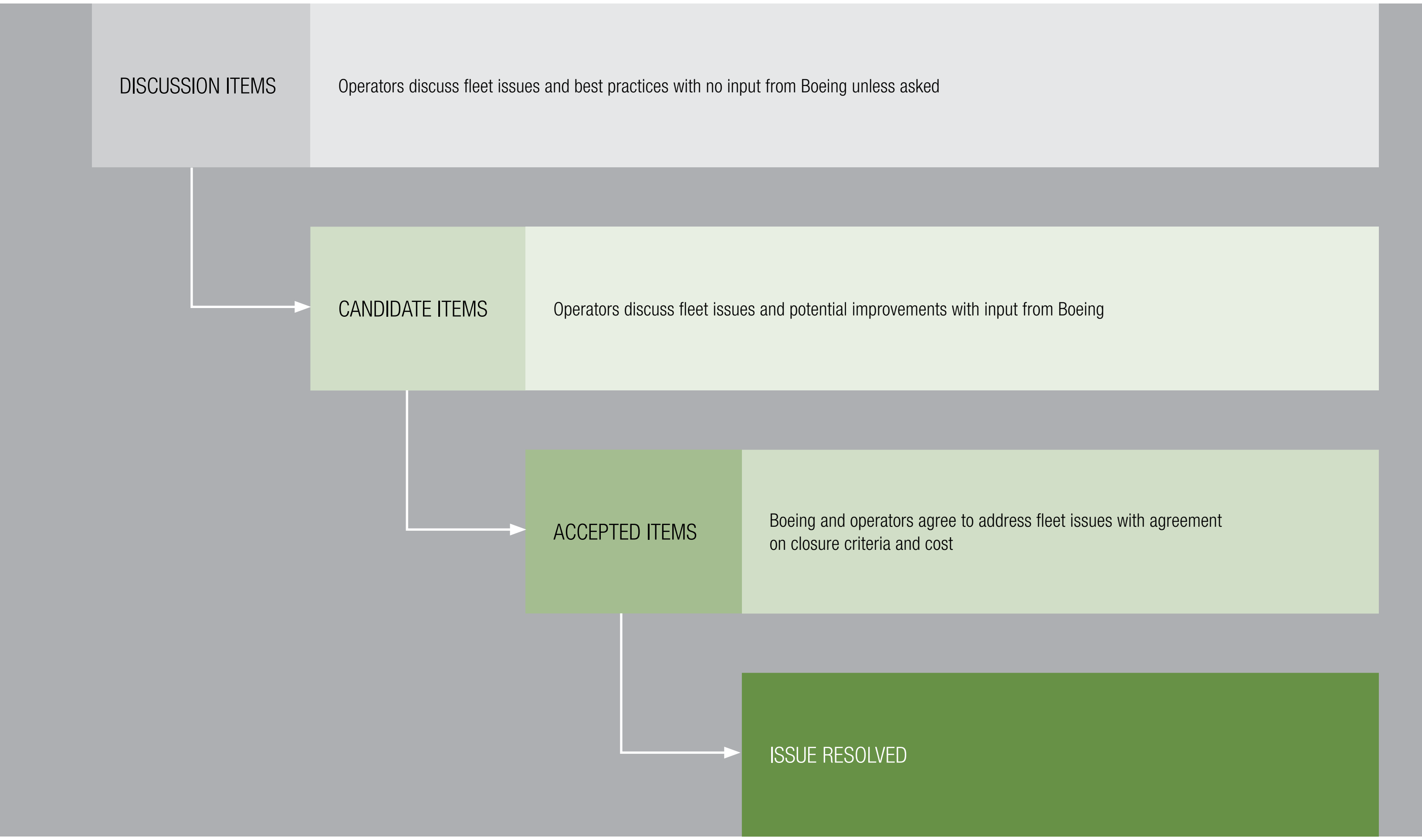
This electronic bulletin board keeps you involved in the development of compliance recommendations for safety-related issues and the investigation of potential safety issues. When a safety-related issue is identified, Boeing posts the latest details on the FLEET TEAM Emerging Issues Bulletin Board along with a reference to the associated FLEET TEAM Digest article. You will find two types of postings on the FLEET TEAM Emerging Issues Bulletin Board: "Standard" items are posted to provide only fleet awareness of an issue; "Attention" items are posted when operator action is requested to provide fleet information, findings, or feedback.

These postings supplement the Air Transport Association's Lead Airline Process, in which association-member airlines help Boeing raise awareness of safety or potential safety issues. Through the FLEET TEAM Emerging Issues Bulletin Board, Boeing works together with the entire fleet to develop appropriate mitigating and final actions, coordinate spares, and provide an industry-harmonized compliance recommendation to the U.S. Federal Aviation Administration.

FLEET TEAM RESOLUTION PROCESS
Set priorities and share best practices

This process allows the operators and Boeing to work together on economic fleet issues and help set the priorities for fleet improvements. An electronic bulletin board facilitates this collaboration.

Issues typically start out in the "Discussion" section, in which an operator may ask whether others have experienced a particular issue or



could answer a question. If the issue has been experienced by other operators and merits consideration to be addressed as a fleet issue, it is moved to the "Candidate" section. As a candidate item, the fleet operators discuss the effect of the issue on the fleet, what a potential solution might look like, and when it should be addressed. If the fleet operators decide the issue should be addressed, it is moved to the "Accepted" section.

When an item is accepted, the fleet operators and Boeing agree on the closure criteria, fleet cost, and implementation schedule. Status of these items is provided through FLEET TEAM Digest articles. Discussion and feedback are provided to Boeing through FLEET TEAM Calls and Meetings.

Nearly 5,000 users work together with Boeing through the FLEET TEAM Emerging Issues and the FLEET TEAM Resolution Process.

FLEET TEAM CALLS AND MEETINGS
Check progress and measure success

Working together via electronic collaboration is useful, but to check progress and measure success, it is important to meet regularly. FLEET TEAM Calls and Meetings are held for each Boeing model. The meetings are co-chaired by the airplane model's Boeing fleet support chief and a representative from the fleet operators. At these meetings, Boeing gathers consensus on the status of current safety and economic issues. Participants often represent 75 to 80 percent of the fleet for a particular model. Schedules for the FLEET TEAM Calls and Meetings vary by model. A complete list of events is included in the calendar section of the FLEET TEAM Resolution Process bulletin board.

It is the participation of our airline customers that has made FLEET TEAM the success it is today. Together, we will continue to improve these tools, using industrywide input and the latest in technology. Our goal is to ensure safe and efficient airplane operations. Your suggestions and ideas are always welcome. Please feel free to contact me anytime.

PETER WEERTMAN
Vice President,
Technical Customer Support
Boeing Commercial Aviation Services

SIGNIFICANT CHANGES COME TO ETOPS WITH THIS NEW RULE, WHICH ESTABLISHES OPERATOR AND AIRPLANE REQUIREMENTS FOR EXTENDED OPERATIONS.

The New FAA ETOPS Rule

by Capt. Chester L. "Chet" Ekstrand, Vice President, Regulatory Affairs; Mohan Pandey, Director, Operational Regulatory Affairs; and Jay Spenser, ETOPS Communications

On January 16, 2007, the U.S. Federal Aviation Administration (FAA) published comprehensive new regulations governing extended operations (ETOPS), which are flight operations on routes that at some point take an airplane far from an airport. This regulatory updating codifies current FAA policy, industry best practices and recommendations, and international standards designed to ensure that long-range flights will continue to operate safely.

The new U.S. ETOPS rule builds further on the success of ETOPS, which is the state-of-the-art in intercontinental air travel. More than 5.5 million ETOPS twinjet flights have been logged worldwide since 1985, and every day some 143 operators perform 1,750 more. These operations set the highest standard for safe, reliable long-range flying.

Significant changes come to ETOPS with this new rule, which updates the requirements for two-engine extended operations and provides a framework under which air carrier operators may safely fly approved twinjets beyond 180 minutes of an airport. As before, ETOPS applies when the twinjet flies beyond 60 minutes of an adequate airport.

For the first time, this new rule also applies ETOPS enhancements and protections to the extended operation of three- and four-engine passenger airplanes. For these "tris and quads," ETOPS applies when the airplane flies beyond 180 minutes of an adequate airport. To ease the transition to the new rule for all current operators, delayed compliance dates are specified for many of this rule's requirements.

In this regulatory updating, the FAA has recognized the outstanding propulsion reliability and overall safety of long-range twinjets. The new ETOPS rule creates the opportunity for carriers to fly properly configured and approved twinjets on optimal flight routings between virtually any two points on earth.

This article:

- Briefly reviews the collaborative global evolution of the new U.S. ETOPS rule.
- Examines this rule's specific regulatory modifications and additions to show what has changed relative to the previous "twinjet-only ETOPS," with which the industry is so familiar.

Although the new ETOPS rule embraces airplane design, maintenance, and operation, this article focuses primarily on the rule's operational impacts. Moreover, the discussion is confined to flights conducted under U.S. Code of Federal Regulations 14 CFR Part 121 (scheduled air carrier operations), even though the new rule for the first time also applies ETOPS to flights conducted under 14 CFR Part 135 (commuter and on-demand operations).

EVOLUTION OF THE NEW RULE

Jetliner range capabilities have grown dramatically over the decades. This trend has allowed flight operations to increasingly traverse remote areas of the world where the airplane is at times far from an airport. By the latter 1990s, the global aviation community recognized that the operational protections and reliability enhancements of ETOPS, which then applied just to twinjets, could also further enhance the safety and reliability of three- and

ETOPS Rule Changes

Authorization. Revised regulation 14 CFR 121.161 codifies ETOPS and provides updated requirements for the authorization of extended operations. For twinjets, ETOPS applies when the airplane is more than 60 minutes from an airport. For three- and four-engine passenger airplanes, it applies when the airplane is more than 180 minutes from an airport.

Operators flying three- and four-engine extended passenger operations have a one-year compliance grace period ending February 15, 2008. Three- and four-engine freighters are exempted from the new ETOPS rule.

This regulation also codifies a *polar policy* formalizing requirements for operators whose planned airplane routes traverse the North and South Polar areas. Within these areas, this non-ETOPS policy applies at all times to all airplanes, whether passenger or cargo, regardless of actual diversion time or number of engines.

Cargo fire suppression and other time-limited systems. New regulation 14 CFR 121.633 maintains current standards for up to 180 minutes ETOPS authority. It requires that ETOPS diversion times shall not exceed the time limit, minus 15 minutes, for that airplane type's most time-limited system, which typically is cargo fire suppression.

Beyond 180 minutes,* this rule requires that diversions for cargo fire suppression be calculated at all-engines-operating cruise speed, corrected for wind and temperature, and that diversions for other time-limited ETOPS significant systems be calculated at one-engine-inoperative cruise speed, corrected for wind and temperature. A six-year compliance grace period is provided to bring existing three- and four-engine fleets into compliance for cargo fire suppression.

four-engine airplanes when flying routes with the potential for an extended-duration diversion.

All airplanes flying extended routes contend with similar operating challenges in terms of weather, terrain, and limitations in navigation and communications infrastructure. Thus, the dual ETOPS philosophy of precluding diversions and also protecting them if they do occur is applicable to all extended operations, not just those performed with two-engine airplanes.

Pursuing this higher and more uniform standard, the FAA in June of 2000 created an Aviation Rulemaking Advisory Committee (ARAC) to review the ETOPS record and recommend how ETOPS requirements should be updated, standardized, and codified. Because the ETOPS program was then being administered via FAA advisory circulars, policy letters, and special conditions, this rulemaking would at last formalize extended operations directly in the federal aviation regulations as befits such large-scale operations.

The ARAC is a U.S. framework that relies on international participation. Its ETOPS Working Group gathered together 50 experts drawn from across the global aviation community. After two-and-a-half years of intensive effort, this ARAC delivered its findings and recommendations to the FAA on December 16, 2002. As the FAA noted, its report reflected an extraordinary degree of consensus about needed updates and improvements.

The FAA published a notice of proposed rulemaking (NPRM) on November 14, 2003, that was largely unchanged from the ARAC findings and recommendations. During an extended comment period, some 50 submissions were received from regulatory agencies, operators, manufacturers, and interested nongovernmental associations around the world. The FAA reviewed these public comments, acted on them as it deemed appropriate, and published a final rule on January 16, 2007. This ETOPS rule became effective 30 days later on February 15.

While the new ETOPS rule closely resembles the ARAC findings and recommendations, there are some differences. One is that three- and four-engine freighters are exempted from the rule because operators contended, and the FAA agreed, that the costs of compliance could not be justified in all-cargo operations.

Another difference is that, while three- and four-engine extended operations with passenger airplanes are subject to the new ETOPS rule, this fleet is exempted from the new rule's maintenance requirements. As explained in the rule's preamble:

"The FAA strongly believes that all operators would benefit from an ETOPS maintenance program. However, the FAA agrees with many of the commenters that the cost of implementing this new requirement for airplanes with more than two engines would be significant. The FAA has determined that this cost cannot be justified based on the current level of safety achieved by the

Communications. New regulations 14 CFR 121.99 and 121.122 require satellite communication (SATCOM) voice communications for all extended operations beyond 180 minutes; another form of communications must also be available in areas where communication is not possible using this technology. A one-year grace period is provided.

Definitions. New regulation 14 CFR 121.7 provides definitions of ETOPS-applicable terms to help ensure proper understanding and compliance.

Design requirements. Regulations governing transport-category airplane (Part 25) and engine design (Part 33) are revised to incorporate ETOPS enhancements that reduce the rate of airplane diversions and protect airplanes if they do divert. For beyond-180-minute ETOPS, new design requirements apply to ETOPS twinjets and three- and four-engine airplanes. Manufacturers have eight years to comply in currently produced three- and four-engine airplanes if these types remain in production past February 17, 2015.

Dispatch. Revised regulation 14 CFR 121.631 specifies ETOPS dispatch or flight-release requirements for weather conditions at ETOPS alternate airports; it also codifies the current requirement that weather information be updated at the start of the ETOPS phase of flight to verify the continuing availability of alternate airports.

Fuel reserve. New regulation 14 CFR 121.646 specifies the amount of reserve fuel to be carried to protect the airplane in the event of a cabin depressurization followed by an extended diversion, at low altitude where fuel consumption is increased, to an alternate airport. Fuel reserve planning assumes this event happens at the most critical point on the flight route.

Maintenance. New regulation 14 CFR 121.374 codifies current ETOPS maintenance practices and applies them to two-engine extended operations. Three- and four-engine passenger planes that fly ETOPS are exempted.

Passenger recovery plan. Revised regulation 14 CFR 121.135 requires all flights on extended routes with diversion times beyond 180 minutes — except those involving three- and four-engine freighters, which are exempted from ETOPS — to prepare a recovery plan for these routes that ensures the well-being of passengers stranded at diversion airports and provides for their safe retrieval without undue delay.

Passenger recovery plans are also required for all polar passenger operations. Moreover, all polar operations and beyond-180-minute ETOPS must comply with the public protection provisions in airport data regulation 14 CFR 121.97.

Performance data. Revised regulation 14 CFR 121.135 requires all ETOPS operators to have the applicable performance data available to support their extended operations.

Rescue and firefighting. Revised regulation 14 CFR 121.106 requires rescue and firefighting equipment to be available at any airport designated as an ETOPS alternate.

Training. Revised regulation 14 CFR 121.415 requires training for crew members and dispatchers for their specific roles and responsibilities in creating and implementing their operator's passenger recovery plans.

Type design. New regulation 14 CFR 121.162 establishes the basis for ETOPS airplane type-design approvals.

* Note that 207-minute ETOPS does not count as "beyond 180 minutes" — the threshold at which most of the new ETOPS requirements apply — because it is a 15 percent operational extension to, and subject to the requirements of, traditional 180-minute ETOPS authority.

combination of engine reliability and the engine redundancy of this fleet of airplanes."[1]

The final rule also differs from the NPRM with respect to polar area flight operations. Whereas the ARAC proposed making ETOPS requirements applicable within the North and South Poles (i.e., everything above 78 degrees north latitude and below 60 degrees south latitude), the FAA instead published a non-ETOPS polar policy in the rule-making that formalizes requirements for polar operations and provides a uniform process for operators seeking polar route authority. This approach results in a similar outcome but through a slightly different regulatory mechanism.

REGULATORY MODIFICATIONS AND ADDITIONS

ETOPS authorization. U.S. regulation 14 CFR 121.161 and associated preamble and advisory material have been revised to:

- Establish the basis and requirements for operating two-engine, turbine-powered airplanes beyond 60 minutes flying time (at single-engine cruise speed with no wind and in standard conditions) of an adequate alternate airport.
- Apply this same regulatory framework to the operation of turbine-powered passenger planes with more than two engines beyond 180 minutes (at one-engine-inoperative cruise speed with no wind and in standard conditions) of an adequate alternate airport.
- Make the designed and certified operating capabilities of the airplane type the basis for determining the maximum diversion authority of that airplane type.
- Use propulsion system reliability levels for two-engine ETOPS to trigger a review of operations and identify common-cause effects and systemic errors.
- Define allowable diversion authorizations and requirements for different regions of the world based on the overall operational needs of each region.

Note that 207-minute ETOPS is not subject to the new ETOPS requirements for "beyond-180-minute flight operations." Flown since 2000, this authority arose as a 15 percent operational extension, for limited use on an exception basis, to 180-minute ETOPS authority. It is thus considered an extension of and subject to the requirements for the traditional 180-minute "twinjet ETOPS" diversion authority.

Cargo fire suppression. To further ensure safety, new regulation 14 CFR 121.633 requires that all time-limited ETOPS significant systems aboard airplanes flying ETOPS shall have sufficient capability to protect the airplane throughout the longest potential diversion for that route. In particular, each flight shall have continuous cargo fire suppression capability for a period equivalent to the maximum planned diversion time plus an additional 15 minutes.

ETOPS twinjets have been required since 1985 to carry sufficient fire suppressant to protect the airplane continuously throughout a maximum-duration diversion. In contrast, although all jetliners have cargo fire suppression systems, airplanes with more than two engines have not previously had to meet this requirement that further protects passengers, crews, and airplanes on extended air routes.

For ETOPS at or below 180 minutes, which only involves twinjets, this cargo fire suppression requirement is based on maximum diversion time in still air plus 15 minutes, as was previously the case. For ETOPS beyond 180 minutes, which involves twinjets and three- and four-engine passenger airplanes, this requirement is to be calculated at all-engines-operating cruise speed, corrected for winds and temperature.

While cargo fire suppression is generally the most time-limited ETOPS significant system, it is just one of many such systems that contribute to safety during flight. For operations beyond 180 minutes, this regulation also requires that airline planning for diversions account for all other time-limited ETOPS significant systems calculating diversion times at one-engine-inoperative cruise speed, corrected for wind and temperature.

Three- and four-engine ETOPS operators are granted until February 15, 2013, to bring their existing fleets into compliance with the cargo fire suppression requirement. This six-year grace period serves to mitigate operator costs by allowing system upgrades to be performed during regularly scheduled airplane heavy-maintenance cycles. It also provides time for manufacturers to develop and certify this upgraded capability in their airplanes.

Communications. Regulations 14 CFR 121.99 and 121.122 (for supplemental operations) require the adoption of a satellite communication (SATCOM) voice system for ETOPS beyond 180 minutes of an alternate airport. Whereas other communication systems (e.g., VHF, HF, and SATCOM or HF datalink) have limitations that can compromise the reliability of communications during extended operations, SATCOM voice allows clear and immediate conversation that can quickly convey the situation and needs of a flight.

This requirement for satellite-based voice communications will ensure that ETOPS flight crews can communicate emergency situations with air traffic control or their airline throughout a long-range ETOPS flight. Alternative means of communication must also be available in the event that this most reliable means does not work for any reason. To mitigate compliance costs, a one-year grace period ending February 15, 2008, is provided.

Boeing plans to certify the long-range versions of the 787 Dreamliner to allow operations up to its design capability. Boeing also plans to extend the diversion capabilities of certain models of the 777, and is looking into extending the cargo fire suppression capabilities of its three- and four-engine models like the new 747-8. These product decisions will be based on customer needs.

Definitions. Many of the terms used in this ETOPS rule are unique to extended operations and demand precise interpretation to ensure common understanding and proper compliance. New regulation 14 CFR 121.7 provides these definitions.

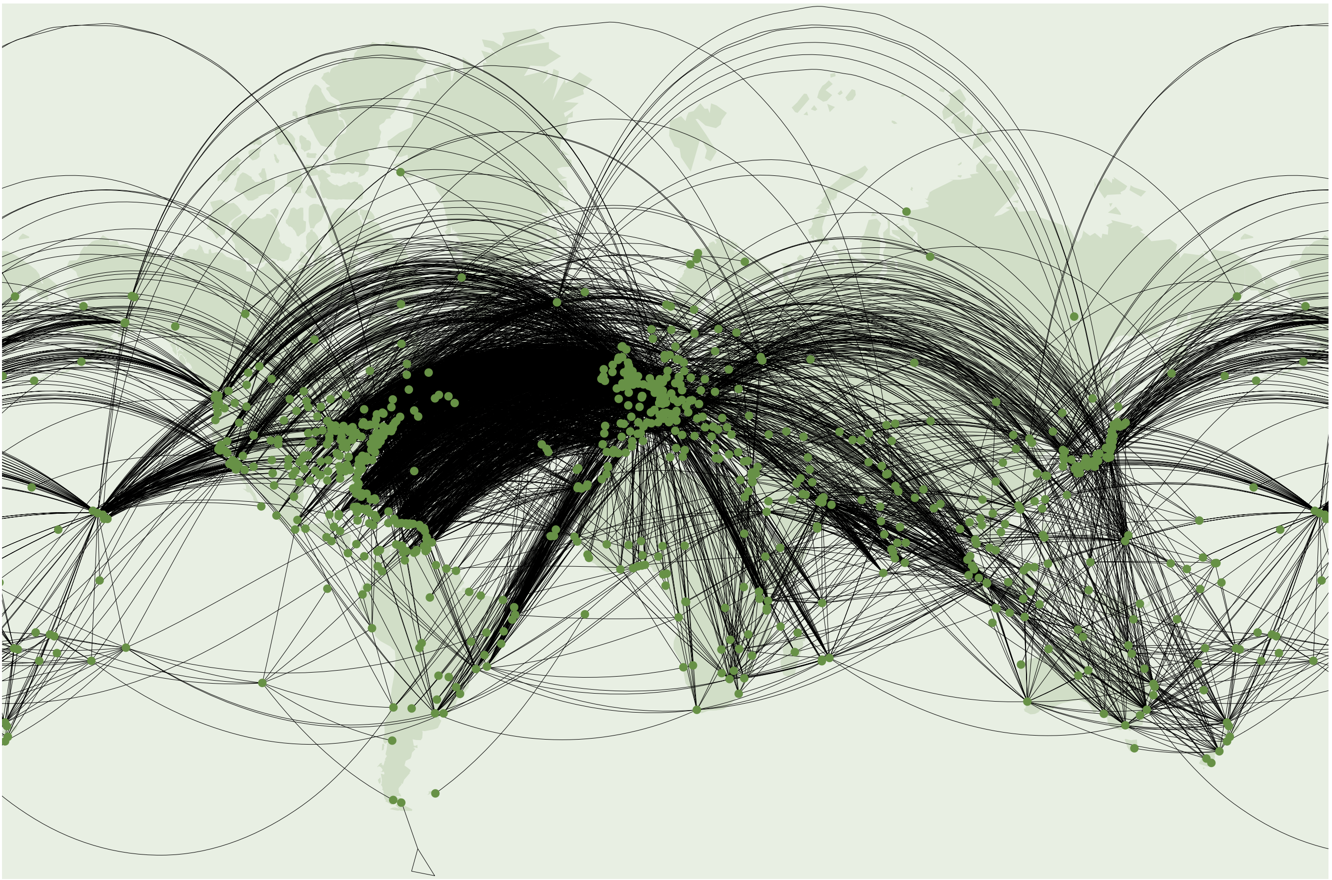
A noteworthy change is the addition of the term "ETOPS alternate airport," which is an adequate airport (i.e., one appropriate for the airplane type) that meets the stated requirements for planned diversion use and is listed in the certificate holder's operations specifications. The weather conditions at these airports are checked at dispatch or flight release, and again in flight, to determine whether they are at or above the operating minimums specified for a safe landing and can thus serve as an alternate for that flight.

"ETOPS alternate" thus replaces the former ETOPS term "suitable airport," which denoted an alternate airport that was both above required weather minimums and available for diversion use. Under the new ETOPS rule, "suitable" no longer has an ETOPS-specific meaning. Therefore, where it appears in the new ETOPS rule, it is to be interpreted only according to its broadly accepted everyday meaning.

Design requirements. Type-design changes made in Parts 21, 25, and 33 of the U.S. federal aviation regulations codify existing ETOPS policies, practices, and special conditions in a uniform set of regulations for airplanes and engines. The new regulations also extend the existing safety standards to allow for design approvals beyond the previous 180-minute ETOPS diversion authority limit. These extended standards ensure that airplane designs approved for beyond-180-minute ETOPS maintain the same high standards that have exemplified ETOPS experience to date. As the FAA noted in this new rule's preamble:

"Because of the potential benefits associated with the superior design of airplane-engine combinations demonstrated under the existing [twinjet] ETOPS certification programs, the FAA has decided to extend those requirements to the airplanes with more than two engines should the manufacturer wish to market these airplanes as suitable for ETOPS operation."[2]

Boeing plans to certify the long-range versions of the 787 Dreamliner to allow operations up to its design capability. Boeing also plans to extend the diversion capabilities of certain models of the 777, and is looking into extending the cargo fire



Two-engine jetliners have logged more than 5.5 million ETOPS flights since 1985. Boeing twinjets alone perform another 1,400 or so every day.

suppression capabilities of its three- and four-engine models like the new 747-8. These product decisions will be based on customer needs.

At present, it appears that a diversion time limit in the neighborhood of 330 minutes will support optimal flight operations between any two points on earth. Boeing is currently assessing the ability of our current and projected widebody fleet to meet this goal, and will in the very near future define program goals.

Dispatch. Revised regulation 14 CFR 121.631 makes only minor changes to the established ETOPS dispatch and flight-release requirements, which specify requirements for weather conditions at ETOPS alternate airports and require that weather information be updated at the start of the ETOPS phase of flight to verify the continuing availability of diversion airports.

Fuel reserve. New regulation 14 CFR 121.646 requires that all airplanes flown in extended operations must carry an ETOPS fuel reserve sufficient to allow flight to an ETOPS alternate airport in the event of these three scenarios:

- A rapid loss of cabin pressure at the most critical point followed by a descent to a safe altitude as defined by oxygen availability.
- A rapid loss of cabin pressure and a simultaneous engine failure at the most critical point followed by a descent to a safe altitude as defined by oxygen availability.
- An engine failure at the most critical point and descent to one-engine-inoperative cruise altitude and diversion at one-engine-inoperative cruise speed.

Whichever of the above requires the greatest amount of fuel shall be the basis of computation for this reserve. Because of the increased fuel consumption of turbine engines at low altitudes, and the corresponding reduction in airplane range, the decompression scenarios logically define this reserve, which ensures sufficient fuel for an extended low-altitude diversion followed by a descent to 1,500 feet at the alternate airport, a 15-minute hold, and an approach and landing. Further allowance is made for possible airframe icing, wind forecasting error, and in-flight use of the auxiliary power unit.

More than two decades of ETOPS twinjet experience have identified areas of excessive conservatism in the original ETOPS fuel reserve requirement. Based on the refinement of models and removal of past uncertainties, this new rule specifies a slightly smaller critical fuel reserve for twinjets. Under the new ETOPS rule, three- and four-engine passenger airplanes flying extended routes will be required to carry an ETOPS fuel reserve.

The FAA has also implemented a non-ETOPS provision, 14 CFR 121.646(a), that addresses an existing concern. This provision requires that all three- and four-engine airplanes carry a decompression fuel reserve whenever they fly beyond 90 minutes of an airport. Although U.S. regulations

Non-ETOPS Provisions Included in This Rulemaking

Polar policy. Regulation 14 CFR 121.161, which authorizes ETOPS, also formalizes requirements for operations north of latitude 78°N (North Pole) and south of latitude 60°S (South Pole). Within these regions, this FAA polar policy applies at all times to all airplanes regardless of actual diversion time or number of engines.

Three- and four-engine airplane fuel reserve. The ETOPS en route fuel supply regulation includes 14 CFR 121.646(a), a general provision that states three- and four-engine airplanes, when flying more than 90 minutes from an airport, shall carry sufficient fuel to safely reach an adequate airport in the event of decompression and diversion at low altitude where fuel consumption is increased.

specify supplemental oxygen in the event that cabin pressure is lost, some operators and flight-plan suppliers have not specified sufficient reserve fuel for the airplane to reach an alternate airport during a low-altitude diversion. It should be noted that many three- and four-engine operators do routinely carry a depressurization fuel reserve as a matter of internal airline policy.

Maintenance. New regulation 14 CFR 121.374 codifies the current ETOPS maintenance practices. These proven practices reduce airplane-related diversions through disciplined procedures like engine condition monitoring, oil consumption monitoring, aggressive resolution of identified reliability issues, and procedures that avoid human error during the maintenance of airplane engines and systems.

The new ETOPS rule makes ETOPS maintenance requirements applicable only to two-engine airplanes that fly extended operations. Because unscheduled landings at alternate airports can be costly and disruptive events for carriers, some three- and four-engine operators have voluntarily raised their maintenance standards to ETOPS levels even though it is not required of them.

Passenger recovery plan. Revised regulation 14 CFR 121.135 requires that for all ETOPS flying beyond 180 minutes (excluding 207-minute ETOPS, as explained above), and for all polar operations, the air carrier must develop a plan to ensure the well-being of passengers and crew members at each approved en route alternate airport listed in this carrier's operations specifications. Because challenging alternate airports tend to be found in the most remote parts of the world, passenger recovery plans are no longer required for ETOPS below 180 minutes.

This passenger recovery plan must address the safety and comfort, in terms of facilities and accommodations, of stranded passengers at the diversion airport. As its name suggests, it must also address their prompt retrieval from the airport.

Polar operations also require passenger recovery plans, as codified in this rulemaking's polar policy. Initially implemented as an FAA policy letter in 2001, this polar policy also requires diversion airport planning, another key ETOPS concept. Despite these similarities, however, polar operations are distinct from ETOPS because North and South Polar operations entail unique requirements, such as special onboard equipment and a fuel freeze strategy.

Performance data. Revised regulation 14 CFR 121.135 also requires the operator to provide its flight crews and dispatchers with airplane performance data to support all phases of extended operations. This data must describe the specific performance of the airplane in normal and non-normal situations, including those that might arise during an extended-duration diversion to an alternate airport.

Rescue and firefighting service (RFFS). During more than two decades of ETOPS and more than 5.5 million ETOPS twinjet flights around the world, there has never been a landing accident following an extended diversion from the ETOPS phase of flight. However, the fact that RFFS has not been needed in the past does not lessen the importance of this ETOPS operational protection.

New regulation 14 CFR 121.106 formalizes RFFS requirements for alternate airports. For ETOPS up to 180 minutes, each airport listed on the dispatch or flight release as an ETOPS alternate airport must have RFFS capability equivalent to or higher than International Civil Aviation Organization (ICAO) Category 4.[3]

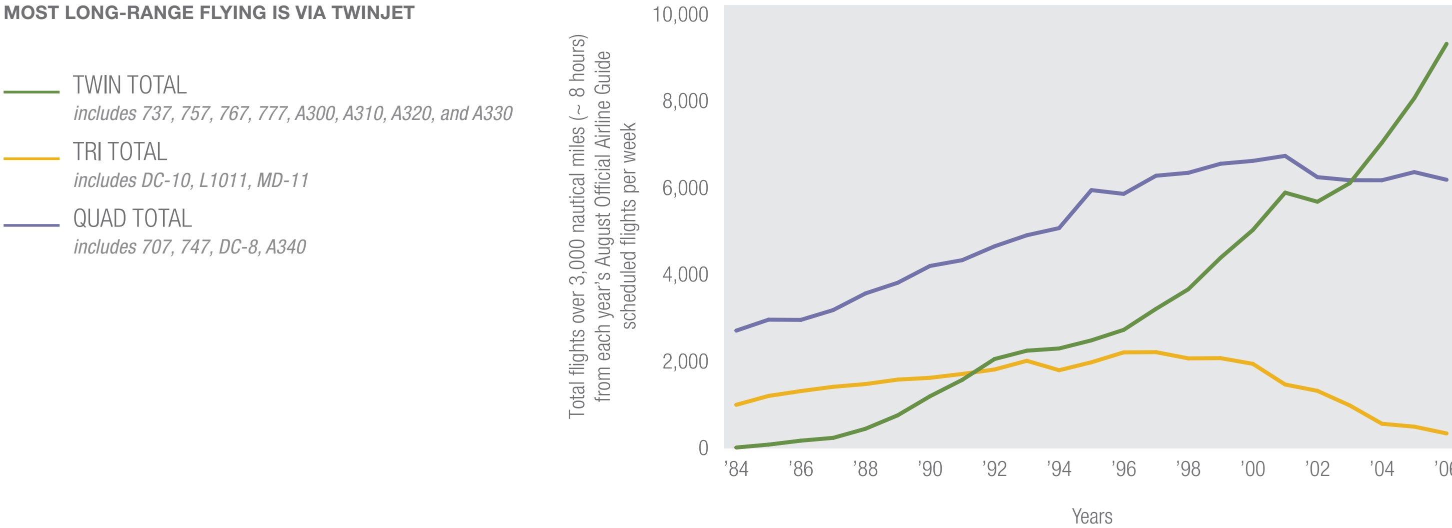
For ETOPS beyond 180 minutes, ICAO Category 4 is required with at least one adequate airport within the authorized diversion time having ICAO Category 7. This provision allows for optimum route planning while providing the flight crew with available alternate airport options in the event a situation arises requiring a higher RFFS capability.

The regulation also makes provision for dispatching even if an otherwise adequate alternate airport lacks sufficient RFFS, provided that local firefighting assets — given 30 minutes notice while the diversion is in progress — can be available to bring the airfield's capability up to the required ICAO standard. There must be a commitment that this supplemental RFFS will be available at arrival and that it will remain at the scene for as long as needed by the diverting airplane.

Training. Revised regulation 14 CFR 121.415 has been modified to require training for crew members and dispatchers for their specific roles and responsibilities in creating and implementing the operator's passenger recovery plans for the alternate airports upon which it relies for its extended operations.

Type design. New regulation 14 CFR 121.162 establishes the basis for ETOPS type-design approvals. This regulation delineates the airworthiness standards required for airplanes to

MOST LONG-RANGE FLYING IS VIA TWINJET



This new ETOPS rule ensures that air carriers performing twinjet extended operations, or three- and four-engine passenger jet extended operations, will have the requisite experience and ability to maintain and operate these airplanes at the required level of reliability and competence. This rule further provides for ETOPS beyond 180 minutes, and it allows the operators of approved long-range twinjets to fly optimal routings between virtually any two cities on earth.

be used in Part 121 ETOPS and it confirms that current ETOPS-qualified operators can continue operating their ETOPS routes without a new approval process.

This new ETOPS rule's remaining regulatory additions or modifications formalize the requirements for weather minimums at these alternate airports (14 CFR 121.625), ETOPS dispatch or flight release (14 CFR 121.631, § 121.687, § 121.689), and ETOPS alternate airports (14 CFR 121.624). General regulation 14 CFR 121.97, which describes what airport information all operators are to be cognizant of, also applies to the alternate airports on which ETOPS and polar area operations depend. The FAA has also updated existing regulation on flight procedures following in-flight engine failure or shutdown (14 CFR 121.565).

CONCLUSION

This new U.S. ETOPS rule ensures that air carriers performing twinjet extended operations, or three- and four-engine passenger jet extended operations, will have the requisite experience and ability to maintain and operate these airplanes at the required level of reliability and competence. This rule further provides for ETOPS beyond 180 minutes, and it allows the operators of approved long-range twinjets to fly optimal routings between virtually any two cities on earth.

On the operational front, this rulemaking ensures the availability of alternate airports as well as sufficient reserve fuel to reach these airports even under the most challenging circumstances. Furthermore, it ensures the availability of rescue and firefighting services, and requires that operators plan for the safety, comfort, and prompt retrieval of stranded passengers.

On the design front, the new ETOPS rule continues to reduce the rate of airplane propulsion and system failures that might cause a diversion. Moreover, it ensures that all time-limited ETOPS airplane systems will support worst-case scenarios by remaining continuously available throughout a maximum-duration diversion to the limit of that flight's authority. For more information, please contact Mohan Pandey at mohan.r.pandey@boeing.com.

1 U.S. Federal Register, Washington, DC, vol. 72, no. 9, January 16, 2007, p. 1836.

2 Ibid., p. 1816.

3 ICAO Annex 14, Volume 1, Aerodrome Design and Operations.

THE MEDA PROCESS IS THE WORLDWIDE STANDARD FOR MAINTENANCE ERROR INVESTIGATION.

MEDA
Investigation Process

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

Since 1995, Boeing has offered operators a human factors tool called the Maintenance Error Decision Aid (MEDA) for investigating contributing factors to maintenance errors. Boeing has recently expanded the scope of this tool to include not only maintenance errors but also violations in company policies, processes, and procedures that lead to an unwanted outcome.

Boeing, along with industry partners, began developing MEDA in 1992 as a way to better understand the maintenance problems experienced by airline customers. A draft tool was developed and nine airline maintenance organizations tested the usefulness and usability of the tool in 1994 and 1995. Based on the results of this test, the tool was improved. In 1995, Boeing decided to offer MEDA to all of its airline customers as part of its continued commitment to safety. Since that time, the MEDA process has become the worldwide standard for maintenance error investigation.

MEDA is a structured process for investigating the causes of errors made by maintenance technicians and inspectors. It is an organization's means to learn from its mistakes. Errors are a result of contributing factors in the workplace, most of which are under management control. Therefore, improvements can be made to the workplace to eliminate or minimize these factors so they do not lead to future events.

Boeing has recently updated the MEDA tool to reflect the latest thinking about maintenance event investigations. This article addresses the following:

- The effect of reducing maintenance errors.
- An overview of the MEDA process.
- The MEDA philosophy.
- Why MEDA has shifted to an event investigation process rather than just an error investigation process.
- Considering violations during an event investigation.
- How errors and violations often occur together to produce an unwanted outcome.
- How addressing the contributing factors to lower-level events can prevent more serious events.

EFFECT OF REDUCING MAINTENANCE ERRORS

The 2003 International Air Transport Association (IATA) Safety Report found that in 24 of 93 accidents (26 percent), a maintenance-caused event started the accident chain. Overall, humans are the largest cause of all airplane accidents (see fig. 1).

Maintenance errors can also have a significant effect on airline operating costs. It is estimated that maintenance errors cause:

- 20 to 30 percent of engine in-flight shutdowns at a cost of US$500,000 per shutdown.
- 50 percent of flight delays due to engine problems at a cost of US$9,000 per hour.
- 50 percent of flight cancellations due to engine problems at a cost of US$66,000 per cancellation.

More than 500 aircraft maintenance organizations are currently using MEDA to drive down maintenance errors. One airline reported a 16 percent reduction in maintenance delays. Another airline was able to cut operationally significant events by 48 percent. Many other operators have reported specific improvements to their internal policies, processes, and procedures.

MEDA OVERVIEW

MEDA provides operators with a basic five-step process to follow:

- Event.
- Decision.
- Investigation.
- Prevention strategies.
- Feedback.

Event. An event occurs, such as a gate return or air turnback. It is the responsibility of the maintenance organization to select the error-caused events that will be investigated.

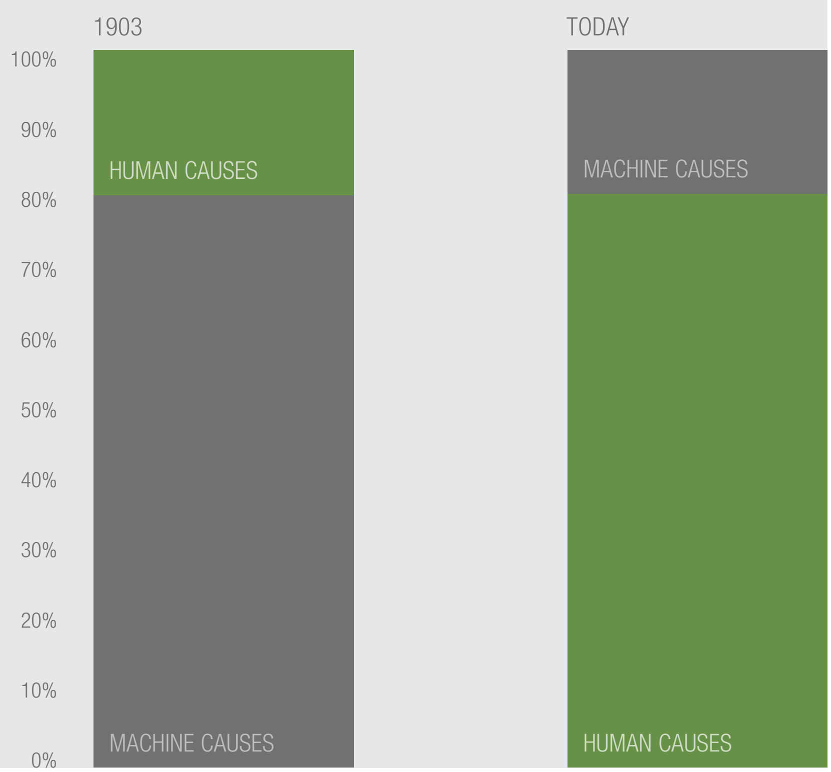
Decision. After fixing the problem and returning the airplane to service, the operator makes a decision: Was the event maintenance-related? If yes, the operator performs a MEDA investigation.

Investigation. The operator carries out an investigation using the MEDA results form. The trained investigator uses the form to record general information about the airplane, including when the maintenance and the event occurred, the event that began the investigation, the error and/or violation that caused the event, the factors contributing to the error or violation, and a list of possible prevention strategies.

Prevention strategies. The operator reviews, prioritizes, implements, and then tracks prevention

CAUSES OF ACCIDENTS
Figure 1

In the early days of flight, approximately 80 percent of accidents were caused by the machine and 20 percent were caused by human error. Today that statistic has reversed. Approximately 80 percent of airplane accidents are due to human error (pilots, air traffic controllers, mechanics, etc.) and 20 percent are due to machine (equipment) failures.



strategies (i.e., process improvements) in order to avoid or reduce the likelihood of similar errors in the future.

Feedback. The operator provides feedback to the maintenance workforce so technicians know that changes have been made to the maintenance system as a result of the MEDA process. The operator is responsible for affirming the effectiveness of employees' participation and validating their contribution to the MEDA process by sharing investigation results with them.

The resolve of management at the maintenance operation is key to successful MEDA implementation. Specifically, after completing a program of MEDA support from Boeing, managers must assume responsibility for the following activities before starting investigations:

- Appoint a manager in charge of MEDA and assign a focal organization.
- Decide which events will initiate investigations.
- Establish a plan for conducting and tracking investigations.
- Assemble a team to decide which prevention strategies to implement.
- Inform the maintenance and engineering workforce about MEDA before implementation.

MEDA PHILOSOPHY AND THE MOVE TO AN EVENT INVESTIGATION PROCESS

The central philosophy of the MEDA process is that people do not make errors on purpose. While some errors do result from people engaging in behavior they know is risky, errors are often made in situations where the person is actually attempting to do the right thing. In fact, it is possible for others in the same situation to make the same mistake. For example, if an inspection error (e.g., missed detection of structural cracking) is made because the inspector is performing the inspection at night under inadequate lighting conditions, then others performing a similar inspection under the same lighting conditions could also miss detection of a crack.

MEDA began as strictly a structured error investigation process for finding contributing factors to errors that caused events. However, in the 11 years that MEDA has been in wide use, Boeing has learned that errors and violations both play a part in causing a maintenance-related event.

An error is defined as a human action (i.e., behavior) that unintentionally departs from the expected action (i.e., behavior). A violation is a human action (i.e., behavior) that intentionally departs from the expected action (i.e., behavior).

Today, MEDA is seen as an event investigation process, not an error investigation process. This new approach means that a maintenance-related event can be caused by an error, a violation, or a combination of an error and a violation.

The central part of the MEDA process is making the improvements needed to eliminate the contributing factors. Some of these improvements will be obvious after a single event and others will be apparent only after analyzing a number of similar events. After the improvements have been made, it is important to inform the employees so they know their cooperation has been useful.

INCLUDING VIOLATIONS IN EVENT INVESTIGATIONS

Violations are made by staff not following company policies, processes, and procedures while trying to finish a job — not staff trying to increase their comfort or reduce their workload. Company policies, processes, and procedures all can be violated.

The revised version of MEDA acknowledges that violations have a causal effect, and they cannot be ignored if an airline is to conduct a complete investigation. The MEDA process distinguishes between three types of violations: routine, situational, and exceptional.

Routine. These violations are "common practice." They often occur with such regularity that they are automatic. Violating this rule has become a group norm. Routine violations are condoned by management. Examples include:

- Memorizing tasks instead of using the maintenance manuals.
- Not using calibrated equipment, such as torque wrenches.
- Skipping an operational test.

Situational. The mechanic or inspector strays from accepted practices, "bending" a rule. These violations occur as a result of factors dictated by the employee's immediate work area or environment and are due to such things as:

- Time pressure.
- Lack of supervision.
- Pressure from management.
- Unavailable equipment, tools, or parts.

Exceptional. The mechanic or inspector willfully breaks standing rules while disregarding the consequences. These types of violations occur very rarely.

CONSIDERING BOTH ERRORS AND VIOLATIONS

Because errors have been the focus of much research, there are many more theories about why errors occur than why violations occur. However, errors and violations often occur together to produce an unwanted outcome. Data from the U.S. Navy suggests that:

- Approximately 60 percent of maintenance events are caused by an error only.
- Approximately 20 percent of these events are caused by a violation only.
- Approximately 20 percent of these events are caused by an error and a violation (see figs. 2 and 3).

HOW ADDRESSING THE CONTRIBUTING FACTORS TO LOWER-LEVEL EVENTS CAN PREVENT MORE SERIOUS EVENTS

A contributing factor is anything that can affect how the maintenance technician or inspector does his or her job, including the technician's own characteristics, the immediate work environment, the type and manner of work supervision, and the nature of the organization for which he or she works.

Data from the U.S. Navy shows that the contributing factors to low-cost/no-injury events were the same contributing factors that caused high-cost/personal-injury events. Therefore, addressing the contributing factors to lower-level events can prevent higher-level events.

In a typical event investigation, as conducted at many airlines in the past, a maintenance event occurs, it is determined that the event was caused by an error, the technician who did the work is found, and the technician is punished. Many times, no further action is taken.

However, if the technician is punished but the contributing factors are not fixed, the probability that the same event will occur in the future is unchanged. The MEDA process finds the contributing factors and identifies improvements to eliminate or minimize these contributing factors in order to reduce the probability that the event will recur in the future.

During a MEDA investigation, it is still necessary to determine whether the event is caused by human behavior and find the individual(s) involved. Instead of being punished, however, the technician is interviewed to get a better understanding of the contributing factors and get the technician's ideas for possible improvements. The information can then be added to a database.

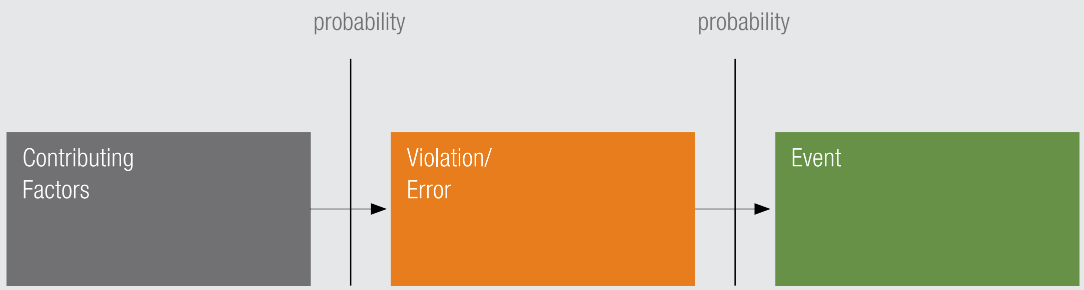
The central part of the MEDA process is making the improvements needed to eliminate the contributing factors. Some of these improvements will be obvious after a single event and others will be apparent only after analyzing a number of similar events. After the improvements have been made, it is important to inform the employees so they know their cooperation has been useful.

Boeing supports the "Just Culture" concept, which is based on moving beyond a culture of blame to a system of shared accountability, where both individual and system accountability are managed fairly, reliably, and consistently.

MEDA EVENT MODEL

Figure 2

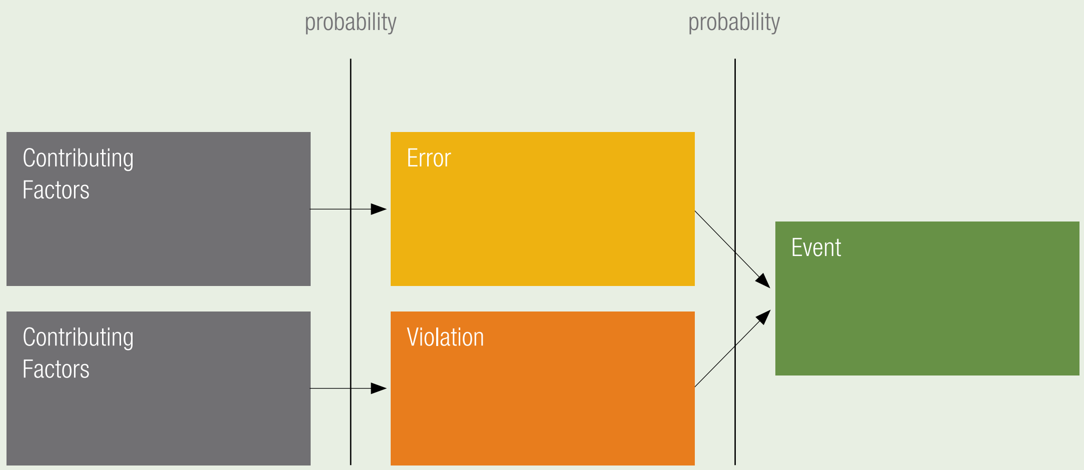
In this example, a mechanic does not use a torque wrench (violation), which leads to an engine in-flight shutdown (event). There are reasons why (contributing factors) the violation occurred (e.g., unavailable torque wrench or work group norm is not to use a torque wrench).



MEDA EVENT MODEL

Figure 3

In this example, the mechanic mistakenly misses a step in the airplane maintenance manual (contributing factor), which leads to an incomplete installation (error). The mechanic decides not to carry out the operational check (violation), thereby missing the fact that the task was not done correctly. Because an error was made and this was not caught by the operational check, an engine in-flight shutdown (event) occurs.



THE IMPORTANCE OF A DISCIPLINE POLICY

It is important to have a discipline policy in place to deal with violation aspects of maintenance events. However, discipline or punishment is only effective for intentional acts. Boeing suggests a policy that:

- Does not punish honest errors.
- Does not punish routine violations.
- Considers punishment for situational violations.
- Provides punishment for exceptional violations.

Boeing supports the "Just Culture" concept, which is based on moving beyond a culture of blame to a system of shared accountability, where both individual and system accountability are managed fairly, reliably, and consistently.

NEW MEDA MATERIALS AVAILABLE

Boeing has updated the MEDA Results Form and User's Guide that reflect the process's new event investigation focus. These materials are provided to anyone at no charge. Boeing will also train operators at no charge if the training takes place in Seattle.

SUMMARY

Maintenance events have negative effects on safety and cost. A maintenance event can be caused by an error, a violation, or a combination of errors and violations. Maintenance errors are not committed on purpose and result from a series of contributing factors. Violations, while intentional, are also caused by contributing factors. Most of the contributing factors to both errors and violations are under management control.

Therefore, improvements can be made to these contributing factors so that they do not lead to future maintenance events. The maintenance organization must be viewed as a system in which the technician is one part of the system. Addressing lower-level events helps prevent more serious events from occurring. For more information, please contact William L. Rankin at william.l.rankin@boeing.com.

OTHER INVESTIGATION PROCESSES

In addition to MEDA, Boeing has three other investigation processes available to the industry. Like MEDA, these tools operate on the philosophy that when airline personnel (e.g., flight crews, cabin crews, or mechanics) make errors, contributing factors in the work environment are a part of the causal chain. To prevent such errors in the future, those contributing factors are identified and, where possible, eliminated or mitigated. The additional investigation processes are:

- Ramp Error Decision Aid (REDA), which focuses on incidents that occur during ramp operations.
- Procedural Event Analysis Tool (PEAT), which was created in the mid-1990s to help the airline industry effectively manage the risks associated with flight crew procedural deviations induced operational incidents.
- Cabin Procedural Investigation Tool (CPIT), which is designed for investigating cabin crew induced incidents.

CASE STUDY

This case study illustrates how the MEDA process can help operators identify factors in the work environment that can lead to serious events.

EVENT SUMMARY

An operator's 767 was diverted when the pilot reported problems with the fuel flow indication system. After a delay, all 210 passengers were flown out on another airplane, which had been scheduled for an overnight check at that airport.

Extensive troubleshooting revealed debris in the fuel tank, including tape, gloves, and several rags that had clogged some of the fuel lines. The debris had been left during fuel tank leak checks and repairs and had not been found by the inspector at the end of the check.

MEDA INVESTIGATION

Scott and Dennis were the two maintenance technicians who performed the fuel tank leak checks and repairs. The MEDA investigation showed that Scott started the series of tasks during the third shift. He used the Airplane Maintenance Manual (AMM) as a reference to do the fuel tank purging and entry procedure. Then, he started the area-by-area leak checks and repairs as shown by the operator's work cards. Scott had trouble moving around in the tank because of his above-average height and weight. Scott made minor repairs in some areas of the tank, but his shift ended before he finished the task. Wanting to get out of the tank as soon as possible, Scott left the tape, gloves, and rags in the tank for Dennis to use to finish the task on the next shift.

Scott checked off the tasks he had completed on the signoff sheets in front of each work card. He also wrote in the crew shift handover report which tank areas had been checked and repaired and in which area he had last worked. However, he did not write in the shift handover report that he had not finished checking and repairing the complete tank, and he did not write down that he had left equipment in the tank. There was no overlap between shifts, so Scott left before the mechanics arrived for the next shift.

James was the lead technician on the next shift. He read the shift handover report. He did not notice that Scott's work card was not signed off, so he assumed that Scott's tank was finished and assigned the rest of the leak check and repair work cards for the other fuel tanks to Dennis. Dennis was the smallest member of his crew and found it easy to work in the fuel tanks.

Dennis completed the leak checks and repairs on the tanks that Scott had not worked on. Dennis saw that the AMM had recently been revised. Technicians were now supposed to count all the gloves, rags, and other equipment that were taken into and out of the fuel tanks to make sure that all equipment was accounted for. He also noticed that the work cards had not been updated to reflect these changes to the AMM. Dennis followed the instructions because they were probably added for safety reasons. Consistent with the AMM revision, he remembered hearing that his employer had moved to a process that called for each mechanic to take all equipment out with him when leaving a tank, even if the task was not completed. He noted to himself that the new process had not yet been briefed at a crew meeting. Dennis finished the remaining fuel tanks shortly before the airplane was due for final inspection. He signed off the remaining work cards and handed them over to his lead, James.

James (following a standard procedure at that operator) put all of the fuel tank work cards together in one stack. Then he attached one inspection signoff sheet to the outside of the stack. James handed this and other stacks of work cards to Bill. Bill, the maintenance inspector, did the final inspection.

The fuel tank access panels were still open when Bill did his inspection. He used a company-provided flashlight and mirror to inspect as much of each fuel tank as he could through the access panel without going inside the tanks. This was an acceptable level of inspection at this particular operator. However, Bill could not see the entire area inside of each fuel tank from the access panel openings. Bill stated during his MEDA interview that the design of the fuel tanks made it impossible for him to see every area using the flashlight and mirror. He also said that the colors of the gloves, tape, and rags were almost the same color as inside the fuel tanks. Bill signed the inspection sheet for each of the fuel tanks. The fuel tank access panels were then closed.

The MEDA investigation also found that the AMM procedures for the fuel tank purging and entry, fuel tank leak checks, and fuel tank repairs all contained instructions to make sure all objects were removed from the tanks when the procedures were complete.

RECOMMENDATIONS

This investigation enabled the operator to develop a number of recommendations to prevent a similar event from occurring in the future. These recommendations include:

- Changing work cards to include the reference, "Equipment removed from tank."
- Using brightly colored rags, gloves, and tape that contrast with the tank color.
- Changing the inspection process to a full-entry inspection or using better lighting to perform the inspection.
- Providing all of the mechanics with information and training on the new tools and equipment removal process.
- Delegating fuel tank work to smaller mechanics.

Preventing Wheel/Brake-Area Fires

by Brian Webber,
Mechanical Systems Engineer,
Service Engineering

While most wheel/brake-area fires pose no serious threat to the airplane or passengers, they can be alarming enough to cause cabin evacuations and costly delays. This article describes proper wheel/axle greasing techniques during wheel and brake maintenance and highlights the importance of not allowing flammable solvents to collect in wheel heat shields during cleaning procedures to minimize the potential for wheel/brake-area fires.

Many airlines, particularly those operating carbon-braked airplanes, have experienced wheel/brake-area fires due to excessive grease buildup, incorrect grease usage, the presence of flammable cleaning solvents in wheel heat shields, or the accumulation of hydraulic fluid on the brake. In the rare instances when wheel/brake-area fires do occur, the grease, solvent, or hydraulic fluid is ignited following landing by heat generated by the application of the brakes.

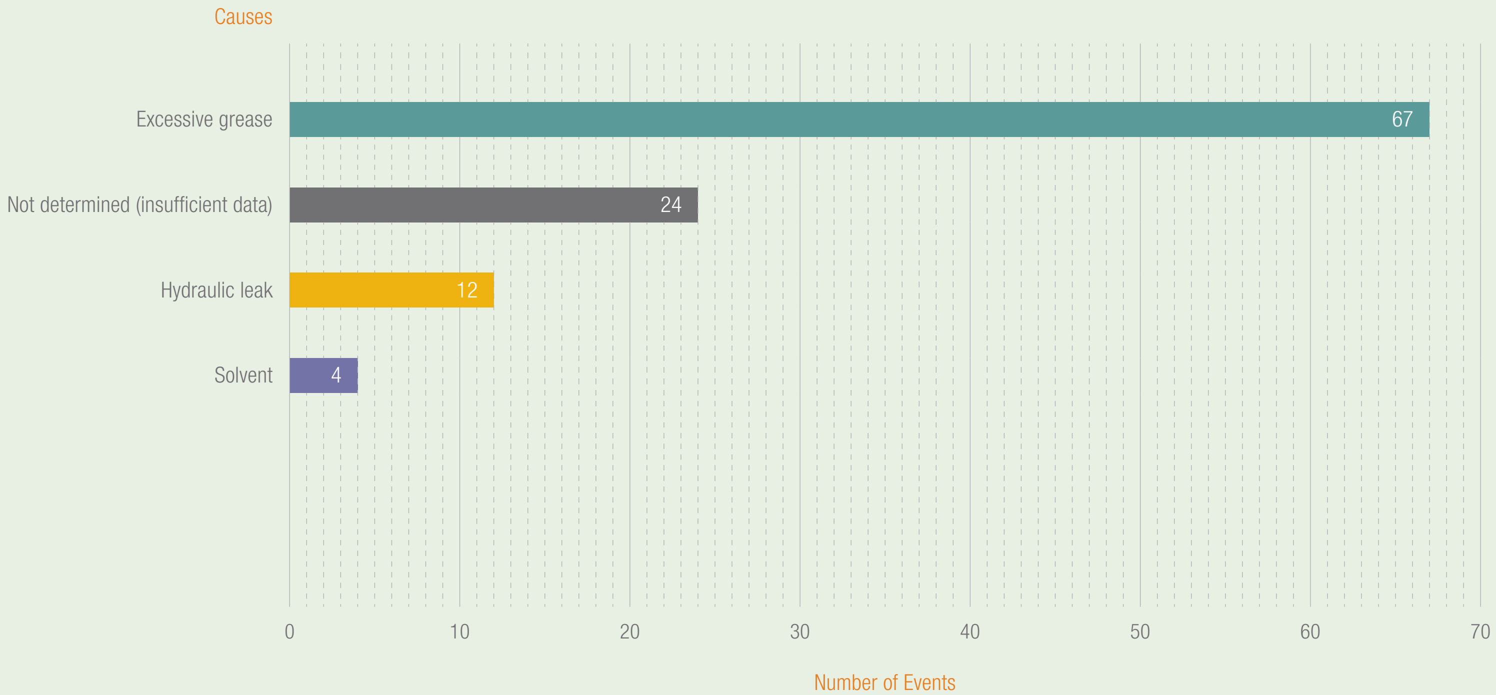
Wheel/brake-area fires are occasionally reported following normal operating brake temperature condition landings (see fig. 1). The cause of the fires can usually be attributed to the ignition of excessive grease that has accumulated on the axle in the brake assembly cavity (see fig. 2). In addition, some wheel heat shields can retain residual cleaning fluids after being saturated with flammable solvents during maintenance. Wheel/brake-area fires have also been reported due to ignition of hydraulic fluid associated with leaks or hydraulic system maintenance (see fig. 3). While these fires generally do not cause major damage to the airplane or endanger passengers and crew, they can prompt evacuations that can lead to injuries, temporarily take the airplane out of service, and result in costly repairs. Yet most wheel/brake-area fires can be avoided by following some simple procedures:

- Clean all grease from the axle before reinstalling the wheel and/or brake assembly.
- Use only approved greases in small quantities at the points where the wheel and brake will contact the axle.
- Follow wheel supplier Component Maintenance Manual (CMM) cautions regarding the use of flammable cleaners on wheel heat shields, including not using dunk tanks on “sealed” heat shields.

ALTHOUGH THESE FIRES DON'T CAUSE MAJOR DAMAGE, THEY CAN LEAD TO DELAYS, ADDED MAINTENANCE COSTS, AND EVACUATIONS.

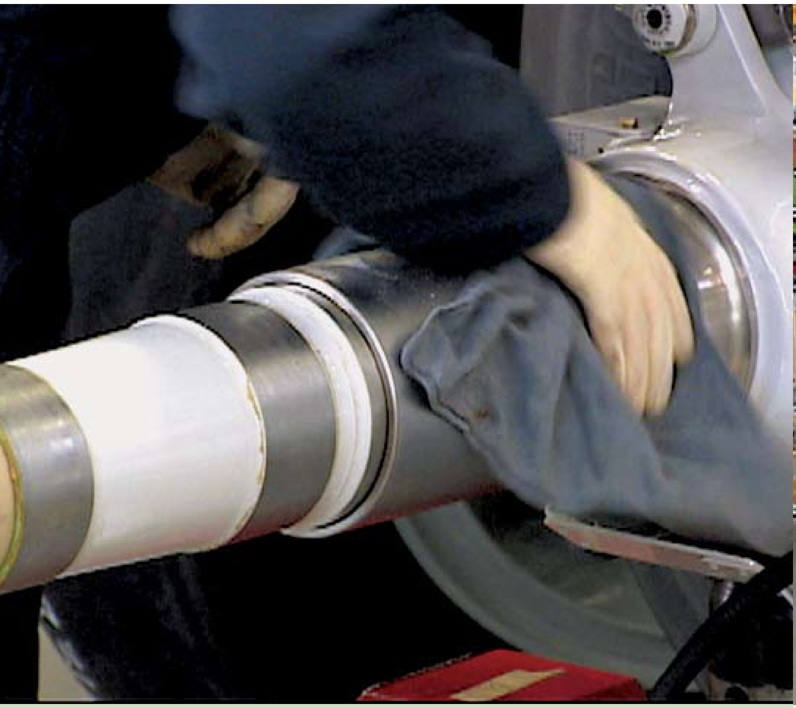
BRAKE-AREA FIRE EVENTS SINCE 1996 (EXCLUDING DRAGGING BRAKES, BRAKE MISASSEMBLY, OR WHEEL BEARING SEIZURES)

Figure 1



REMOVED BRAKE FOLLOWING FIRE FROM EXCESSIVE AMOUNT OF GREASE
Figure 2

REMOVED BRAKE FOLLOWING FIRE FROM HYDRAULIC FLUID LEAK
Figure 3



ESSENTIAL STEP: EXISTING (OLD) GREASE BEING REMOVED
Figure 4

THIN LAYER OF GREASE BEING APPLIED TO BRAKE/AXLE SLEEVES
Figure 5

WHAT CAUSES WHEEL/BRAKE-AREA FIRES

Wheel/brake-area fires are typically caused by a buildup of grease on the axle during service or the application of excessive amounts of grease during wheel/tire changes and brake installations, and the presence of a heat source, namely the brakes. During brake lubrication, excessive grease can also collect in the cavity between the piston housing and torque tube pedestal bushing due to a damaged or missing grease seal or excessive lubrication through the brake piston housing axle bushing lubrication fitting.

Wheel/brake-area fires have also been linked to cleaning fluids retained in the heat shield. Some heat shield designs can absorb cleaning solvents, causing the shield to become saturated with flammable cleaning fluids if they are sprayed or immersed during cleaning.

During normal braking on landing, the temperatures in the main landing gear wheel/brake area can cause grease and residual cleaning fluids in these areas to ignite. Carbon brakes normally operate at slightly higher temperatures than steel brakes, which explains why nearly all reports are associated with carbon brakes. These types of wheel/brake-area fires usually occur within the first few cycles following a wheel or brake change, or following lubrication of the piston-housing grease fitting when a grease seal is damaged or missing. Fires due to leaking hydraulic system components can occur immediately following fluid spillage onto a hot brake.

PREVENTING WHEEL/BRAKE-AREA FIRES

Because their cause is well known, wheel/brake-area fires can be prevented by following proper maintenance procedures. These include:

- Cleaning existing grease from the axle. When removing or installing wheels and brakes, it is essential to remove old grease from the axle (see fig. 4). Because cleaning fluids and solvents can damage carbon brakes and titanium components, a dry rag must be used to remove the grease.
- Removing old grease from the axle every time wheels and brakes are installed or removed.
- Using only approved greases in small quantities. While it is important to have adequate lubrication within the wheel bearings, only a thin layer of grease is necessary at the wheel/axle interface for wheel/tire installations. Similarly, only a thin layer of grease needs to be applied to the interface surfaces of the brake and axle sleeves when installing brakes (see fig. 5). When applying grease to the axle bushings on the brake assembly, it is important to completely fill the grooves in the bushings with grease.
- Being certain that the brake axle bushing grease seal (on airplanes that have them) is not damaged before installing brakes and that the grease seal is properly installed per the applicable Airplane Maintenance Manual (AMM) or CMM instructions.
- Following wheel supplier CMM cautions when cleaning wheel heat shields. The main wheel heat shield must be cleaned by following the manufacturer's recommended maintenance procedures in the appropriate supplier CMM. Spraying or immersing certain heat-shield designs in cleaning fluids can trap residual fluids within the shield, which can lead to a subsequent fire. The wheel heat shields should be removed according to the supplier CMM during wheel-cleaning operations.

ADDITIONAL INFORMATION

The recommendations in this article are provided in addition to the standard AMM statements to use only approved "wheel bearing" greases and not apply excessive amounts of grease during main gear wheel and brake installations. This information can be found in AMM chapters 12 and 32. The specific wheel and brake component cleaning maintenance practices can be found in the applicable supplier CMM.

Boeing also updated a Maintenance Tip in July 2006 titled "Main Landing Gear Wheel/Brake-Area Fires" that addresses this issue (707 MT 32-002 R1, 727 MT 32-002 R1, 737 MT 32-010 R1, 747 MT 32-045 R1, 747-400 MT 32-022 R1, 757 MT 32-016 R1, 767 MT 32-026 R1, 777 MT 32-021 R1).

TRAINING AID

Boeing has developed a training aid to help maintenance personnel visualize and understand proper wheel and axle greasing and cleaning techniques. This aid is a 12-minute digital video disc (DVD) titled "Main Landing Gear Wheel/Brake Area Fire Prevention: Maintenance Tips." Boeing recommends showing this DVD to engineering and maintenance personnel associated with landing gear duties during crew meetings. This DVD (VPS48559) is available from Boeing Data and Services Management at csd.boecom@boeing.com.

SUMMARY

Wheel/brake-area fires, while usually not serious themselves, can result in minor airplane damage, possible injuries to crew members and passengers when evacuating an airplane, and flight delays. Most wheel/brake-area fires, however, can be avoided simply by following proper maintenance procedures for cleaning and greasing components. For more information, please contact Brian Webber at brian.k.webber@boeing.com

Fuel Conservation Strategies: Cost Index Explained

Used appropriately, the cost index (CI) feature of the flight management computer (FMC) can help airlines significantly reduce operating costs. However, many operators don't take full advantage of this powerful tool.

by Bill Roberson,
Senior Safety Pilot, Flight Operations

This article is the first in a series exploring fuel conservation strategies.

VARIABLE FUEL PRICES, FUEL TANKERING, AND FUEL HEDGING MAKE THE COST INDEX CALCULATION COMPLICATED.

COST INDEX DEFINED

The CI is the ratio of the time-related cost of an airplane operation and the cost of fuel. The value of the CI reflects the relative effects of fuel cost on overall trip cost as compared to time-related direct operating costs.

In equation form:
$$\text{CI} = \frac{\text{Time cost} \sim \$/\text{hr}}{\text{Fuel cost} \sim \text{cents/lb}}$$

The range of allowable cost indices is shown in Figure 1. The flight crew enters the company-calculated CI into the control display unit (CDU) of the FMC. The FMC then uses this number and other performance parameters to calculate economy (ECON) climb, cruise, and descent speeds.

For all models, entering zero for the CI results in maximum range airspeed and minimum trip fuel. This speed schedule ignores the cost of time.

Conversely, if the maximum value for CI is entered, the FMC uses a minimum time speed schedule. This speed schedule calls for maximum flight envelope speeds, and ignores the cost of fuel (see fig. 2).

THE RANGE OF ALLOWABLE COST INDICES FOR GIVEN BOEING AIRPLANES

Figure 1

Airplane Model	737-300 737-400 737-500	737-600 737-700 737-800 737-900	747-400	757	767	777
Cost Index Range	0-200	0-500	0-9999	0-999 or 0-9999	0-999 or 0-9999	0-9999

COMPARING RESULTS FOR COST INDEX VALUES OF ZERO AND MAXIMUM

Figure 2

	CLIMB	CRUISE	DESCENT
Cost Index 0	Minimum Fuel*	Maximum Range	Max L/D
Cost Index Max	VMO/MMO	VMO/MMO	VMO/MMO

Entering zero for the cost index results in maximum range airspeed and minimum trip fuel. Entering the maximum value for cost index results in a minimum time speed schedule.

* *Minimum climb contribution to trip fuel; this is different from minimum fuel to cruise altitude.*

CALCULATED VALUES FOR A TYPICAL 757 FLIGHT

Figure 3

	CLIMB	CRUISE	DESCENT	ALTITUDE RECOMMENDATIONS
Cost Index 0	290/.778	.778	250	OPT 328, MAX 362, RECMD 310
Cost Index 9999	345/.847	.847	.819/334	OPT 268, MAX 268, RECMD 260
Cost Index 70	312/.794	.794	.80/313	OPT 327, MAX 363, RECMD 310

COST INDEX IMPACT

Figure 4

FLEET	CURRENT COST INDEX	OPTIMUM COST INDEX	TIME IMPACT MINUTES	ANNUAL COST SAVINGS ($000's)
737-400	30	12	+1	US$754 – $771
737-700	45	12	+3	US$1,790 – $1,971
MD-80	40	22	+2	US$319 – $431

COST INDEX USAGE

In practice, neither of the extreme CI values is used; instead, many operators use values based on their specific cost structure, modified if necessary for individual route requirements. As a result, CI will typically vary among models, and may also vary for individual routes.

Clearly, a low CI should be used when fuel costs are high compared to other operating costs. The FMC calculates coordinated ECON climb (see fig. 5), cruise, and descent speeds (see fig. 6) from the entered CI. To comply with Air Traffic Control requirements, the airspeed used during descent tends to be the most restricted of the three flight phases. The descent may be planned at ECON Mach/Calibrated Air Speed (CAS) (based on the CI) or a manually entered Mach/CAS. Vertical Navigation (VNAV) limits the maximum target speed as follows:

- 737-300/-400/-500/-600/-700/-800/-900: The maximum airspeed is velocity maximum operating/Mach maximum operating (VMO/MMO) (340 CAS/.82 Mach). The FMC-generated speed targets are limited to 330 CAS in descent to provide margins to VMO. The VMO value of 340 CAS may be entered by the pilot to eliminate this margin.
- 747-400: 349 knots (VMO/MMO minus 16 knots) or a pilot-entered speed greater than 354 knots (VMO/MMO minus 11 knots).
- 757: 334 knots (VMO/MMO minus 16 knots) or a pilot-entered speed greater than 339 knots (VMO/MMO minus 11 knots).
- 767: 344 knots (VMO/MMO minus 16 knots) or a pilot-entered speed greater than 349 knots (VMO/MMO minus 11 knots).
- 777: 314 knots (VMO/MMO minus 16 knots) or a pilot-entered speed greater than 319 knots (VMO/MMO minus 11 knots).

FMCs also limit target speeds appropriately for initial buffet and limit thrust.

Figure 3 illustrates the values for a typical 757 flight.

FACTORS AFFECTING COST INDEX

As stated earlier, entering a CI of zero in the FMC and flying that profile would result in a minimum fuel flight and entering a maximum CI in the FMC and flying that profile would result in a minimum time flight. However, in practice, the CI used by an operator for a particular flight falls within these two extremes. Factors affecting the CI include time-related direct operating costs and fuel costs.

TIME COST

The numerator of the CI is often called time-related direct operating cost (minus the cost of fuel). Items such as flight crew wages can have an hourly cost associated with them, or they may be a fixed cost and have no variation with flying time. Engines, auxiliary power units, and airplanes can be leased by the hour or owned, and maintenance costs can be accounted for on airplanes by the hour, by the calendar, or by cycles. As a result, each of these items may have a direct hourly cost or a fixed cost over a calendar period with limited or no correlation to flying time.

In the case of high direct time costs, the airline may choose to use a larger CI to minimize time and thus cost. In the case where most costs are fixed, the CI is potentially very low because the airline is primarily trying to minimize fuel cost. Pilots can easily understand minimizing fuel consumption, but it is more difficult to understand minimizing cost when something other than fuel dominates.

FUEL COST

The cost of fuel is the denominator of the CI ratio. Although this seems straightforward, issues such as highly variable fuel prices among the operating locations, fuel tankering, and fuel hedging can make this calculation complicated.

A recent evaluation at an airline yielded some very interesting results, some of which are summarized in Figure 4. A rigorous study was made of the optimal CI for the 737 and MD-80 fleets for this particular operator. The optimal CI was determined to be 12 for all 737 models, and 22 for the MD-80. The table (see fig. 4) shows the impact on trip time and potential savings over the course of a year of changing the CI for a typical 1,000-mile trip. The potential annual savings to the airline of changing the CI is between US$4 million and $5 million a year with a negligible effect on schedule.

SUMMARY

CI can be an extremely useful way to manage operating costs. Because CI is a function of both fuel and nonfuel costs, it is important to use it appropriately to gain the greatest benefit. Appropriate use varies with each airline, and perhaps for each flight. Boeing Flight Operations Engineering assists airlines' flight operations departments in computing an accurate CI that will enable them to minimize costs on their routes. For more information, please contact FlightOps.Engineering@boeing.com.

THE EFFECT OF COST INDEX WHEN CLIMBING TO CRUISE ALTITUDE
Figure 5

A cost index of zero minimizes fuel to climb and cruise to a common point in space.

THE EFFECT OF COST INDEX WHEN DESCENDING
Figure 6

A cost index of zero minimizes fuel between a common cruise point and a common end of descent point.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