

A QUARTERLY PUBLICATION
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THE BOEING EDGE

Boeing 787-9
Takes Flight

**Estimating
Maintenance
Reserves**

Safe Transport of
Lithium Batteries
as Air Cargo

747-8 Performance
Improvement
Package to
Enhance Efficiency

Avoiding Tail
Strikes

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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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The second member of the game-changing 787 family made its inaugural flight Sept. 17, 2013.

Boeing 787-9 Takes Flight

Fewer than two years after delivering the first 787, we have launched a comprehensive flight-test program for the second member of the Dreamliner family: the 787-9. The airplane, which extends the efficiencies and innovations of this game-changing line, recently completed its first flight as it progresses toward certification and delivery in mid-2014.

That inaugural flight marked a significant milestone for our team. As veteran 787 Capts. Mike Bryan and Randy Neville said, it was a “no-squawk” flight of more than five hours, accomplishing the testing we set out to do. And, as promised that day, the 787-9 flew its second flight just two days later.

Since then, the 787-9 test program continues to advance on all fronts. The first airplane has demonstrated initial airworthiness and continues to fly regularly. The second entered the test program in late September, and the third and fourth airplanes also are progressing well. We’re pleased with the performance of the test fleet and our test progress, which reflect our preparation and focus throughout development of the 787-9. We look forward to delivering the first 787-9 to our launch customer Air New Zealand in the middle of next year.

The 787-9 will complement and extend the 787 family, offering airlines more seats, cargo capacity, and range, and the ability

to grow routes first opened with the 787-8 — with the same passenger-pleasing features and exceptional environmental performance. And the family will soon grow again, with the 787-10 targeted for delivery in 2018.

We are committed to developing and delivering the super-efficient, passenger-preferred airplanes you need to continue your success.

MARK JENKS

Vice President, 787 Development
Boeing Commercial Airplanes



Boeing's economic modeling tool provides lessors and lessees with accurate and credible cost estimates.

Estimating Maintenance Reserves

The negotiation of maintenance reserves is very important to the business plans of both the airplane lessor and the lessee. Accurately estimating maintenance reserves requires knowledge of historic maintenance costs and an ability to project future maintenance requirements, based on the age and type of airplane being leased.

By **David Schulte**, Regional Director, Airline Economic Analysis

Currently, nearly 40 percent of the world's commercial airplane fleet is under a lease agreement, and the number of leased airplanes is expected to exceed 50 percent during the next 20 years. Maintaining an airplane to high levels of safety while retaining high long-term asset value is the objective of both lessors (i.e., airplane owners) and lessees (i.e., airplane operators). Maintenance reserves are funds negotiated between the lessor and the lessee to cover the cumulative allocated usage of a regular maintenance event. The allocated usage or consumed maintenance

is often referred to as the maintenance utility of the airplane. Maintenance reserves protect the asset value by ensuring funds are available in the event of a lease default. Maintenance reserves are also often viewed by airlines as a means to mitigate risk by ensuring available funds for major events. Irregular or out-of-schedule events are not planned, and, therefore, reserves do not cover such events and are not collected.

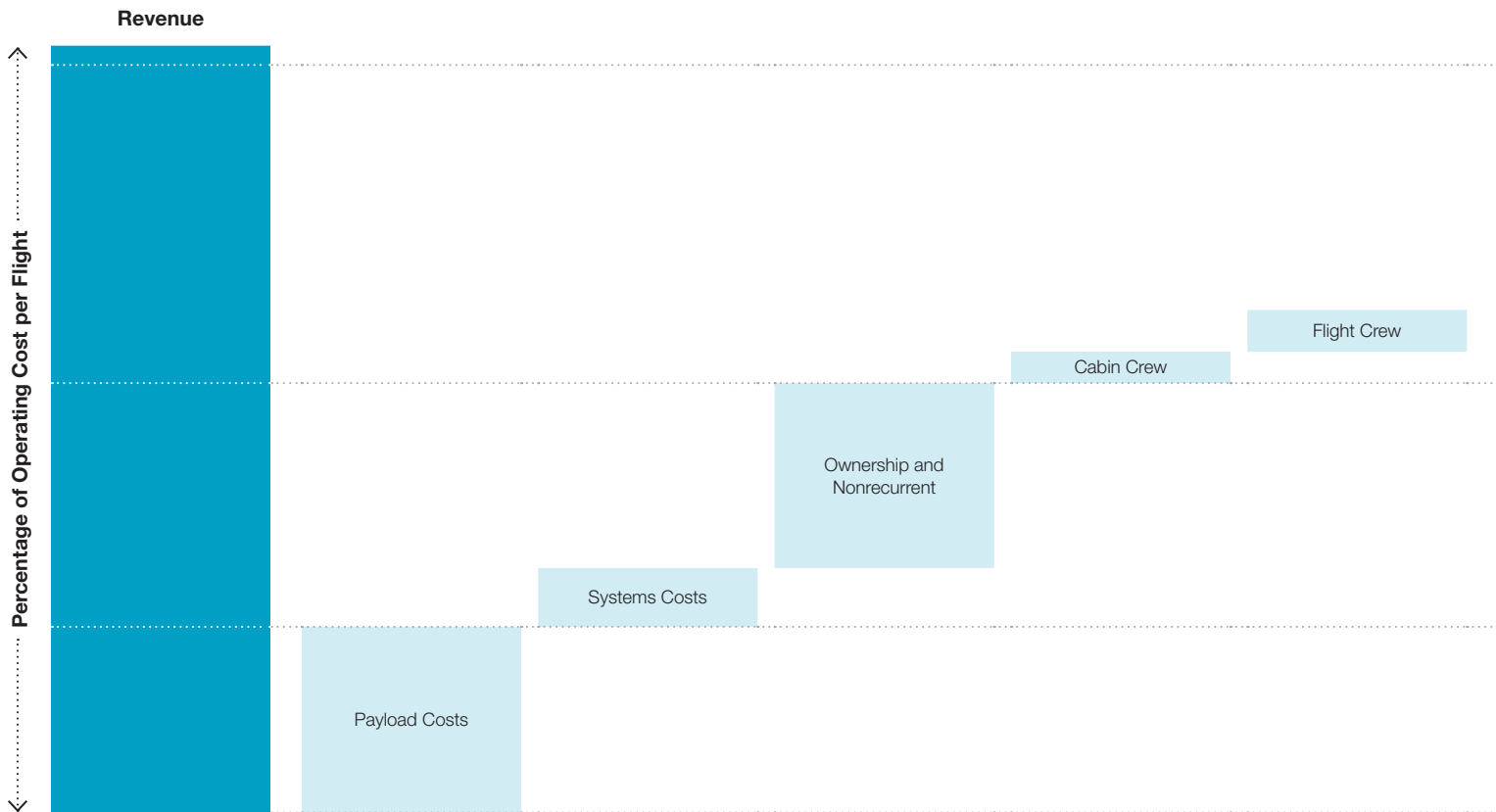
This article describes how Boeing models and estimates maintenance event costs to assist lessors and lessees at the early stages of negotiations.

NEGOTIATING MAINTENANCE RESERVES

Maintenance reserves are payments a lessee makes to a lessor toward the cost of major maintenance, such as airframe heavy structural inspections, landing gear overhauls, auxiliary power unit (APU) restoration, engine performance restoration, engine life limited parts, or other high-value items. Line maintenance, A-Checks, wheels, tires, brakes, and other components are typically not included in a

Figure 1: ICAS is a comprehensive operating cost model

Boeing's approach to estimating maintenance costs quantifies key economic items, such as cash airplane-related operating costs (CAROC) (or direct operating costs) and airplane-related operating costs (AROC).



reserve rate. Items not typically reserved are expected to be performed and paid for by the operator. When the appropriate amount of maintenance reserves has been established, the fund should be able to pay for major maintenance when it is required or when reimbursement is requested.

The negotiation of maintenance reserves is very important to the business plans of the airplane lessor and the lessee. The lessee typically wants to pay no more than is needed in order to conserve cash for regular operations, while the lessor often views maintenance reserves as a means of protecting the value of its asset. Having a

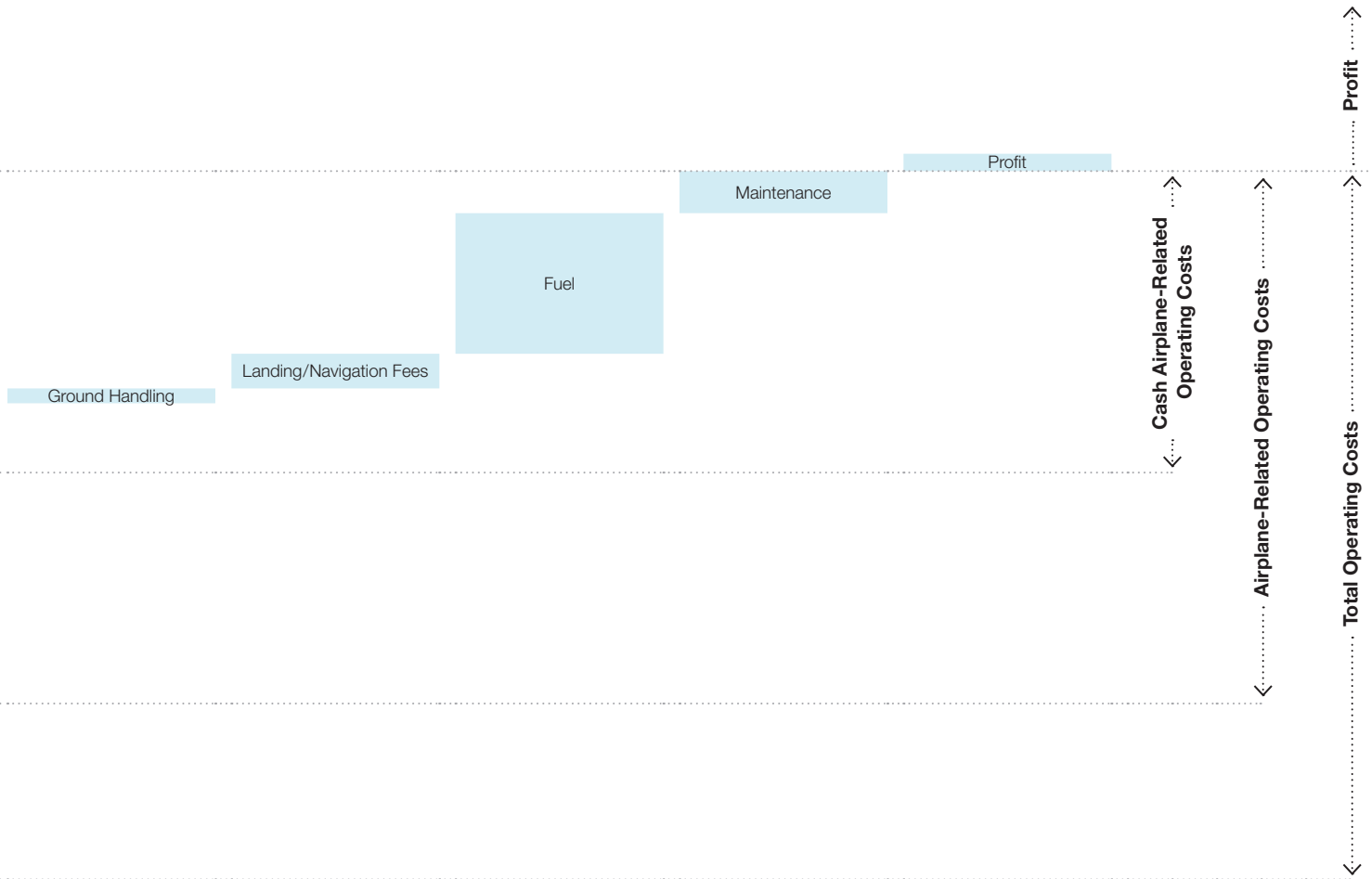
dedicated expert at each airline assigned to manage the contract and negotiate the reserve rates is essential.

Because the amount of maintenance reserves needed in a given situation is tied closely to expected maintenance costs, Boeing provides maintenance cost estimates to support the negotiations of maintenance reserves, but it does not provide estimates for reserve rates due to the highly variable effects of negotiations. The data provided to lessors and lessees is called Boeing Cost Estimates for Leasing. Boeing's maintenance cost estimates are based on a new event-based modeling approach that replaces

the traditional "mature airplane" approach with a life-cycle average.

HOW BOEING ESTIMATES MAINTENANCE COSTS

Boeing uses a comprehensive approach that quantifies all key economic items to estimate maintenance costs (see fig. 1). Boeing has developed a detailed cost methodology for each economic item that is linked to historical industry costs and can be modified to match an airline's cost structure.



The Aircraft Economic Handbook

Boeing has produced the first edition of *The Aircraft Economic Handbook*. This book was assembled to empower lessors, appraisers, and operators with a transparent approach to the Boeing view of airplane economics. Included in the handbook are cash airplane-related operating costs estimates, fuel use comparison charts, and estimated maintenance event costs for various airplanes. Also included is a section highlighting some continuous improvements to the Next-Generation 737 product line.

Cost estimates will vary between specific airline operator ground rules and assumptions; however, cost data provided to all interested parties are derived from the same source. Costs are estimated using Boeing's new Integrated Cost Analysis System (ICAS) economic modeling tool; industry acceptance has proven accurate, real-world cost estimates.

Figure 2: Boeing's maintenance cost analysis

Maintenance cost can be derived based on many accounting practices; estimates and invoices are subject to inclusions. Below is a list of what is included and excluded in the Boeing cost modeling tool.

INCLUDES
All routine and associated nonroutine maintenance tasks (scheduled and unscheduled).
Direct labor and material.
Noncapitalized airworthiness directives, service bulletins up to \$100,000.*
Interior refurbishment and upkeep.
Airplane touch-up painting.
Airline unique tasks (non-maintenance planning document [MPD] tasks).
Line maintenance, minor and major checks, airframe and engine maintenance (MPD tasks).
Component repair and overhead costs (e.g., wheels, tires, brakes, auxiliary power units, landing gear, plus all other components).
Labor-burdened costs or technical department overhead.
EXCLUDES
Capitalized modifications (e.g., interior upgrades, livery changes, performance modifications, life enhancement modifications, major modifications).

* U.S. dollars

Maintenance costs are broken down into airframe and engine costs.

- **Airframe** maintenance cost estimates are based on discrete event cost data and align closely with industry sources.
- **Engine** maintenance costs are based on original equipment manufacturer shop-visit costs. The manufacturer also provides a severity curve, which helps to predict when the engine overhaul will need to occur based on how the engine is utilized. By analyzing the shop visit and severity curve costs provided,

Boeing can estimate when the event will occur and how much it will cost.

In addition to items typically reserved, Boeing's maintenance cost analysis includes virtually every type of maintenance expense except capitalized modifications (see fig. 2).

MODELING TOOL OFFERS INCREASED ACCURACY

Boeing has developed a comprehensive economic modeling tool called the Integrated Cost Analysis System (ICAS).

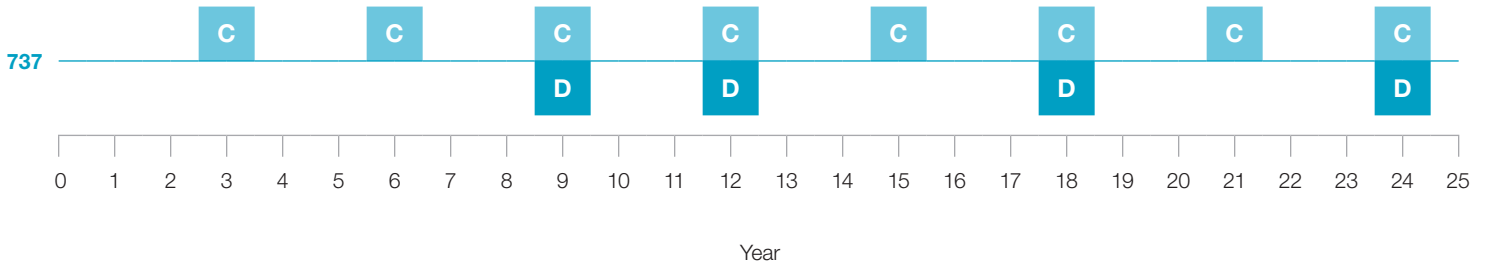
ICAS offers a number of features designed to provide lessors and lessees with accurate, credible, reality-based cost estimates. These features include:

- **Event-based costs.** ICAS allows Boeing to model costs on a maintenance event basis, which can predict when an event is going to occur and how much that event is going to cost.
- **Costs occur as airplane utilization drives maintenance events.** Tasks or groups of tasks defining traditional maintenance checks and component overhauls often have any combination of calendar, flight

Figure 3: Next-Generation 737 scheduled maintenance cost estimates example

Boeing provides maintenance cost estimates for any airplane model and uses the same analysis techniques to estimate any competitive model. The Next-Generation 737 now has more than 12 years in-service experience allowing for the optimization of task intervals, grouping like tasks in three-year increments. Assuming typical labor rates, event costs are predicted.

737 Scheduled Maintenance Cost Estimates



Forecasted Event Cost and Labor Hours

	25-Year Average Event Cost*	25-Year Average Labor Hours
Average C-Check (including lesser checks)	\$222,000 ~ \$272,000	2,968
Average D-Check	\$426,000 ~ \$476,000	5,026
Average Total	\$648,000 ~ \$748,000	7,994

* U.S. dollars

hour, or flight cycle limiters. Using specified utilization, ICAS can predict the timing of a maintenance event based on any of these constraints.

- **Each maintenance event type ages at its own rate.** Each maintenance event — from A-Checks to brake overhauls — ages differently. For example, wheels and tires require frequent overhauls, so they are expected to age at a very low rate (i.e., overhaul occurs at short intervals, minimizing

aging effects), in contrast to a heavy maintenance visit occurring every 12 years that will age more significantly over the long interval.

- **Lifecycle costs based on selected study period.** Because ICAS models the magnitude and timing of each maintenance event, it provides the capability to analyze cash flows for up to 50 years, or any age bracket within that period.

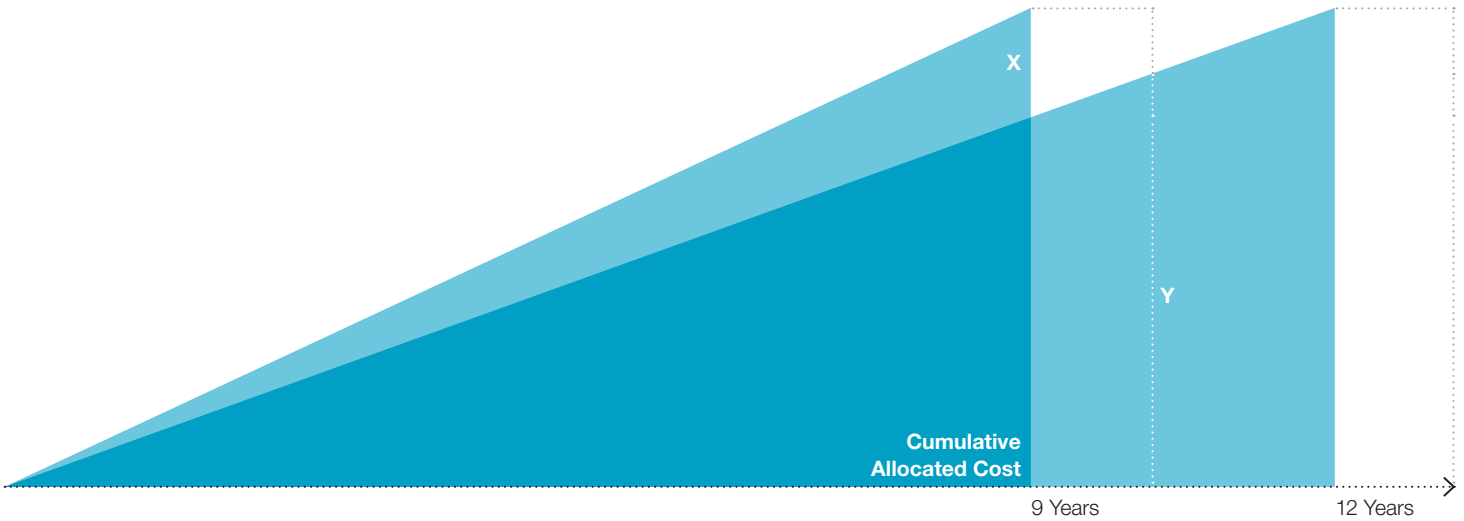
- **Higher levels of customization and data control.** The real-life cost data that comprises the ICAS databases can be customized to high levels of detail to accurately represent the real costs of an airline, leasing company, or other entity interested in maintaining a commercial airplane.

ICAS uses a wider spectrum of maintenance data than has been previously available. In addition to publicly available

Figure 4: Allocation of costs

Maintenance reserves are typically the sum of maintenance cost plus risk. Below is an example showing how to estimate the allocated maintenance cost portion of a reserve rate. Assuming a 12-year lease term on a Next-Generation 737, a fund for two heavy maintenance visits may be created: the nine-year heavy and the 12-year heavy. Each maintenance task has its own interval or threshold; however, common grouping of major tasks aligns at the nine-year and 12-year maintenance visits. Because the two groups of tasks are unique events, both costs can be amortized to year zero, allowing for the operator and lessor to establish an accurate fund on a monthly basis.

Typical Allocation of Costs for a 12-Year Next-Generation 737 Lease Agreement



	Average Event Cost	X (Allocation)	+	Y (Allocation)	=	Estimated Rate
Average Total*	\$648,000 ~ \$748,000	\$6,000 ~ \$6,900/Month	+	\$4,500 ~ \$5,200/Month	=	\$10,500 ~ \$12,100/Month

* U.S. dollars

sources that Boeing has used for decades — such as air carrier financial reports (e.g., U.S. Department of Transportation [DOT] Form 41 and International Air Transport Association [IATA] Maintenance Cost Task Force) — ICAS incorporates information from a number of other sources. For example, the airplane Maintenance Planning Document is used to model maintenance intervals. Operator-reported data enables the model to gauge fleet average on-condition maintenance perfor-

mance for components such as APUs or brakes. Additional reliability information is drawn from Boeing’s In-Service Data Program (see *AERO* first-quarter 2008).

Boeing is constantly benchmarking to various industry sources. Significant time and resources are used in the field to compare cost estimates across all parts of the industry, including owners, operators, maintenance facilities, conferences, publications, and any other format of sharing and gathering actual feedback. Boeing also

receives cost data from customers through other channels, such as Boeing’s Technical Operations Performance Improvement and Cost Solutions conferences (see *AERO* second-quarter 2010). Any nonpublic cost data is amalgamated and used on an anonymous basis. In addition, many other industry sources are used to benchmark Boeing cost estimates.

Finally, Boeing utilizes studies performed by industry consultants and published in journals and magazines.

Figure 5: Average performance restoration cost estimate

In coordination with its suppliers, Boeing can provide restoration cost estimates for individual major airplane components, which can then be factored into maintenance cost reserves. Actual costs vary with ground rules, including labor rates, utilization, and efficiencies, to name a few.

Example of Average Performance Restoration Cost Estimate

737-800 CFM56-7B26E

Time Between Overhaul	Assumed Derate	10%
	Average Flight Length	2 Hours
	Average Shop Visit (SV) Rate (1,000/SV)	0.0429
	Interval (Flight Hours)	23,300
Average Shop Visit Cost (\$/Engine)		\$2.2 Million ~ \$2.3 Million*

* U.S. dollars

MAINTENANCE COST ESTIMATES FOR LEASING

Once maintenance costs have been estimated, Boeing provides the same perspective on costs to lessors and lessees. Cost estimates will vary, however, based on ground rules, including assumed labor rates, efficiencies, and airplane utilization rates, to name a few. Boeing provides cost estimates; the lessors and lessees negotiate the actual reserves. This allows for a single starting point for maintenance reserve discussions.

Maintenance cost estimates include forecasted labor hours and average event costs (see fig. 3), which are then extrapolated into cumulative allocated costs for a given lease period (see fig. 4). Boeing, in coordination with its suppliers, also provides detailed maintenance cost estimates for airplane components such as engines, landing gear, and APUs (see fig. 5).

Cost estimates can be customized by airplane model and projected usage (such as short-haul or long-haul flights) and are provided with any amount of detail required by the specific lease transaction.

Alternatives to Maintenance Reserves

For an operator, the benefits of paying into a reserve rate may include having funds available for events as they come due. Some operators may prefer this as a risk management measure. However, maintenance reserves are not the only option. Because maintenance reserves are negotiated terms, other alternatives exist, including an agreed return condition, letter of credit, or a power-by-the-hour agreement.

Trends within the industry seem to point toward higher occurrences of these alternatives to maintenance reserves, when appropriate. From both the lessor and the lessee perspective, managing the maintenance reserves of each asset can be costly and time consuming. Therefore, it is recommended to have a dedicated expert overseeing negotiations, managing reserves, and monitoring maintenance activity.

SUMMARY

Maintenance reserve rates are negotiated and can be a complex process. Estimating maintenance reserves correctly requires accurate and up-to-date maintenance cost estimates and projections, which reflect real-life average or budgetary costs. Boeing's ICAS tool is designed to provide lessors and lessees with accurate, credible, reality-based cost estimates.

For more information, contact AERO_maintenance@exchange.boeing.com. [A](#)



Operators can reduce risks by understanding and adhering to current regulations governing the air transport of lithium batteries.

Safe Transport of Lithium Batteries as Air Cargo

Operators that transport lithium batteries as cargo need to be aware of current regulations to ensure their shipments are compliant.

By Darrin Noe, Technical Lead Engineer, Cargo Systems Engineering

The last several years have seen changes in regulations pertaining to transporting lithium batteries as hazardous-material cargo in freighter and passenger airplanes. Operators need to understand current regulations governing the air transport of lithium batteries and understand how to implement industry best practices for their safe transport as air cargo.

This article provides an overview of lithium batteries, outlines causes of battery failures and concerns about shipping lithium batteries as cargo, describes recent aviation-related lithium battery incidents, reviews recent changes to the regulations, and shares industry best practices applicable to the safe transport of lithium batteries as Class 9 Miscellaneous Dangerous Goods aboard airplanes. This classification is one of nine

hazard classes established by the United Nations to categorize the type of hazard associated with a particular substance or material.

LITHIUM BATTERY OVERVIEW

The term “lithium battery” refers to a family of batteries having anodes, cathodes, or electrolytes that contain either metallic lithium or a lithium compound. Lithium batteries are generally divided into two categories.

Lithium-metal (primary) batteries are non-rechargeable. They feature higher energy density than other older nonrechargeable battery chemistries and are frequently used to power cameras, watches, and medical devices, including implantable devices.

Lithium-ion (secondary) batteries are rechargeable. They feature a relatively high energy density and a relatively slow loss of charge when not in use. Lithium-ion batteries are frequently used in consumer electronics, such as mobile telephones and laptop computers. Included within the lithium-ion battery category are lithium-polymer (Li-Po) batteries, sometimes referred to as “pouch cells.”

CAUSES OF ENERGETIC LITHIUM BATTERY FAILURES

Thermal runaway is failure of a lithium-type cell characterized by a rapid self-heating of the cell due to an exothermic chemical

Figure 1: Aviation-related lithium battery incidents by year

Most aviation-related lithium battery incidents have occurred during the last nine years.

reaction of the highly oxidizing positive electrodes and the highly reducing negative electrode. Thermal runaway can result in an energetic failure of the cell (i.e., fire and/or explosion).

Thermal runaway can occur for a number of reasons, including:

- Poor cell design (e.g., electrochemical or mechanical).
- Cell manufacturing flaws.
- External abuse of cells (e.g., thermal, mechanical, or electrical).
- Poor battery-pack design or application.
- Poor protection electronics design or manufacture.
- Poor charger/system design or manufacture resulting in overcharging of the battery.

CONCERN ABOUT SHIPPING LITHIUM BATTERIES AS CARGO

Driven by growth in the demand for consumer and industrial goods powered by lithium batteries, the size and frequency of lithium battery air cargo shipments

continues to increase. Concern about lithium battery cargo fires has led the U.S. Federal Aviation Administration (FAA) to conduct battery fire tests. Key findings from this testing include:

- A relatively small fire source can ignite lithium-ion or lithium-metal cells.
- Fire from one cell will ignite adjacent cells in a bulk shipment of batteries.
- Energetic failure of lithium cells often creates a pressure pulse (i.e., small explosion) that may damage fire-resistant cargo-compartment liners and/or compromise their decompression features.
- Halon fire suppressant is effective on lithium-ion electrolyte fires, but it will not prevent the propagation of thermal runaway through bulk shipments of batteries.
- Halon does not suppress lithium-metal battery fires.
- Failed lithium-metal batteries can eject molten lithium, which may damage cargo-compartment liners.
- Metal pails and drums used for packaging other dangerous goods as recommended by the International

Civil Aviation Organization (ICAO) are not effective in controlling lithium-metal cell fires but are effective in containing lithium-ion cell fires.

- Containers designed to ship oxygen generators can contain a 100-cell lithium-ion cell fire.

AVIATION-RELATED LITHIUM BATTERY INCIDENTS

During the period of March 1991 to July 2013, 135 air incidents involving batteries were recorded by the FAA. In 64 of these incidents, lithium batteries were directly involved, resulting in smoke, fire, extreme heat, or explosion. Two of these 64 incidents were the direct result of mishandling of the package containing the lithium batteries and would not have been presented for transport; thus, these two incidents were not considered in the following evaluation.

Sorting the remaining 62 incidents by year of occurrence shows an increase in incidents starting in the early 2000s (see fig. 1).

Mar. 20, 1991, to July 23, 2013
62 Lithium Battery Incidents

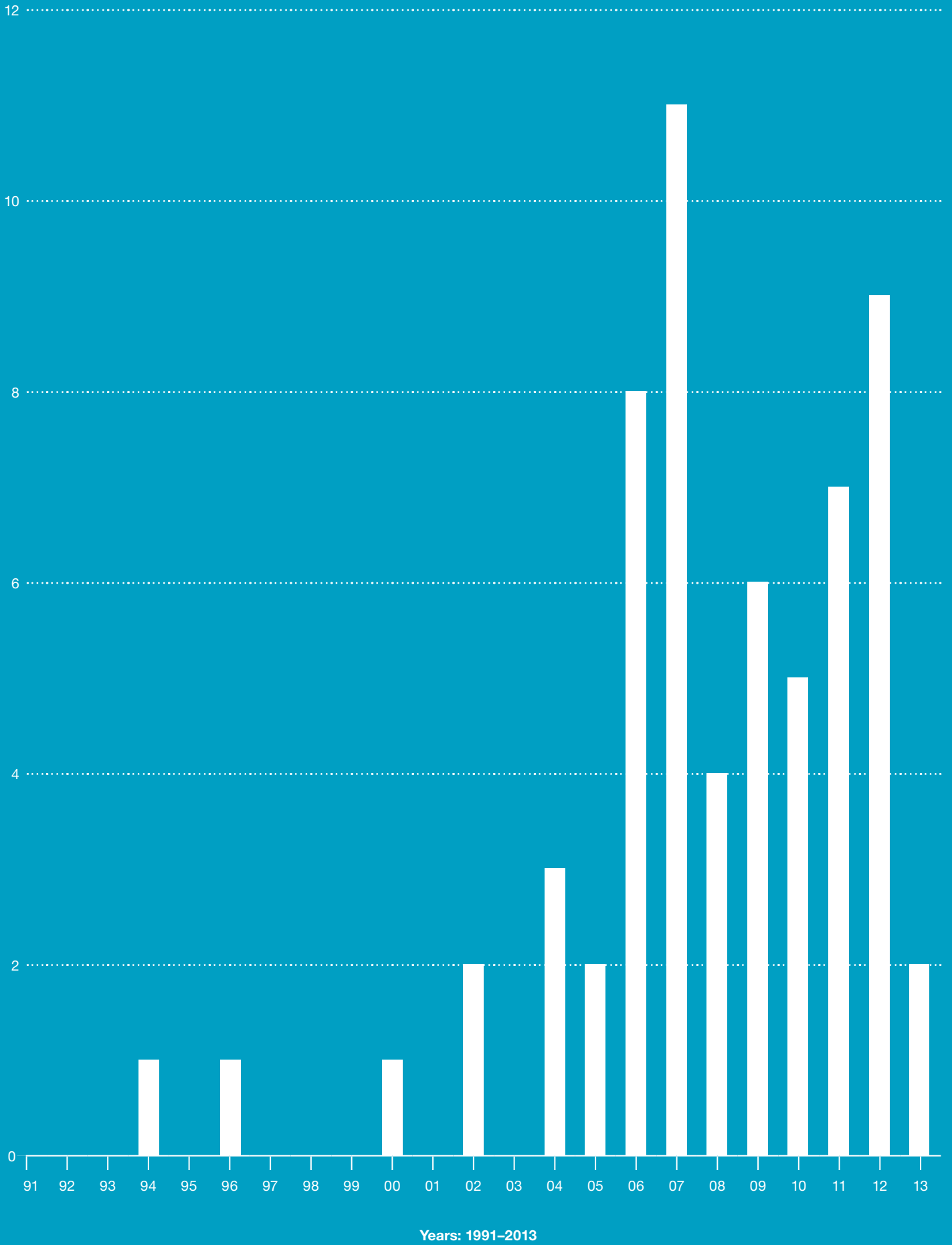


Figure 2: Aviation-related lithium battery incidents

Lithium battery incidents occur in a variety of situations.

Incidents also were categorized by a number of measures (see fig. 2):

- **Airplane type** — cargo or passenger.
- **When incident occurred** — boarding, in-flight, before loading, or after transport.
- **Where incident occurred** — vehicle, onboard, ramp, cargo facility, or terminal.
- **Battery location** — equipment, unit load device, package, carry-on, or checked bag.

LITHIUM BATTERY TRANSPORT REGULATIONS

Air transport of lithium batteries is controlled by international and local regulations governing the transport of dangerous goods (also referred to as hazardous-material regulations). Most countries follow the ICAO Technical Instructions for the Safe Transport of Dangerous Goods by Air. But many also have local variations contained in their own regulations.

An example of local variations is United States 49 Code of Federal Regulations Parts 171-180 administered by the Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA). A significant U.S. variation is that lithium-metal batteries packed alone are prohibited from being transported on passenger airplanes. Some airlines also have their own policies for transporting specific types of dangerous goods (known as airline variations).

Many airlines, freight forwarders, and shippers use the International Air Transport Association (IATA) Dangerous Goods Regulations as the working reference for dangerous goods transport requirements because they include the ICAO Technical Instructions, local variations, airline variations, and additional requirements agreed to by IATA-member airlines to reflect operational considerations.

RECENT DEVELOPMENTS

New ICAO lithium battery air cargo transport regulations that became effective Jan. 1, 2013, increase control over shipments of batteries having relatively high power or large quantities of cells/batteries in a single package.

In the United States, the DOT PHMSA has harmonized U.S. rules with ICAO standards (mandatory compliance required by Jan. 1, 2014), as required by the FAA Modernization and Reform Act of 2012. As a result of this legislation, the DOT is not allowed to issue or enforce any regulation regarding the transportation by airplanes of lithium batteries that is more stringent than the requirements of the ICAO Technical Instructions; the only exception is for the existing passenger airplane prohibition on lithium metal batteries or if a credible report demonstrates that lithium batteries transported in compliance with the technical instructions have substantially contributed to the initiation or propagation of an onboard fire.

Airplane Type



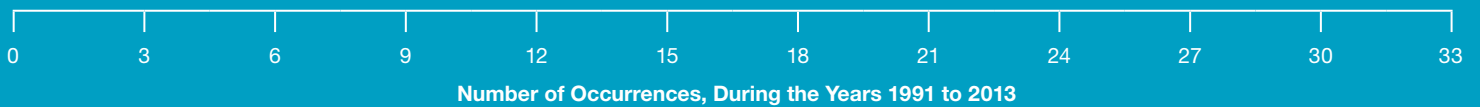
When Incident Occurred



Where Incident Occurred



Battery Location



BOEING COMMUNICATIONS TO OPERATORS

Boeing released a multi-operator message (MOM-12-0356-01B) on May 12, 2012, to share regulatory and guidance information for lithium battery cargo transport. In the multi-operator message, Boeing supports the recommendations made by the FAA in its Safety Alert for Operators 10017, issued in October 2010, for transport of lithium batteries, including:

- Requesting that customers identify bulk shipments of currently excepted lithium batteries by information on air waybills and other documents provided by shippers offering shipments of lithium batteries.
- Where feasible and appropriate, stowing bulk shipments of lithium batteries in Class C cargo compartments or in locations where alternative fire suppression is available.
- Evaluating the training, stowage, and communication protocols in an operation with respect to the transportation

of lithium batteries in the event of an unrelated fire.

- Paying special attention to ensuring careful handling and compliance with existing regulations covering the air transportation of Class 9 hazardous materials, including lithium batteries.

Additional guidance can be found in the European Aviation Safety Agency safety information bulletin 2010-30R1 and the ICAO electronic bulletin 2011/7 and on the IATA Web site www.iata.org.

ADDITIONAL RECOMMENDATIONS

Boeing also provides the following non-mandatory recommendations to help minimize the hazards associated with transporting lithium batteries as cargo:

- Only accept lithium battery shipments that comply with applicable regulations (i.e., ICAO and/or local regulations).
- When possible, divide lithium battery shipments into smaller and separated groupings to minimize the size of a potential battery fire.

- When possible, segregate lithium battery shipments from other dangerous goods that present a fire hazard (e.g., Class 3 flammable liquid shipments) to minimize the effects of a lithium battery fire and the potential for involving lithium batteries in adjacent cargo fire events.
- Consider establishing a policy to notify the flight crew of all lithium battery shipments (including exempted shipments) so the flight crew is aware of the potential hazard.
- Implement methods or programs to increase customer awareness of issues surrounding the transport of lithium batteries. Items to consider might include:
 - Identifying customers who ship large volumes of lithium batteries.
 - Creating customer education materials to increase awareness around safely shipping lithium batteries and to minimize undeclared battery shipments.
 - Conducting compliance audits of high-risk shippers, high-volume shippers, and high-risk product locations.

The fire-resistant cargo lining systems of airplane cargo compartments are an integral part of the overall cargo compartment fire protection system. Operators are reminded that airplane master minimum equipment lists and dispatch deviations guides do not allow cargo (except for ballast) to be transported in cargo compartments that have missing or damaged cargo compartment liners.

- Creating employee education regarding regulations, handling procedures, the dangers of mishandling, and methods to identify lithium battery shipments.
- Take precautions to avoid unrestrained or shifting cargo that might cause damage to shipments of lithium batteries by establishing and following procedures to ensure cargo is properly secured within containerized/palletized cargo compartments, cargo unit load devices, and bulk cargo compartments.
 - When possible, avoid loading lithium batteries in loosely packed bulk cargo compartments to minimize the potential for damage to the lithium batteries from shifting, or by the shifting of other cargo within the bulk compartment, unless the cargo in the compartment is restrained against movement.
- Transporting bulk shipments of lithium metal batteries to, from, or through the United States on passenger airplanes is forbidden by U.S. DOT regulations. In accordance with these regulations, consider eliminating bulk shipments of lithium metal batteries on passenger airplanes.
 - The fire-resistant cargo lining systems of airplane cargo compartments are an integral part of the overall cargo compartment fire protection system. Operators are reminded that airplane master minimum equipment lists and dispatch deviations guides do not allow cargo (except for ballast) to be transported in cargo compartments that have missing or damaged cargo compartment liners.

SUPPORT FOR INDUSTRY INITIATIVES

Boeing supports lithium battery fire research, including testing by the U.S. National Transportation Safety Board and the FAA, and is participating in the Commercial Aviation Safety Team Safety Enhancement 126: Mitigation for Hazardous Material Fires.

Boeing will continue working with ICAO, government agencies, operators, and other industry groups to develop and share information and guidance to promote safe air

transport of lithium batteries. This work is based on an understanding that an overall solution that reduces the risks associated with transport of lithium batteries will likely require concerted efforts by an industry forum consisting of airlines, airplane manufacturers, regulatory agencies, battery producers, package manufacturers, shippers, freight forwarders, unit load device and equipment manufacturers, and other involved parties.

SUMMARY

There are risks involved with transporting lithium batteries as hazardous-material cargo in commercial freighter and passenger airplanes. However, operators can reduce these risks by understanding and adhering to current regulations governing the air transport of lithium batteries and implementing industry best practices for their safe transport.

Article contributors include Mike Spry, Mike Madden, Doug Ferguson, and Mike Dunican. [A](#)



The 747-8 PIP lowers fuel use and improves the environmental signature of upgraded 747-8 airplanes.

747-8 Performance Improvement Package to Enhance Efficiency

The new 747-8 Performance Improvement Package (PIP) combines engine performance and flight management computer (FMC) software improvements to increase fuel efficiency by 1.8 percent and enhance operational efficiency.

By **Bruce Dickinson**, Vice President and Chief Project Engineer, 747-8 Program

Boeing has continued to improve the 747-8 since its entry into service in 2011. New PIP improvements will give operators an airplane with an additional 1.8 percent fuel efficiency. This improvement in fuel efficiency can save an operator approximately \$1 million annually in fuel per airplane. The 747-8 PIP is scheduled to be implemented on in-production airplanes in December 2013. The improvements also will be available for retrofit on airplanes already in service.

This article reviews the elements of the 747-8 PIP and the propulsion efficiency and

software upgrades that result in reduced fuel consumption and improved performance for operators.

COMPONENTS OF THE 747-8 PIP

The 747-8 PIP comprises improvements to the airplane's GENx-2B engines and FMC software.

Engine upgrades. The improved GENx-2B engines include a new low-pressure turbine design and improvements to the compressor, combustor, and high-pressure

turbine (see fig. 1). These improvements enhance aerodynamics and durability. The result is an airplane that has the best economics of any commercial passenger or freighter airplane and a 1.8 percent fuel use improvement over the current engine.

FMC software improvements. The latest version of FMC software offers customers greater capabilities, allowing them to operate at maximum efficiency in today's air traffic control environment. These improvements include Quiet Climb, Required Navigation Performance, and Optimum Steps.



- **Quiet Climb** automatically manages engine thrust during takeoff to comply with noise-abatement departure procedures and economy during climb. The Quiet Climb feature maintains a safe and fuel-efficient rate of climb and airspeed, eliminating the need for the crew to make multiple manual thrust reductions to reach the proper thrust and climb angle during departure. Quiet Climb allows optimization of airplane performance while still complying with noise abatement, often with a more significant thrust reduction than may be available through other techniques, such as engine derate.
- **Required Navigation Performance-Authorization Required (RNP AR) Approach** procedures are the latest generation of approach and departure procedures being adopted at airports worldwide to save fuel and cut emissions. In order to exploit the benefits, the RNP AR-capable flight management system (FMS) utilizes global-positioning-system and monitoring equipment to transit a narrowly defined airspace corridor. RNP AR approach-capable airplanes allow operators to achieve greater operational efficiency while shortening the flight paths on final approaches and departures, reducing fuel use and carbon emissions, and shifting noise away from residential areas.
- **Optimum Steps** allows the flight crew to evaluate the effect of winds along the planned route of flight to determine whether the future step climbs calculated by the FMS should be made over the flight route to achieve improved overall fuel efficiency. When the flight crew is provided data about winds at a given flight level, this FMS feature allows the crew to evaluate the tradeoffs of climbing to a higher flight level to get better engine performance versus flying at the suggested flight level with



Figure 1: Improvements to GEnx-2B engines

The 747-8 Performance Improvement Package includes GEnx-2B engines with a new low-pressure turbine design and improvements to the compressor, combustor, and high-pressure turbine.

unfavorable winds along the entire route of flight. By utilizing the FMS to optimize climbs with this feature, operators can achieve reduced fuel use, particularly on long-haul flights where vast variations in flight level winds are common.

BENEFITS TO OPERATORS

Improving fuel efficiency by 1.8 percent can save an operator approximately \$1 million

annually in fuel per airplane and reduces the carbon footprint.

The PIP program is a continuation of the improvements Boeing has made to the 747-8. After the PIP program is complete, fuel use improvements on the 747-8 will add up to 3.5 percent overall since the airplane entered service, and many FMC-produced operational improvements will be available with the new software.

SUMMARY

The 747-8 PIP lowers operational cost and improves the environmental signature of 747-8 airplanes that are upgraded with the 747-8 PIP. It demonstrates Boeing's commitment to continually improve its airplanes. **A**



Standard Boeing recommendations and training are designed to greatly reduce the risk of tail strikes.

Avoiding Tail Strikes

Any airplane model can experience a tail strike. Although there are a number of reasons tail strikes occur, they can almost always be avoided. The key to avoidance is ongoing training of flight crews and an emphasis on following prescribed procedures.

By **Capt. Dave Carbaugh**, Chief Pilot, Flight Operations Safety, and
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Because of the severe damage tail strikes can cause, they can result in millions of dollars in repair costs and lost revenue. It is even possible for a tail strike to cause pressure bulkhead failure, which can lead to structural failure. However, all of these scenarios can be prevented by providing regular training to help flight crews understand what causes tail strikes and ensuring that they follow specific standard procedures.

Tail strikes often result from a lack of awareness of their potential on the part of flight crews. This can be mitigated by providing crews with reminders of prevention strategies on a recurring basis. It's also important to promote discussion about tail strikes among members of the flight crew as part of takeoff and landing

briefings, particularly when strong wind conditions are present.

Boeing conducts extensive research into the causes of tail strikes and designs solutions to prevent them, such as an improved elevator feel system. Enhanced preventive measures, such as the tail strike protection feature in the Boeing 787 and some 777 models, further reduce the probability of incidents.

This article examines tail strike causes and prevention and reviews training recommendations and preventive measures. For additional details, including information about avoiding tail strikes in gusty wind conditions, please see *AERO* first-quarter 2007.

TAIL STRIKE CAUSES AND PREVENTION

Takeoffs. A number of factors increase the chance of a tail strike during takeoff, including:

- Mistrimmed stabilizer.
- Improper rotation techniques.
- Improper use of the flight director.
- Rotation prior to V_R :
 - Early rotation: Too aggressive.
 - Early rotation: Incorrect takeoff speeds.
 - Early rotations: Especially when there is a significant difference between V_1 and V_R .
- Excessive initial pitch attitude.

For current production airplanes, the feel pressure should be the same as long as the center of gravity/weight and balance are done correctly. For most cases, there is no reason to be aggressive during rotation.

- Strong gusty winds and/or strong crosswinds may cause loss of airspeed and/or a requirement for lateral flight control inputs that can deploy some flight spoilers, reducing the amount of lift generated by the airplane.
- Improper weight and balance (e.g., improper loading of cargo).

These factors can be allayed by using proper takeoff techniques (refer to the flight operations manual for specific model information), including:

- **Executing normal takeoff rotation technique.** For current production airplanes, the feel pressure should be the same as long as the center of gravity/weight and balance are done correctly. For most cases, there is no reason to be aggressive during rotation.
- **Rotating at the appropriate time.** Rotating early, prior to V_r , means less lift and less aft tail clearance.
- **Rotating at the proper rate.** Do not rotate at an excessive rate or to an excessive attitude. Boeing manuals provide guidance for each model.
- **Using correct takeoff V speeds.** Be sure to adjust for actual thrust used and be familiar with quick reference handbook and airplane operating manual procedures for takeoff speed calculations.

- **Consider using a greater flap setting** to provide additional tail clearance on some models.
- **Using the proper amount of aileron** to maintain wings level on takeoff roll.

Landings. Tail strikes on landing generally cause more damage than takeoff tail strikes because the tail may strike the runway before the main gear, damaging the aft pressure bulkhead. These factors increase the chance of a tail strike during landing:

- Unstabilized approach.
- Holding airplane off the runway in the flare.
- Mishandling of crosswinds.
- Overrotation during go-around.

Following proper procedures and maintaining a stabilized approach can reduce the chance of a tail strike during landing. Additional items include:

- Fly the approach at the specified target airspeed and maintain an airspeed of $V_{ref} + 5$ knot minimum to start of flare.
- The airplane should be in trim at start of flare; do not trim in the flare or after touchdown.
- Do not prolong the flare in an attempt to achieve a perfectly smooth touchdown.
- Use only the appropriate amount of rudder/aileron during crosswind approaches and landing.

- Following main landing gear touchdown, when the pilot flying (PF) is assured that the main landing gear will remain on the runway, relax the back pressure on the control column and gently fly the nose wheel onto the runway.
- Do not allow pitch attitude to increase after touchdown.
- Do not attempt to use aerodynamic braking by holding the nose off the ground.

Sometimes the best decision for a successful approach is a go-around. It is important that the culture within the airline promote go-arounds when needed without punitive measures.

TRAINING RECOMMENDATIONS AND PREVENTIVE MEASURES

Tail strikes can be prevented. The most effective means of prevention is a training program that reinforces proper takeoff and landing procedures. There are a number of steps both management and flight crews can take to help prevent tail strikes.

MANAGEMENT

- Ensure instructors and evaluators stress proper landing and takeoff techniques during all training and evaluations.

- Make tail strike prevention part of the safety program through posters, briefings, videos, computer-based training, and other elements that are available from Boeing Field Service representatives.
- Make tail clearance measuring tools available in the simulator for all takeoffs and landings during simulator training and evaluations and provide feedback to crews.
- Use a self-measuring tail strike operational tool in the airline's fleet (see "Flight Crew" section below).
- Ensure that flight operational quality assurance programs are not used as a punitive device.
- When setting airspeed bugs, ensure that the speeds make sense based on your experience.
- Be aware of the differences between models and types, especially when transitioning from other equipment. Boeing manuals contain touchdown body attitudes and tail clearance information.
- If a tail strike occurs, follow the checklist. Even if you only suspect you have had a tail strike, act as if you were positive you did.
- Make sure that crew resource management is an integral part of training. Crews can get complacent during routine operations, yet a real threat exists, especially in strong gusty crosswinds. How the crew plans for and mitigates the threat can make the difference between a safe takeoff or landing and one that results in a tail strike. Every crew should have a plan for identifying and discussing the threat. For example:

the rotation phase to takeoff target pitch attitude.

- During takeoff, the PM should monitor pitch rate and attitude and call out any deviations and be prepared to intervene.

Other approaches include a self-monitoring tail strike analysis tool that provides a pitch report for every takeoff and landing. If the tail gets within 2 degrees of a potential tail strike, an auto printout is provided to the crew after the respective takeoff or landing. Airlines that have adopted this program have had significant drops in tail strike rates.

FLIGHT CREW

- Adhere to proper takeoff and landing techniques.
- Never assume — double-check the takeoff data, especially if something doesn't look right. Coordinate insertion of the zero fuel weight (ZFW) in the flight management computer with another crew member. Double-check data with the load sheet. Inaccurate (i.e., low) ZFW entries have caused significant tail strikes.
- Know your airplane — having an idea about the approximate takeoff and approach speeds can help catch gross errors.

PREVENTION AND DETECTION MEASURES

Boeing is actively developing tail strike prevention and detection measures. Some airplane models have additional features that help prevent or detect tail strikes:

787 tail strike protection. During takeoff or landing, the primary flight computers calculate if a tail strike is imminent and decrease elevator deflection, if required, to reduce the potential for tail contact with the ground. Activation of tail strike protection does not provide feedback to the control column. Authority is limited so that pilot input can override its effect and rotate to tail contact attitude via additional column

force. Protection does not degrade takeoff performance and is compatible with the autoland system.

787 tail strike detection system. The tail strike alert system detects ground contact which could damage the airplane pressure hull. A two-inch blade target and two proximity sensors are installed on the aft body of the airplane. The EICAS caution message TAIL STRIKE is displayed when a tail strike is detected. This indication is accompanied by a beeper and Master CAUTION light.

777 tail strike protection. If installed, the flight control system receives input that a tail strike is imminent, and elevator deflection is decreased to reduce the potential for ground contact. Elevator deflection will not activate during a normal rotation and will not provide feedback to the control column.

777-300/-300ER semi-levered main landing gear. Because the vast majority of the weight of the airplane is borne by the lift of the wings at the time of rotation, the semi-levered gear acts as if it were pushing down like a longer gear. This allows a higher pitch attitude for the same tail clearance or more clearance for the same pitch attitude. A hydraulic strut provides the

energy to provide this increased takeoff performance. Although designed to increase takeoff capability, it provides increased tail clearance for the same weight and thrust as non-equipped airplanes.

777-300/-300ER tail skid. The tail skid helps protect the pressurized part of the airplane from contact with the runway. The tail skid retracts and extends along with the landing gear and is connected to the center hydraulic system. If the tail skid position disagrees with the landing gear lever position, the EICAS advisory message TAIL SKID appears. Tail skid contact with the runway will not cause the TAIL STRIKE message to appear unless the tail strike sensor has also made contact.

737-800/-900 tail skid. The tail skid assembly consists of a cartridge assembly, tail skid, fairing (skirt), and shoe. The fairing provides an enclosure for the actual tail skid structure. The shoe is fitted to the bottom of the fairing. The cartridge assembly consists of a crushable honeycomb material. When the tail skid strikes the runway, the skid moves upward and the honeycomb material crushes. The shoe contacts the runway in the event of an overrotation.

Douglas twinjet tail bumpers. All Douglas twinjet models have tail bumpers similar to the tail skids on Boeing models.

MD-11 pitch attitude protection (PAP).

The MD-11 has a PAP feature of the longitudinal stability augmentation system. Refer to the MD-11 Flight Crew Operations Manual for a detailed description.

IF A TAIL STRIKE OCCURS

In the event that a tail strike occurs, the air carrier must perform a tail skid inspection and tail strike inspection as specified in the Aircraft Maintenance Manual, chapter 5.

SUMMARY

Tail strikes are preventable. Boeing's recommendations for preventing tail strikes are consistent with Boeing's philosophy of addressing operational issues through training, procedures, and technologies.

If standard recommendations are followed for all Boeing models, the chance of tail strikes is greatly reduced. Training is the key to preventing tail strikes. Technology enhancements can also contribute to solutions for Boeing production airplanes.

Please send all questions regarding this article to the Chief Pilot, Flight Technical and Safety, through the Service Requests Application (SR App) on the Web portal MyBoeingFleet.com. **A**

