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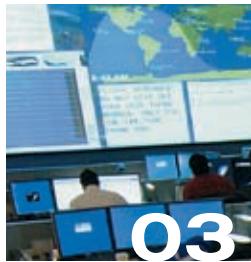
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# AERO



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We're Here for You – 24/7/365

The Operations Center works around the clock to answer urgent in-service requests.

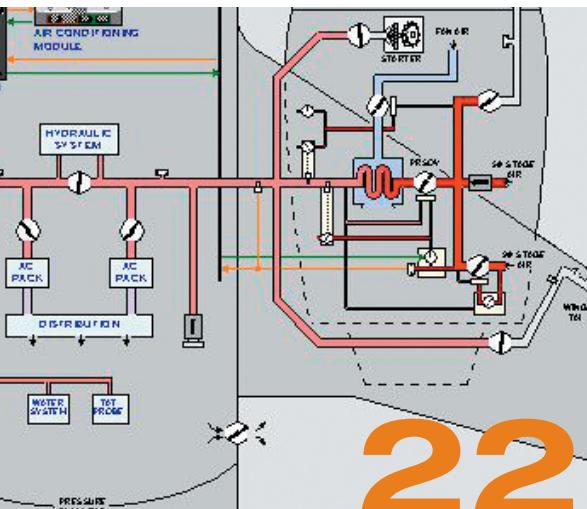


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Tail Strikes: Prevention

Environmental factors, such as gusty winds and strong crosswinds, can often be overcome by a well-trained and knowledgeable flight crew following prescribed procedures.



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*Deicing and Anti-icing Fluid Residues*

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# AERO

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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.

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# We're here for you – 24/7/365



LOU MANCINI  
Vice President and General Manager  
Boeing Commercial Aviation Services

One year ago, we opened the Boeing Commercial Airplanes Operations Center in response to customer demand for more integrated and comprehensive around-the-clock airplane support. The Operations Center focuses on urgent airplane in-service issues that require resolution within 24 hours – issues often referred to as “airplane-on-ground,” or “AOG.”

In its first year of operation — with the support of our entire Service Engineering organization and others in Commercial Aviation Services — the center has handled an average of 55 service requests each day and fielded some 150 phone calls. When we first opened the center, we responded to more than 80 percent of customer requests within the time the customer expected. A year later, that same metric now stands at more than 90 percent. And we continue to make improvements to bring us closer to 100 percent on-time performance.

In some ways, the Operations Center can be viewed as a physical manifestation of Boeing's continued commitment to customer support and how we are more closely aligning our operation to match the way you do business. You told us that you were looking for this type of centralized support because airlines and others in the industry use these centers in their own operations to improve performance. Operations centers are now the industry standard.

Our Operations Center is an outgrowth of the Rapid Response Center, which we formed in 1999 to provide commercial airplane operators with support during nights, weekends, and holidays. The Rapid Response Center's

off-hours capability supplemented the ongoing daytime support of our technical experts in Service Engineering. Now, with our Operations Center, all urgent requests — day or night — are coordinated through one centralized area — with the goal of providing you, our valued customer, with better quality responses in shorter time.

## How the center works

When you contact the Operations Center, you talk with a controller, who is responsible for all incoming work to the center. You and the controller discuss and define the issue. The controller then works with functional leads — representing structures, systems, spares, and other disciplines — to develop options to resolve the issue. Following this collaboration, you and the controller reach a joint decision on the optimum solution. Boeing then starts work to fulfill your request within the agreed-upon time, and the performance of the center is measured against that exact time — to the minute — until the job is complete.

*The engineering staff at the Operations Center uses the latest technology to track, minute-by-minute, the status of urgent in-service requests from airlines around the world.*



## How to submit requests

There are three ways that customers submit requests to the Operations Center:

- Through their local Field Service representative, who submits the request directly into the Boeing Communication System.
- Through the MyBoeingFleet.com Web portal using the technical in-service request.
- By e-mail to [boc.boecom@boeing.com](mailto:boc.boecom@boeing.com).

Customers may follow up their request with a telephone call to the Operations Center at 206-544-7500, or wait for one of the controllers on duty to call when the controller receives the request.

## What to include in a request

- To ensure that urgent AOG requests are routed directly to the Operations Center, customers are asked to clearly label requests as "AOG" and identify the product type as "airplane" or "flight operations."
- Requests should include an available point of contact who has both a complete understanding of the situation and is in a position to decide how to proceed.
- The most complete information about the incident should be included whenever possible: sketches, photographs, clear requirements, the airplane return-to-service date (or time), affected part numbers if known, and ATA chapter-section numbers. These all will help expedite our response to you.

You can find out more at our Operations Center Web site at [boeing.com/commercial/global/opscenter.html](http://boeing.com/commercial/global/opscenter.html).

If you haven't already had the opportunity to visit our Operations Center, I invite you to tour the facility the next time you are in the Seattle area. We welcome your interest and rely on your feedback to ensure that we are meeting — and, we hope, exceeding — your expectations.

The Operations Center is an essential part of our customer support commitment to you. We look forward to answering your in-service requests with speed, ease, and a positive attitude.



LOU MANCINI

Vice President and General Manager  
Boeing Commercial Aviation Services

# Tail Strikes: Prevention

by Capt. Dave Carbaugh, Chief Pilot,  
Flight Operations Safety

Tail strikes can cause significant damage and cost operators millions of dollars in repairs and lost revenue. In the most extreme scenario, a tail strike can cause pressure bulkhead failure, which can ultimately lead to structural failure; however, long shallow scratches that are not repaired correctly can also result in increased risks. Yet tail strikes can be prevented when flight crews understand their causes and follow certain standard procedures.

Two vital keys to prevention are raising awareness of tail strikes among flight crews and including tail strike prevention in standard training procedures. 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.

This article:

- Provides an overview of tail strikes and how Boeing is addressing them.
- Examines tail strike causes and prevention.
- Discusses operations in strong gusty winds.
- Reviews training recommendations and preventive measures.

Boeing has done design work to reduce tail strikes, including implementing an improved elevator feel system in some airplanes. For example, the 747-100/-200/-300 has varied feel (column forces) throughout the center of gravity (CG) and weight envelope. The newer 747-400's elevator feel system design provides

## TAIL STRIKES: AN OVERVIEW

A tail strike occurs when the tail of an airplane strikes the ground during takeoff or landing. Although many tail strikes occur on takeoff, most occur on landing. Tail strikes are often due to human error.

Tail strikes can cause significant damage to the pressure bulkhead. Failure of the pressure bulkhead during flight can cause a catastrophic event if the flight continues while pressurized.

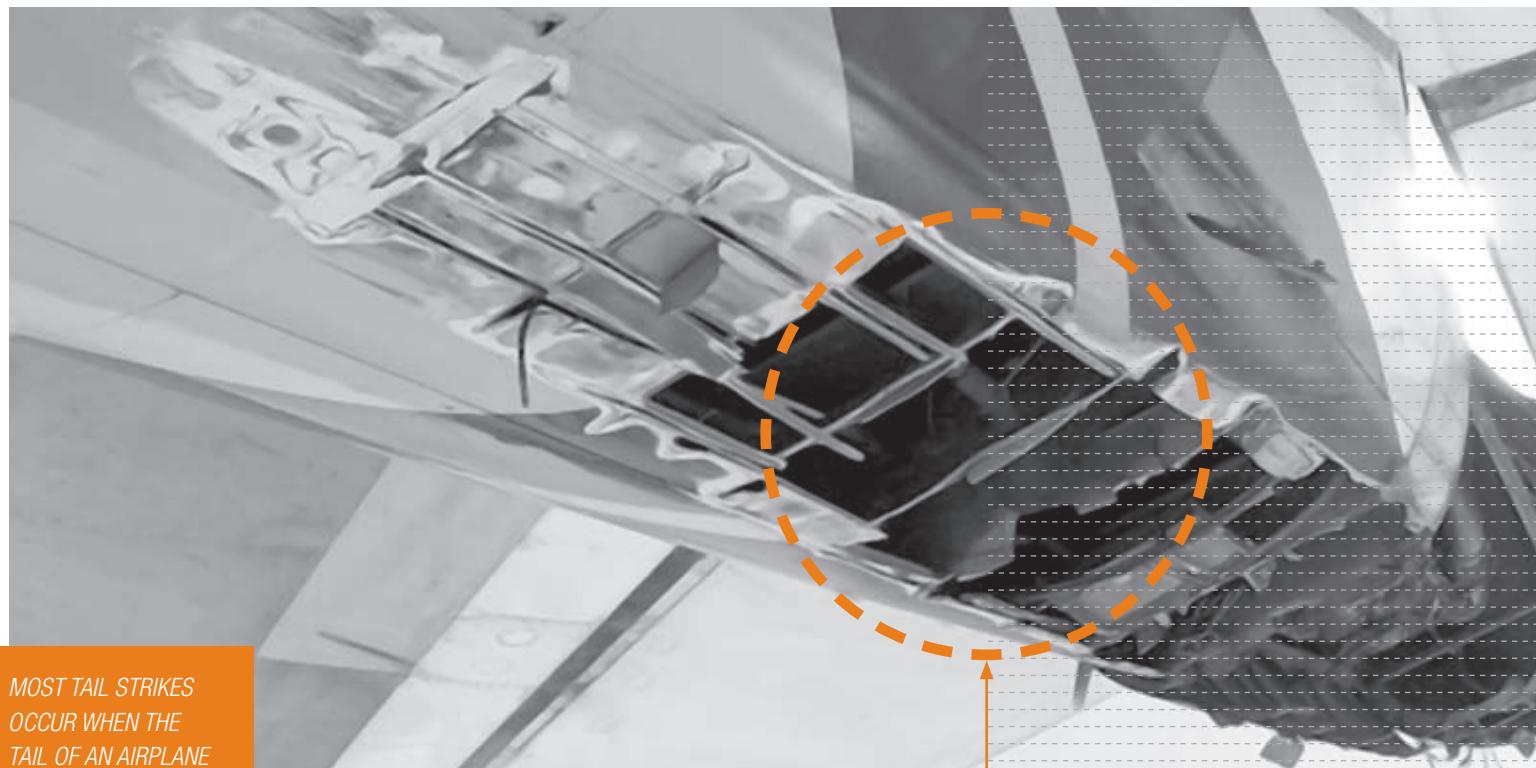
Tail strikes are expensive, too. During a safety investigation, one airline reported that a single tail strike cost its company \$12 million in repair cost and loss of revenue during the repair.

a constant feel elevator pressure, which has reduced the potential of varied feel pressure on the yoke contributing to a tail strike. The 747-400 has a lower rate of tail strikes than the 747-100/-200/-300.

In addition, some 777 models incorporate a tail strike protection system that uses a combination of software and hardware to protect the airplane. And some models of the 737, 767, and 777 have a tail skid that prevents damage from most takeoff tail strikes. However, these devices do not guarantee protection for landing tail strikes and some takeoff tail strikes. They also reduce tail clearance distances.

Many of the longer-bodied Boeing airplanes use relatively higher speeds than their shorter-bodied major models (e.g., the 757-300 versus the 757-200). The subsequent higher  $V_1$ ,  $V_r$ , and  $V_2$  speeds, or approach speeds, are designed to improve the tail clearance. Higher speeds make the tail clearance equivalent to the shorter-bodied equipment of the same model.

Regardless of airplane model, tail strikes can have a number of causes, including gusty winds and strong crosswinds. But environmental factors such as these can often be overcome by a well-trained and knowledgeable flight crew following prescribed procedures. Boeing conducts extensive research into the causes of tail strikes and continually looks for design solutions to prevent them, such as an improved elevator feel system. Enhanced preventive measures, such as the tail strike protection feature in some Boeing 777 models, further reduce the probability of incidents.



*MOST TAIL STRIKES  
OCCUR WHEN THE  
TAIL OF AN AIRPLANE  
STRIKES THE GROUND  
DURING LANDING AND  
ARE PREVENTABLE.*

*IN THIS INCIDENT, THE CREW MADE AN ERROR  
AND CALCULATED TAKEOFF DATA INCORRECTLY.  
THIS RESULTED IN AN EARLY ROTATION.*

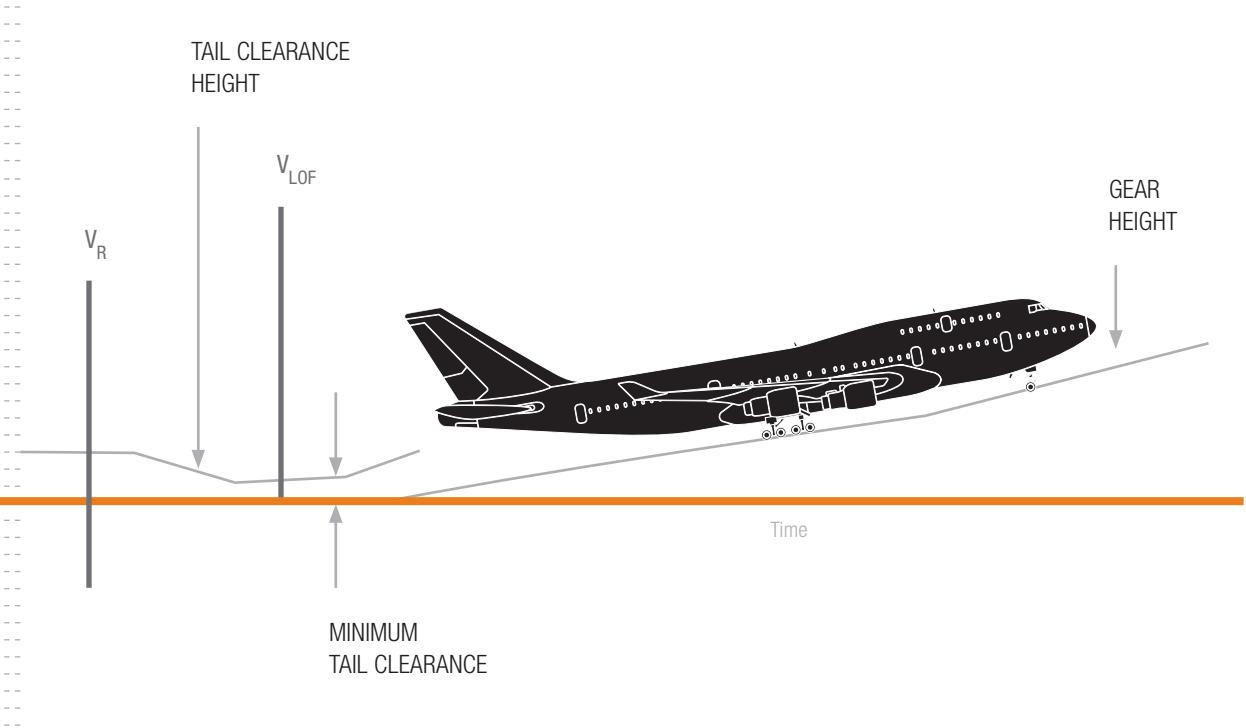
**TYPICAL TAIL  
CLEARANCE FOR  
TAKEOFF**

Figure 1

Model	Flap	Liftoff Attitude (deg)	Minimum Tail Clearance [inches (cm)]	Tail Strike Pitch Attitude (deg)
747-400	10	10.1	39 (99)	12.5
747-400	20	10.0	40 (102)	12.5

*This diagram indicates the effect of flap position on liftoff pitch attitude as well as minimum tail clearance during takeoff. The minimum tail clearance depicted is predicated on a no-wind, no-crosswind control, and constant rate of 2 to 3 degrees per second rate of rotation.*

Height above runway



**TYPICAL TAIL  
CLEARANCE FOR  
ENGINES-OUT  
TAKEOFF**

Figure 2

Model	Flap	Liftoff Attitude (deg)	Minimum Tail Clearance [inches (cm)]	Tail Strike Pitch Attitude (deg)
747-400	10, 20	10.6	34 (86)	12.5

*When operating with an engine failed at  $V_1$  with only 75 percent of thrust available for a four-engine airplane or 50 percent of thrust available for a two-engine airplane, minimum tail clearance is reduced. If there is a crosswind, the aileron/spoiler displacement will further reduce minimum tail clearance. In all cases, whether operating in one-engine or two-engine configuration during the rotation, a high average rate of rotation above what is recommended will further reduce minimum tail clearance.*

Boeing also works to reduce tail strikes through exhaustive takeoff testing, which is a part of certification for any new airplane program. During flight testing, takeoff test conditions are specifically designed to investigate the impact of early rotation, rapid rotation, no flare during landing, and long flare. During this testing, an acceptable margin per certification criteria is established for the design operational use of the airplane. In all cases, Boeing commercial airplanes meet or exceed the design certification criteria for takeoffs and landings, as well as for crosswind takeoffs and landings (see fig. 1). Criteria for engine-out takeoffs and landings are also evaluated (see fig. 2).

**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, misinterpretation.
  - Early rotation: Incorrect takeoff speeds.
  - Early rotations: Especially when there is a significant difference between the  $V_1$  and  $V_r$ .

- Excessive initial pitch attitude.
- 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 on the airplane.

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

- *Normal takeoff rotation technique.* For current production airplanes, the feel pressure should be the same as long as the CG/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 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.
- *Using correct takeoff  $V$  speeds.* Be sure to adjust for actual thrust used and be familiar with quick reference handbook and airplane operations manual procedures for takeoff speed calculations.
- *Consider use of greater flap setting* to provide additional tail clearance on some models.
- *Use the proper amount of aileron* to maintain wings level on takeoff roll.

**During testing, an acceptable margin per certification criteria is established for the design operational use of the airplane. In all cases, Boeing commercial airplanes meet or exceed the design certification criteria for takeoffs and landings, as well as for crosswind takeoffs and landings. Criteria for engine-out takeoffs and landings are also evaluated.**

Approximately two years ago, Boeing revised wording in all production model flight crew training manuals (FCTM) to incorporate input from industry and safety professionals regarding tail strikes during strong and gusty winds. The Boeing FCTM recommends that crews use thrust settings higher than the minimum required. The use of a higher takeoff thrust setting reduces the required runway length and minimizes the airplane exposure to gusty conditions during takeoff roll, rotation, liftoff, and initial climb.

**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.

Techniques that can reduce the chance of a tail strike during landing include:

- Maintain an airspeed of  $V_{ref} + 5$  knot minimum to start of flare and fly the approach at the "specified target airspeed."
- The airplane should be in trim at start of flare; do not trim in the flare or after touchdown.
- Do not "hold the airplane off" in an attempt to make an excessively smooth landing.
- Use only the appropriate amount of rudder/aileron during crosswind approaches and landing.
- Immediately after main landing gear touchdown, release the back pressure on the control wheel and 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 option for the approach is a go-around. It is important that the culture within the airline promote go-arounds when needed without punitive measures.

#### OPERATIONS IN STRONG, GUSTY WINDS

Tail clearance is reduced during takeoffs performed in strong gusty winds and crosswinds because of the lift loss incurred by flight control inputs, primarily spoilers. With very large inputs, this loss can be significant (see figs. 3 and 4).

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Pilots can take a number of steps to reduce the possibility of tail strikes during takeoff in gusty winds or strong crosswinds, including:

- Momentarily delaying rotation during the gust. As airspeed fluctuates back and forth (what is sometimes referred to as "bounce"), ensure that the airplane starts rotation at a speed that averages above rotate speed.
- Using a normal rate of rotation, but not a greater rate of rotation than normal. This faster rate may be a tendency if the airplane is slow to liftoff due to airspeed stagnation.
- Limiting wheel input to that necessary to maintain wings level. Pre-setting too much aileron increases drag and reduces lift with higher probability of cross control and reduced tail clearance margins. When safely airborne, smoothly transition from the slip by slowly releasing the rudder while maintaining desired track.
- Avoiding the tendency to quickly rotate the airplane off the ground during rotation in these wind conditions. Gusts up to 20 knots have been noted in the review of tail strike incidents.
- Rotating on the conservative side of gusts. Use normal rate of rotation a bit on the side of a slower versus faster rotation, similar to the engine-out case noted earlier.

## TAIL STRIKE COMPARISON

Figure 3

This is a comparison of a normal takeoff and a tail strike takeoff in gusty wind conditions. Note that takeoff #2 suffers a 9- to 10-knot airspeed loss during the rotation. The pitch attitude increases at an increasing rate until the tail strike. This is primarily due to the continued elevator increased deflection during rotation.



## AFT BODY CLEARANCE BREAKDOWN

Figure 4

Guidelines that relate to Boeing airplanes show that airspeed loss, lateral control deflection, a greater than average pitch rate, and a maximum pitch rate in excess of 4 degrees per second all contribute to reduced tail clearance margins. The numbers change, but the concepts hold true for other models.

Factor	Incremental Difference from Nominal	Reduction in Aft Body Clearance
Airspeed loss	Each 1 knot below the nominal liftoff speed	=2.8 inches <sup>†</sup>
-ΔCL from lateral controls	Each 0.1 of (-ΔCL) from lateral controls	=14 inches
Pitch rate*		
Either/Or	Average pitch rate to 10 degrees pitch attitude	Each 0.1 deg/sec in the average pitch rate above 2.5 deg/sec =2.8 inches <sup>†</sup>
	Maximum pitch rate	Each 0.1 deg/sec above 4.0 deg/sec =1.3 inches

\* If the maximum pitch rate up to the point of contact was less than 4.0 deg/sec, the average pitch rate corrections are used. If the maximum pitch rate up to the point of contact was above 4.0 deg/sec, then the maximum pitch rate correction should be used. In all cases, only one method or the other is employed.

### 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 which 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 “Crew” section).
- Ensure that flight operational quality assurance programs are not used as a punitive device.

#### 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 (low) ZFW entries have caused significant tail strikes.
- Know your airplane—have an idea about the approximate takeoff and approach speeds.
- When setting airspeed bugs, always do a “reasonable check.”
- Be aware of the differences between models and types, especially when transitioning from other equipment.
- If a tail strike occurs, follow the checklist.

**Crew resource management should be an integral part of training. Crews can get complacent during routine operations, yet a real threat exists during operations 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.**

- Crew resource management should be an integral part of training. Crews can get complacent during routine operations, yet a real threat exists during operations 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 entire crew should review appropriate crosswind takeoff procedures and techniques for operating in strong gusty winds.
  - The pilot flying (PF) should review threat strategy for the takeoff or landing with the pilot monitoring (PM).
  - The PM should monitor airspeed versus rotation callout to the PF and identify airspeed stagnation during the rotation phase to takeoff target pitch attitude.
  - If the first officer is making the takeoff, the captain 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.

**Preventive measures.** Boeing is actively developing tail strike preventive measures.

Some 777s have two additional features that help prevent tail strikes: the semi-levered main gear and tail strike protection.

**Boeing 777 semi-levered main 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, the system provides increased tail clearance for the same weight and thrust as nonequipped airplanes.

**Boeing 777 tail strike protection.** Timely elevator input can help avoid tail strikes on both takeoff and landing. The tail strike protection command (TSP CMD) is summed with the pilot’s input to form a total elevator command. The TSP CMD is limited in size to 10 degrees, which allows the pilot to overcome its effects, if desired, by pulling the column farther aft. The size of the

TSP CMD is controlled by excessive tailskid rate relative to a nominal threshold of tailskid rate, and by excessive nearness of the skid to the runway, relative to a nearness threshold. Different thresholds are used for takeoff and landing. The TSP CMD is limited to commanding nose down increments only. Tailskid height and rate are computed from radio altimeter signals, pitch attitude, pitch rate, vertical speed, and the length between the radio altimeter location and the tailskid location. A complementary filter is used to provide acceptably smooth rate and height signals. Provisions are included to account for the bending of the forward fuselage when the nose wheel gear lifts off the ground.

#### SUMMARY

Tail strikes are preventable. If standard recommendations are followed for all Boeing models, the chance of tail strikes is greatly reduced. There are additional challenges and solutions when operating during strong crosswinds and gusty winds. Training is the key to preventing tail strikes. Technology enhancements can also contribute to solutions for Boeing production airplanes. For more information, contact Capt. Dave Carbaugh at [dave.c.carbaugh@boeing.com](mailto:dave.c.carbaugh@boeing.com). 



RESIDUE FROM  
DEICING/ANTI-ICING  
FLUID IS AN INDUSTRY-  
WIDE ISSUE THAT  
AFFECTS A VARIETY  
OF AIRPLANE MODELS.

# Deicing and Anti-icing Fluid Residues

by Joel Hille, Lead Engineer, Boeing Service Engineering

Airplane deicing and anti-icing fluids can leave residue in critical areas in the wings and stabilizers. This residue can rehydrate and expand into a gel-like material that can freeze during flight and cause restrictions in the flight control systems. Therefore, attention to this residue should be part of a regularly scheduled inspection and cleaning process. Additionally, industry experience has shown that using a two-step deicing/anti-icing process helps to reduce the amount of fluid residue that forms in the wings and stabilizers.

Operating airplanes during winter conditions can be very challenging. Removing ice, frost, or snow is obviously a requirement for safe airplane operations. But the use of thickened deicing/anti-icing fluids to allow takeoff during active snowfall adds another dimension to winter operations: Although these fluids have undoubtedly made winter operations safer, they have also been known to cause problems that may degrade the airworthiness of an airplane. This article provides insight into these problems and how to resolve them. It includes:

- Overview of deicing and anti-icing fluids and fluid residues.
- Differences in deicing and anti-icing practices between Europe and North America.
- Interaction of airplane fluids and runway fluids.
- Inspection and cleaning recommendations.
- Industry actions.

## OVERVIEW OF DEICING AND ANTI-ICING FLUIDS AND FLUID RESIDUES

One of the most significant consequences of winter operations is the need for ground application of deicing and anti-icing fluids to protect against performance degradation due to snow, ice, or frost in critical locations on the airplane. When these fluids are properly used and applied, they will maintain the airplane in the approved configuration for takeoff and safe flight. However, events in recent years have shown that residue from thickened deicing/anti-icing fluids (Types II, III, or IV) can remain in aerodynamically quiet areas and accumulate over time.

During suitable weather conditions, this residue can rehydrate and form into a gel-like substance that swells to many times the original size. The residue gel can freeze during flight, and if located in areas of flight control components and linkages, control surface movement may be restricted,

which could result in airplane controllability issues on one or more of the flight axes (see figs. 1–3). Accordingly, airplanes exposed to deicing/anti-icing fluids should be subjected to periodic inspections for fluid residue, and any residue found should be removed. Failure to do so may degrade the airworthiness of the airplane.

During the last two winter seasons there have been reports of impaired flight controls on airplanes operating throughout the European region. These reports have involved regional and commuter airplanes as well as small commercial jetliners. The events have occurred on both types of airplanes — those that have hydraulically powered flight control systems and those that have nonhydraulically powered flight control systems. The events are more common on smaller airplanes because, during severe winter weather, small- and medium-sized airplanes may receive many fluid treatments every day, increasing the possibility of anti-icing fluid residue accumulation.



Figure 1

Anti-icing residue gels can freeze during flight, causing interference with flight control linkages and surfaces, such as these MD-90 elevator tab control rods.



Figure 2

Residue gel under the input arm of the MD-90 elevator power control unit interfered with the pilot input, making the restriction evident to the pilot through the control column feel forces.

RESIDUE GEL  
UNDER INPUT  
LINK



Figure 3

Residue in gel form on the elevator balance panel of a 737-800 airplane.

**It is important for all operators to realize that keeping airplanes safe for winter operations now involves more than inspecting for snow or ice on the wings and stabilizers and treating the airplane with deicing/anti-icing fluids. It also involves inspecting for and removing deicing/anti-icing fluid residues in hidden places in the wings and stabilizers.**

The wide variety of airplanes that have been affected makes it clear that deicing/anti-icing fluid residues are an industrywide issue. Airplanes from several different manufacturers have experienced in-flight control issues that have resulted from the presence of residue gel. In several cases, it was determined that the residue had been generated from fluids that were applied during previous winter seasons. Although Type III fluids have not been specifically linked to any events involving flight controls, the composition of these fluids makes them equally susceptible to residue problems as the Type II and Type IV fluids. It is important to note that Type III fluids have only been commercially available for a short time, and on a limited basis, which is likely the reason they have not caused any known residue problems so far.

It is also important for operators and/or their service providers to take steps to ensure that all deicing/anti-icing fluids are being stored and handled properly in accordance with the fluid manufacturers' recommendations. Improper storage and use could result in degraded fluid performance or the use of greater volumes of fluid, which could contribute to the formation of more residue. For example, spraying fluid from the rear of the wing rather than from the front, which is the correct method, might result in more fluid entering the flight control areas through the control surface vent gaps.

As a result, it is important for all operators to realize that keeping airplanes safe for winter operations now involves more than inspecting for snow or ice on the wings and stabilizers and treating the airplane with deicing/anti-icing fluids. It also involves inspecting for and removing deicing/anti-icing fluid residues in hidden places in the wings and stabilizers.

#### DIFFERENCES IN DEICING AND ANTI-ICING PRACTICES BETWEEN EUROPE AND NORTH AMERICA

A larger number of deicing/anti-icing fluid residue problems have occurred in Europe compared to North America and Asia. Industry experts agree that one of the reasons for this is the difference in deicing and anti-icing practices between the continents.

In Europe, a one-step deicing/anti-icing process is commonly used. This process involves the application of deicing/anti-icing fluids in a single application, using a heated mixture of Type II fluid and water, usually in a ratio of 75/25.

In North America, a two-step process is commonly used. This process involves deicing with heated Type I fluid, or a heated mixture of Type I fluid and water, which is followed by an application of Type IV anti-icing fluid. Experience and testing has shown that deicing with heated Type I fluid will help clear away residue from previous anti-icing fluid treatments.

#### INTERACTION OF AIRPLANE FLUIDS AND RUNWAY FLUIDS

Early research also indicates that the interaction between airplane deicing/anti-icing fluids and runway deicing fluids may contribute to the formation of residue gels.

Airplane deicing/anti-icing fluids typically comprise glycols with thickening agents (polymers). Runway deicing fluids contain potassium acetate- or potassium formate-based fluids (deionizing salts). When these fluids combine, the separation of the anti-icing fluid thickeners may be enhanced, leading to a more rapid formation of the residue.

The fluids can be mixed together in two different ways — when the airplane fluid flows off the wing during the takeoff roll and goes onto a runway that has been treated with deicers, or when the engine thrust reversers send runway fluids up onto the wing during the landing roll and they flow into the rear spar areas through the control surface vent gaps. These situations make it possible for residue gel to form on the external wing surfaces as well as the internal quiet areas of the rear spar and the balance bays.

While research is ongoing as fluid manufacturers continue to conduct tests on the interaction between airplane deicing/anti-icing fluids and runway deicing fluids, it is prudent to remove as much of all types of residue as possible.

# INSPECTION > CLEANING > RELUBRICATION > FOLLOW-UP

## INSPECTION AND CLEANING RECOMMENDATIONS

Boeing issued a multi-model service letter (No. 737-SL-12-014) in January 2000 that advised operators about the potential for deicing/anti-icing fluid residue problems. At that time, the service letter quoted a new caution note that had been added to the Society of Automotive Engineers (SAE) Aerospace Recommended Practice (ARP) 4737 Methods Document. The note was also added to the Airplane Maintenance Manual (AMM) Cold Weather sections at that time.

New multi-model service letters (Nos. 737-SL-12-019 and MD80-SL-12-104) have been issued that include information about where to inspect for residue and updated procedures for cleaning residue. The service letters also advise of AMM revisions that include more information about where to look for fluid residue.

The service letters and AMM revisions recommend that the inspection and cleaning processes outlined below be followed for all airplanes that are exposed to deicing/anti-icing fluids during winter operations. The frequency of the inspections should be based on each operator's experience during winter operations. Boeing recommends that all airplanes that have been exposed to deicing/anti-icing fluids should be subjected to the inspection and cleaning procedures

both prior to and at the end of the winter season. Boeing also recommends that during the winter season, each airplane should be inspected and cleaned no less than once per month.

This frequency is based upon information from operators that have experienced multiple occurrences of flight control issues due to deicing/anti-icing fluid residues. Some operators perform inspections much more frequently than once per month, and Boeing encourages operators to inspect as frequently as practical until sufficient data has been accumulated to more accurately define the inspection period.

Boeing recommends that the inspection and cleaning be performed as follows:

## INSPECTION

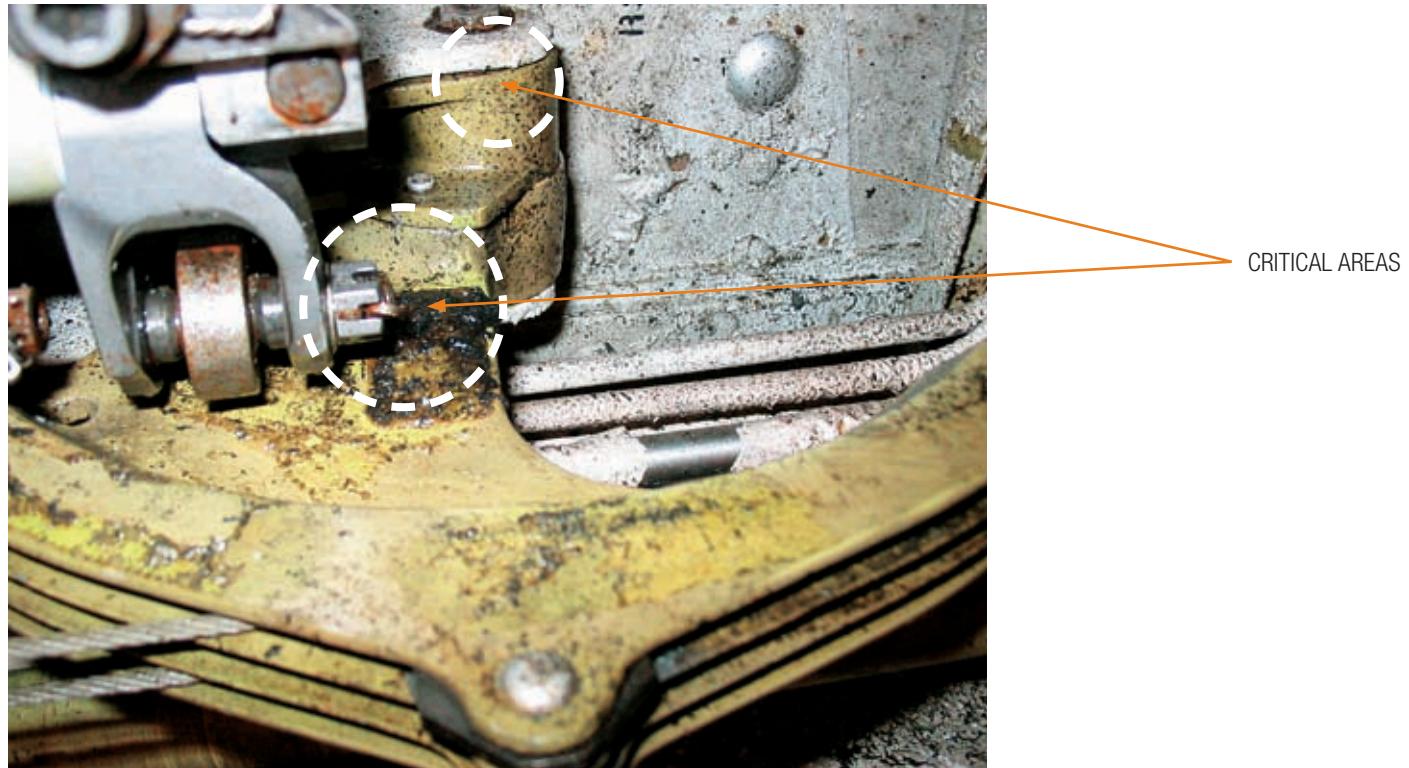
1. Gain access to the following areas where flight controls and other systems components are located:
  - Wing rear spar area, including the actuating components for the spoilers, ailerons, flaps, flaperons (if applicable), and the control surface hinges and balance bays.
  - Wing leading edge devices, including the actuating components.

- The horizontal stabilizer rear spar, including the actuating components for the elevators, elevator tabs (if applicable), and the control surface hinges and balance bays.
- Vertical stabilizer, including actuating components for the rudder, and the control surface hinges.
- The auxiliary-power-unit bay and the bilge area of the tailcone.

2. Visually inspect for the presence of dry or rehydrated residue anywhere in these areas. The residue may be very hard to see, especially if dry. Dry residue will normally be a thin film that may be partially covered with dirt or grease (see fig. 4). Rehydrated residue will often be a gel-like substance of more visible thickness.
3. Spray the area with a fine mist of warm water to rehydrate any residue that may be present and to make it easier to identify. In some cases, rehydration may occur quickly, but the process often may be slow, especially if residue has accumulated from multiple applications over a long period of time. Wait at least 15 minutes to allow rehydration to take place.

Figure 4

Deicing/anti-icing residues  
gel on a 737-300 flight  
spoiler power control unit  
input quadrant.



During the winter season, each airplane should be inspected and cleaned no less than once per month. This frequency is based upon information from operators that have experienced multiple occurrences of flight control issues due to deicing/anti-icing fluid residues. Some operators perform inspections much more frequently than once per month, and Boeing encourages operators to inspect as frequently as practical until sufficient data has been accumulated to more accurately define the inspection period.



*Large volumes of deicing/anti-icing fluids are commonly used during severe winter weather, especially on small- and medium-sized airplanes.*

4. If no rehydrated residue is visible, repeat this step at least three more times, if practical, including the wait time of 15 minutes to allow rehydration to take place. This recommendation to perform repetitive spraying and wait for rehydration to occur is based on the experience of several operators during the previous two winter seasons.

Do not spray the controls with water when the ambient temperature is below freezing unless the airplane is in a heated hangar. Doing so may result in ice that impairs the flight controls.

#### CLEANING

1. Once identified, the residue should be removed by using warm water with rags and/or soft brushes to hand clean the gel-like substances away. You may also use a low-pressure stream of water or compressed air to rinse away the residue. Make sure the water or compressed air do not cause the residue to enter crevice areas that are not accessible.

Research and experience have shown that the use of Type I deicing fluid, or a mixture of water and Type I fluid, is also a good cleaning agent for removal of residue. Test data indicates that use of a detergent additive with water may actually reduce the cleaning effectiveness.

2. This cleaning process has the potential of removing grease from control system bearings and fittings, and removing corrosion inhibitors from control cables. Care should be taken to avoid spraying cleaning fluids onto bearings, fittings, control cables, and electrical connectors.

The cleaning process also has the potential to wash the residue into other areas, where it may deposit and create a future problem. Attention should be paid to the runoff from the cleaning process into other areas of the airplane, and these areas should also be flushed until the operator is confident that any deicing/anti-icing fluid residues have completely left the airplane.

Similar to the inspection phase, do not spray the controls with water when the ambient temperature is below freezing unless the airplane is in a heated hangar. Doing so may result in ice that impairs the flight controls.

#### RELUBRICATION

1. If residue has been found and removed by cleaning, Boeing recommends that all bearings, fittings, and control cables in the area that was cleaned should be relubricated in accordance with appropriate AMM instructions.

2. Any areas from which corrosion-inhibiting compound has been removed or depleted by the residue-cleaning process should be retreated in accordance with the appropriate standard overhaul practice manual procedures.

#### FOLLOW-UP ACTIONS

Operators have reported that it can be very difficult to remove all residue with a single cleaning, and that residue may slowly migrate out of crevices after it is removed from open areas by cleaning. If practical, Boeing recommends reinspection within three days of any areas from which residue has been cleaned, following the inspection instructions above.

If residue is found, additional cleaning is recommended. These inspections and cleanings should be continued on a frequent basis until no additional residue is found. These recommendations are based upon the experience of several operators during previous winter seasons. However, the recommendations are also dependent on the specific schedules for each airplane and the amount of deicing/anti-icing treatments being encountered. Some operators have developed their own maintenance programs to remove existing deicing/anti-icing fluid residue based on their own data.

Service experience by many operators using several different airplane models has shown that use of thickened deicing/anti-icing fluids can result in the accumulation of residue that may rehydrate and expand into a gel-like substance which can interfere with airplane flight control systems. Failure to regularly remove this residue may degrade the performance of the airplane.

#### INDUSTRY ACTIONS

Numerous reports of problems due to deicing/anti-icing fluid residues prompted the formation of a Residues Working Group as part of the SAE G-12 Aircraft Ground Deicing Fluids Subcommittee. Among the group's responsibilities is the development of improved fluid dryout and residue tests for the SAE Aerospace Material Specification (AMS) 1428.

Also, the SAE G-12 Aircraft Ground Deicing Methods Subcommittee is making new revisions to the caution note regarding residue in the Methods Document, SAE ARP 4737, section 6.3.1.2.

The subject of deicing/anti-icing fluid residues is also under discussion by the European Regions Airline Association.

In the United Kingdom (UK), the Air Accidents Investigation Branch (AAIB) issued four safety recommendations in early 2006 regarding the subject of deicing/anti-icing fluid residues. In response to the AAIB recommendations, the UK Civil Aviation Authority has recently issued Flight Operations Division Communication number 15/2006, which recommends specific procedures for the use of deicing/anti-icing fluids, and for cleaning of fluid residue, on airplanes with nonpowered flying controls. In addition, the European Aviation Safety Agency (EASA) has released Safety Information Notice (SIN) No. 2006-09. This notice includes information and recommendations regarding deicing/anti-icing fluid residue in section 8, Special Operation Considerations, and section 9, Special Maintenance Considerations. Please note that the SIN is only an advisory document, and further regulatory action may be expected by EASA.

#### SUMMARY

Service experience by many operators using several different airplane models has shown that use of thickened deicing/anti-icing fluids can result in the accumulation of residue that may rehydrate and expand into a gel-like substance which can interfere with airplane flight control systems. Failure to regularly remove this residue may degrade the performance of the airplane. As a result, these considerations should be part of an airline's winter operations:

- Be aware of how frequently your airplanes are being deiced/anti-iced.
- Be aware of what deicing/anti-icing fluids are being applied to the fleet. Is the fleet undergoing a one-step or two-step process? Is the process the same at all airports?
- Make sure that proper procedures are being followed by airline personnel or a third-party service provider. Are the fluids being stored and handled properly, and are they being applied properly?
- Establish an inspection and cleaning schedule for deicing/anti-icing fluid residue to ensure no flight control restrictions will occur.
- Include the application of lubricants and corrosion inhibitors as necessary to the areas where residue cleaning occurs.

For more information, contact Joel Hille at [joel.d.hille@boeing.com](mailto:joel.d.hille@boeing.com). 4

# Maintenance Performance Toolbox

by Rex Douglas, Product Manager,  
Maintenance Performance Toolbox

THE TOOLBOX IS DESIGNED TO HELP OPERATORS IMPROVE SYSTEM TROUBLESHOOTING AND REDUCE REPAIR TURNAROUND TIMES.

The Boeing Maintenance Performance Toolbox is an online system that provides operators with up-to-date fleet maintenance information using intelligent documents and visual navigation methods. The Toolbox is designed to improve the performance of technical operations staff responsible for airplane system troubleshooting, structural repair record management, parts management, task card management, content authoring, and training. The Toolbox is available through subscription to a hosted service delivered via the Web portal MyBoeingFleet.com, and is built on an industry-standard J2EE architecture to ensure maximum security, availability, reliability, and scalability.

Operators today have the substantial task of creating, managing, distributing, and accessing vast amounts of maintenance information. This task is complicated by the composition of today's fleets, which often comprise both purchased and leased airplanes. The Boeing Maintenance Performance Toolbox uses two-dimensional (2D) and three-dimensional (3D) graphical user interfaces, combined with advanced data mining and search capabilities, to increase operators' efficiency and effectiveness in locating and accessing relevant maintenance information. It also allows operators to deploy maintenance performance solutions that meet their specific needs at lower cost to their in-house maintenance organization or external service providers.

For example, Maintenance Performance Toolbox facilitates the:

- Organized documentation of structural damage and repair.
- Communication of structural damage and repair situations with external service providers and Boeing.
- Reuse of repair information for similar structural incidents.
- Identification of systemic structural issues and problems within a fleet.
- Transfer of structural incident information during lease transfers.

## MANAGING MAINTENANCE INFORMATION

Figure 1

- EXPERIENCED EMPLOYEE
- EMPLOYEE

*Boeing research shows that maintenance personnel spend about 30 to 40 percent of their time researching and documenting maintenance activities.*



### IMPROVING MAINTENANCE PERFORMANCE

Even with electronic data and document management systems, the time required to research and document maintenance information is a significant percentage of maintenance work. Boeing discovered that maintenance personnel spend as much as 30 to 40 percent of their time researching and documenting information (see fig. 1).

Because CD-ROMs and document management systems are unable to provide maintenance information in a format that optimizes maintenance performance for operators, Boeing's goal in developing the Maintenance Performance Toolbox was to increase efficiencies and help operators become more effective. The Toolbox:

- Uses 2D schematics of airplane systems as “graphical” tables of content that enable point-and-click access to all information related to a specific airplane location or component.

- Uses advanced data-mining techniques and search capabilities to ensure that all relevant information (e.g., fault code lookup, repair history, maintenance procedures, part numbers, maintenance tasks) is part of the troubleshooting process.
- Automates the workflow required to review and approve documentation revisions and changes, while providing real-time editing tools that allow maintenance personnel to create and add their own documentation and notes.
- Integrates on-demand training within the maintenance information so it is available for reference and review where and when it is needed.
- Delivers capabilities as a managed, hosted service — securely accessible globally — and eliminates the costs associated with information technology (IT) infrastructure and data distribution.

*The Maintenance Performance Toolbox uses intelligent graphical user interfaces to streamline access to specific maintenance information and improve the efficiency and effectiveness of maintenance and engineering staff.*

SPECIFICALLY DESIGNED TO  
IMPROVE MAINTENANCE  
PERFORMANCE



A new maintenance support solution to improve the efficiency and effectiveness of maintenance and engineering staff

Tools deployed stand-alone or combined to create “solutions” that meet specific operational needs

Delivered as a hosted service, securely accessible globally

Intelligent graphical user interfaces to streamline access to specific maintenance information

#### **INTELLIGENT, GRAPHICAL USER INTERFACES STREAMLINE ACCESS TO SPECIFIC MAINTENANCE INFORMATION**

The Maintenance Performance Toolbox uses 2D schematics of airplane systems that enable point-and-click access to all of the information related to a specific airplane location or component (see fig. 2).

This intelligent graphical user interface allows maintenance personnel to quickly locate information about the exact area of the airplane that requires maintenance. For instance, instead of spending time searching manually or electronically through the Fault Isolation Manual to troubleshoot the problem and then through the Airplane Maintenance Manual (AMM) for repair information, maintenance personnel can click on 2D airplane system diagrams to retrieve line-replaceable-unit information, including maintenance procedures, troubleshooting information, parts data, wiring diagrams, maintenance tips, in-service activity reports, and service letters.

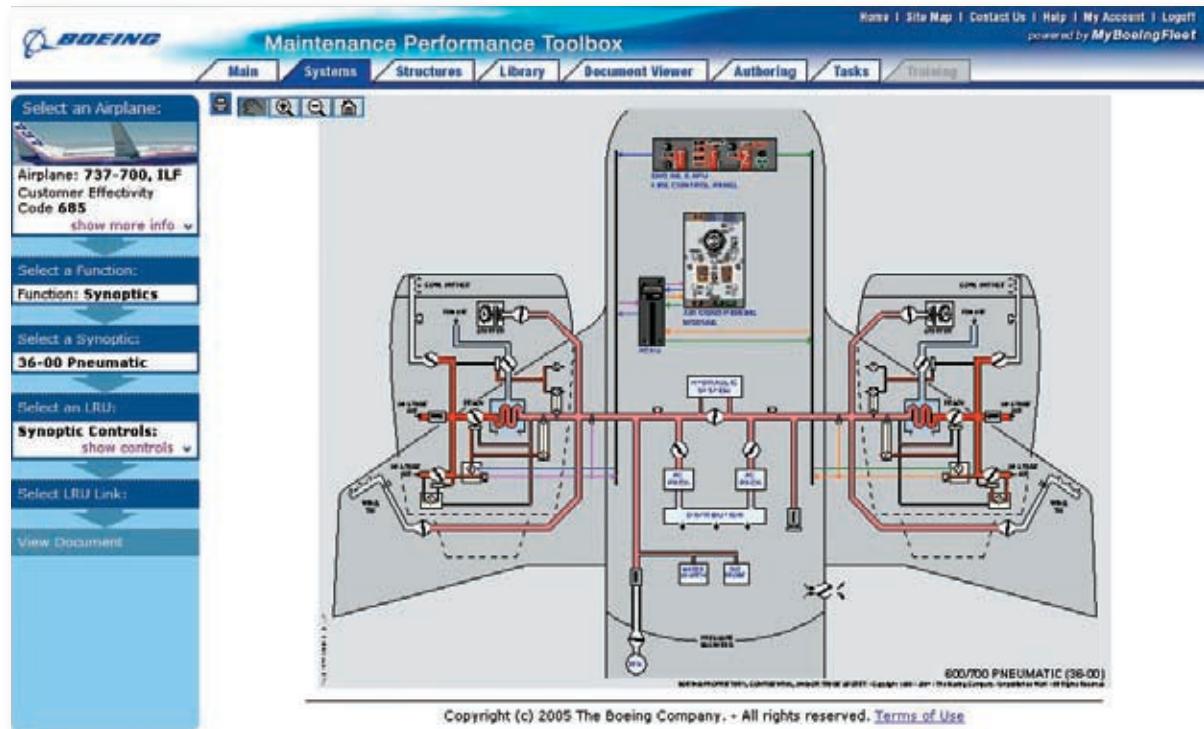
This same system can be used to locate troubleshooting information associated with central-maintenance-computer messages, fault codes, cabin faults, and flight deck effects. It also enables retrieval of part information directly from the airplane Illustrated Parts Catalog (IPC).

The location of structural damage can be indicated graphically on a 3D airframe model (see fig. 3). Clicking on a plotted “incident” provides information about that particular incident. Repair information is structured to standardize record contents and format. This enables operators and maintenance organizations to:

- Comply with recordkeeping requirements of regulatory authorities.
- Retain airplane values during transfers of airplane ownership by having proof-of-repair records.
- Share repair information for teams in different geographic locations in real time.

Because the Maintenance Performance Toolbox emphasizes a role-based design, it aligns with work activities (such as structures, maintenance control, engineering, and maintenance planning) to meet operators’ information needs. The graphical user interface streamlines access to information across all documentation. And the intuitive user interface and common look and feel minimize user learning curves.

Figure 2



ADVANCED DATA-MINING TECHNIQUES AND SEARCH CAPABILITIES LOCATE ALL RELEVANT INFORMATION

The vast amount of historical and engineering information available for Boeing commercial airplanes provides maintenance personnel with virtually everything they need to diagnose and repair most maintenance issues. However, the sheer quantity of information can make it more difficult to locate needed information in a timely manner.

The Maintenance Performance Toolbox uses advanced data-mining techniques and search capabilities to ensure that all relevant information — such as fault code lookup, repair history, maintenance procedures, part numbers, and maintenance tasks — from all documentation sources is part of the troubleshooting process. The Toolbox provides a common information repository for each fleet type and enables free text search across the entire document set.

These tools enable maintenance personnel to locate and use information sources that they may not otherwise have had time for. At the same time, the tools encourage visualizing and understanding airplane systems from a global perspective instead of viewing them simply in terms of their parts.

AUTOMATES WORKFLOW AND ALLOWS MAINTENANCE PERSONNEL TO CREATE AND ADD DOCUMENTATION AND NOTES

Operators need to be able to revise maintenance information for their specific operations and to distribute it to their workforce. The Maintenance Performance Toolbox automates the workflow required to review and approve documentation revisions and changes, while providing real-time editing tools that allow maintenance personnel to create and add their own documentation and notes, as well as online authoring of structured extensible markup language (XML) data.

The system enables editing of:

- Original equipment manufacturer's publication revisions.
- Airline documents.
- Airline revisions.
- Data supplements.

Three-dimensional airframe models make it easy to document and research structural incidents. Incidents can be plotted graphically to show exactly which part of the airframe was affected. Clicking on an incident brings up detailed information about it.

## STREAMLINES ACCESS TO MAINTENANCE INFORMATION



Role-based to align with work activities (e.g., structures, maintenance control, engineering, maintenance planning) to meet information needs

Graphical user interface to streamline access to information across all documentation

Training information deeply integrated and available as-needed

Intuitive user interface and common look and feel to minimize user learning curve

Distributed staff and service partners work from a common information set

Operators can create and customize maintenance documentation sets to capture and reuse best practices and defined procedures. The Toolbox also includes the ability to manage documentation revisions and approval processes and allows for the configuration of promotion and publishing rules.

The Toolbox may also be used to automate task cards. It can:

- Keep task cards in sync with AMM revisions.
- Maintain complete audit trails for regulatory compliance.
- Organize and maintain task card collections to support maintenance program requirements.
- Create and assign task cards to specific airplanes, locations, and schedules.
- Transmit task cards.

### INTEGRATES ON-DEMAND TRAINING

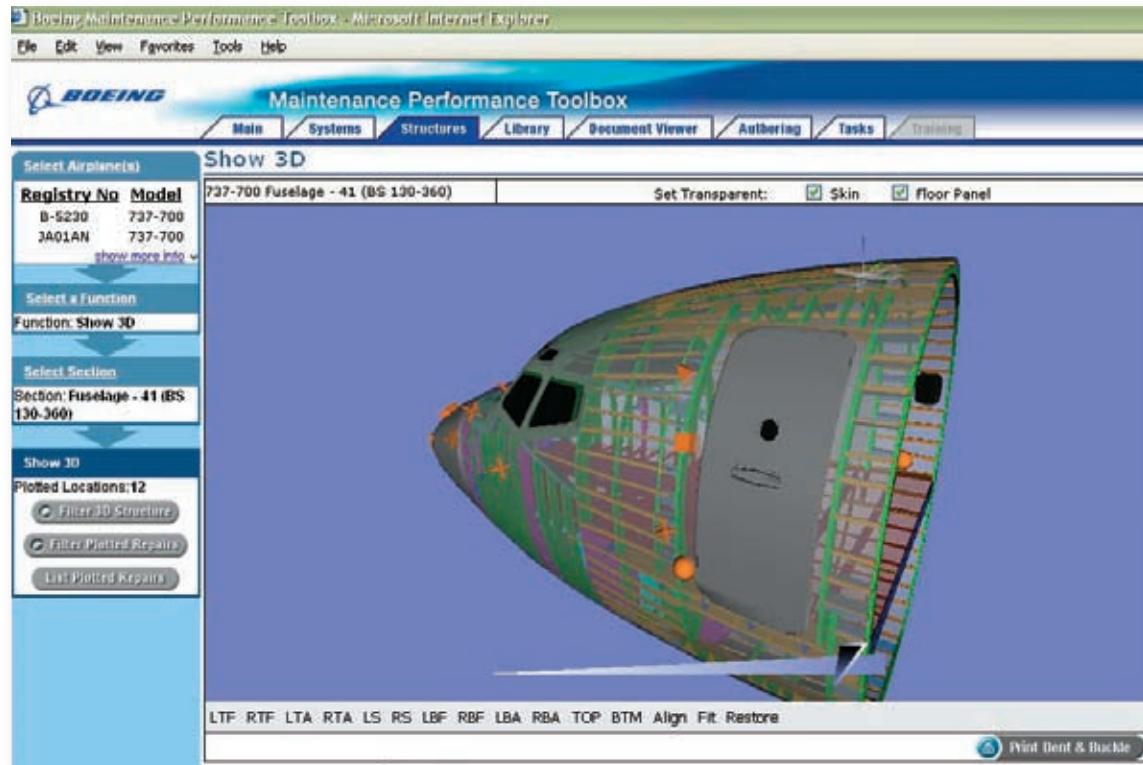
Future plans call for the Maintenance Performance Toolbox to integrate on-demand training within the maintenance information, making it available for reference and review where and when it is needed.

The Toolbox will provide direct access to up-to-date training information and offer access and navigation to existing and new training media. Additional training functionality will include links to desktop simulations.

### A SECURE, MANAGED, HOSTED SERVICE

The Maintenance Performance Toolbox eliminates the costs associated with IT infrastructure and data distribution because it is a managed, hosted service — securely accessible globally — through MyBoeingFleet.com.

The Toolbox is available to operators as individual tools, providing operators the ability to deploy tools individually, or in combination, to match changing requirements.



Operators can create and customize maintenance documentation sets to capture and reuse best practices and defined procedures. The Toolbox also includes the ability to manage documentation revisions and approval processes and allows for the configuration of promotion and publishing rules.

All tools are hosted on Boeing's highly reliable and secure infrastructure. This approach offers operators lower initial infrastructure costs, reduced ongoing IT maintenance burden, quicker deployments, and the most current, approved maintenance information.

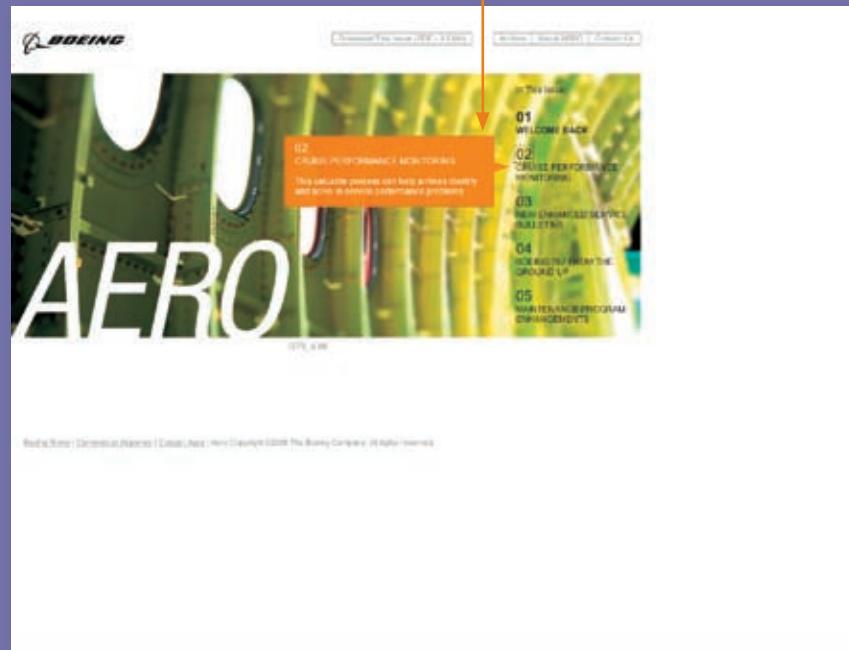
#### SUMMARY

The Maintenance Performance Toolbox is designed to go beyond CD-ROMs and document management solutions to provide maintenance information in a format and functionality that helps operators optimize their maintenance performance. Its graphical interfaces, combined with advanced data-mining and search capabilities, reduce the time required to access and use maintenance information. The functionality it provides allows operators to effectively control and customize their maintenance information. The Toolbox can help operators improve airplane system troubleshooting, reduce repair turnaround times, eliminate redundant tasks, and maximize knowledge transfer and retention. The entire system is delivered as a secure, highly reliable hosted service that allows operators to deploy flexible maintenance performance solutions at lower cost. For more information, contact Rex Douglas at [rex.b.douglas@boeing.com](mailto:rex.b.douglas@boeing.com). 

# AERO online

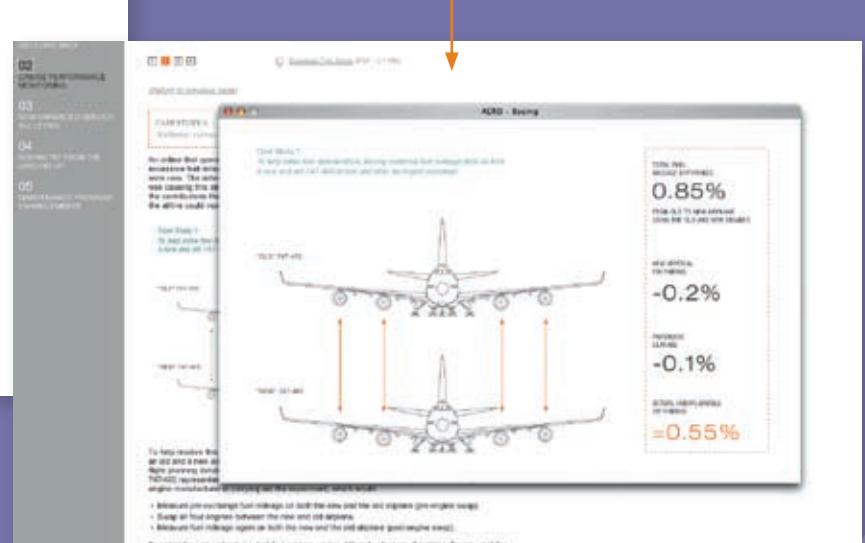
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