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Special Issue on Operational Efficiency and Environmental Performance:

AERO

Cover photo: *Boeing airplane in production.*

AERO

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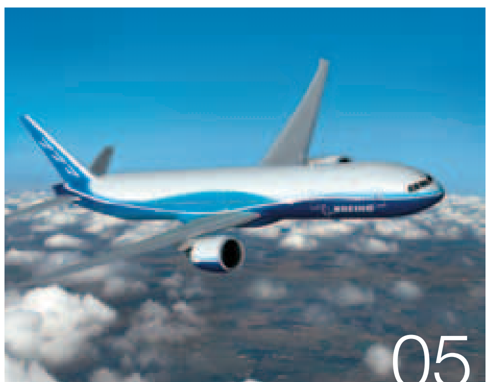
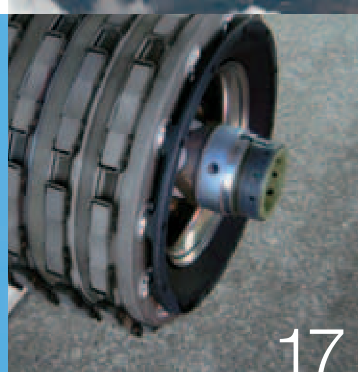
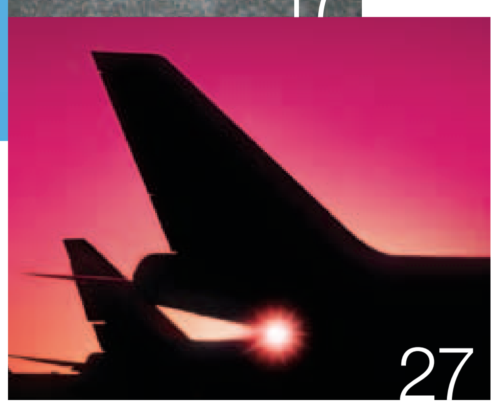
Special Issue: Operational Efficiency and Environmental Performance

Boeing technologies are helping operators be more efficient. Our goal is to help you drive reductions in fuel burn while increasing the efficiency of individual airplanes and entire fleets.







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AERO magazine is published quarterly by Boeing Commercial Airplanes and is distributed at no cost to operators of Boeing commercial airplanes. *AERO* provides operators with supplemental technical information to promote continuous safety and efficiency in their daily fleet operations.

The Boeing Company supports operators during the life of each Boeing commercial airplane. Support includes stationing Field Service representatives in more than 60 countries, furnishing spare parts and engineering support, training flight crews and maintenance personnel, and providing operations and maintenance publications.

Boeing continually communicates with operators through such vehicles as technical meetings, service letters, and service bulletins. This assists operators in addressing regulatory requirements and Air Transport Association specifications.

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

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Operational Efficiency and Environmental Performance

PER A. NORÉN
Director of Aviation Infrastructure, Boeing Commercial Aviation Services (Formerly Director of Environmental Strategy and Solutions)

Working closely with airlines to optimize their operational efficiency — while at the same time progressively improving their environmental performance — is a passion of mine. Before joining Boeing, I was chief executive officer of Carmen Systems, a software company providing crew and fleet management efficiency solutions to airlines around the world. Carmen Systems is now an integral part of Boeing subsidiary Jeppesen and The Boeing Company itself.

Operational efficiency and environmental performance are a priority at Boeing, and I'm proud to introduce this issue of *AERO* magazine, which is dedicated to these topics. Opportunities to improve operational efficiency can be found in all phases of an airplane's lifecycle. In this issue, you will see how Boeing technologies are helping operators be more efficient — from fuel conservation to blended winglets to flight planning to monitoring real-time airplane performance. Our goal is to help you drive reductions in fuel burn while increasing the efficiency of individual airplanes and entire fleets.

One of our more recent improvements is the 777 Performance Improvement Package, which helps operators of 777s fly their airplanes more efficiently. Each package installed on a 777-200ER can save 1 percent of fuel and reduce carbon-dioxide emissions by 1,500 tons annually.

Boeing is always looking for ways to help you, our valued customer, improve fleet efficiency. In fact, we recently announced performance improvements to the Next-Generation 737 that will reduce fuel burn by 2 percent and maintenance costs by 4 percent by 2011. You can find out more at http://boeing.mediaroom.com/index.php?s=43&item=633.

At Boeing, we will continue to increase the rate at which we offer technology solutions that help you improve your operational efficiency and environmental performance — and save you money. We know that each product improvement that we make — each new technology that we offer — helps you release the full potential of your Boeing airplanes.

To learn more about Boeing's environmental commitment, see the Boeing 2009 Environmental Report *at http://www.boeing.com/environment.*

The 777 PIP package lowers operational costs and improves the environmental profile of existing, in-service airplanes.

Delivering Fuel and Emissions Savings for the 777

By Ken Thomson, Project Manager, Modification Services, Business Development & Strategy, Commercial Aviation Services; and
E. Terry Schulze, Manager, Aerodynamics

Boeing's new 777 Performance Improvement Package (PIP) provides operators with a cost-effective way to retrofit their existing 777-200, 777-200 Extended Range (ER), and 777-300 airplanes in order to save fuel and reduce carbon dioxide (CO_2) and nitrogen oxide (NOx) emissions. The 777 PIP provides a typical 777-200ER airplane with an annual savings of 1 million pounds of fuel and an annual reduction of CO_2 emissions of more than 3 million pounds (1,360,800 kilograms). Operators can realize tremendous savings when multiplying these benefits across their 777 fleet.

When Boeing was designing the 777-300ER, several performance enhancements were made to extend the airplane's range and payload capabilities. Boeing engineers realized that many of these enhancements could be retrofitted to earlier models of the 777 to improve their performance.

The result is the 777 PIP, which is available for 777-200, -200ER, and -300 airplanes. It reduces fuel consumption by 1 percent or more, depending on range, with corresponding reductions in CO_2 and NOx emissions. Since Boeing made the PIP available in late 2008, kits for approximately 300 airplanes have been sold to 17 customers.

This article describes the elements comprising the 777 PIP, the performance improvements the PIP makes possible, and information for operators considering implementing the PIP.

COMPONENTS OF THE 777 PIP

The 777 PIP has three separate elements: an improved ram air system, aileron droop, and resized vortex generators.

Improved ram air system. The new exhaust housing has exit louvers that provide exhaust modulation to the environmental control system ram air system. The ram air flow through the system is controlled by using an optimized modulation schedule for the ram air inlet door and the exit louver positions. The improved system lowers airplane drag by improving thrust recovery at the exit of the system (see fig. 1).

Drooped aileron. This software-based modification reduces drag by creating higher aerodynamic loading on the outboard part of the wing and making the spanwise loading more elliptical. As the aileron droops, the increased loading also causes a wing twist change that reduces the local flow incidence toward the wingtip. This reduces the shock strength on the outboard wing, thereby reducing drag even further (see fig. 2).

Figure 1: Ram air system improvement

The improved ram air system is designed to increase performance by reducing drag.

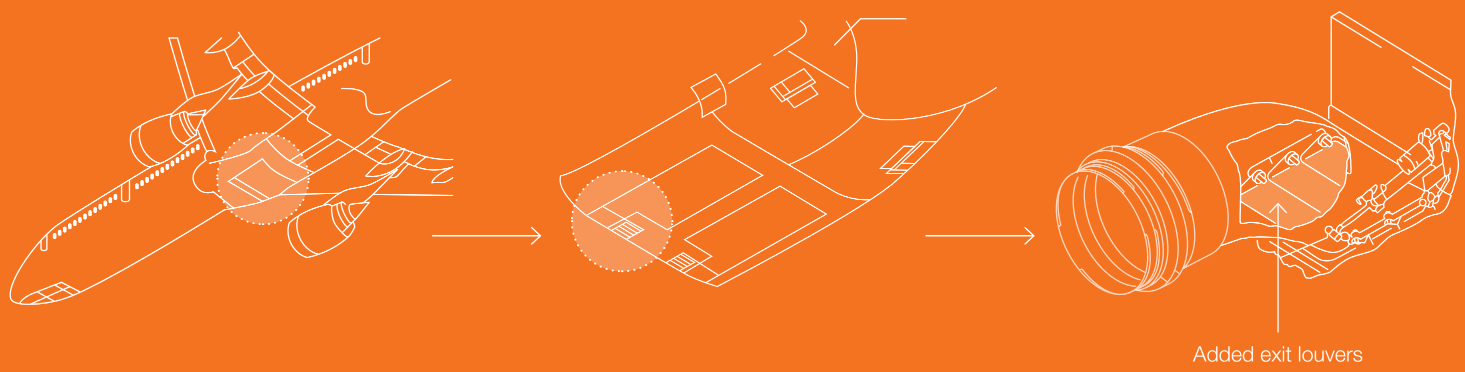


Figure 2: Drooped aileron

Boeing engineers determined that a 2-degree aileron droop was optimal for flight performance.

Detail of aileron cross section

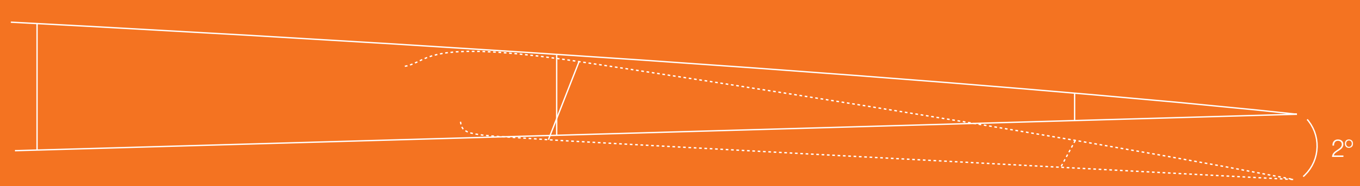
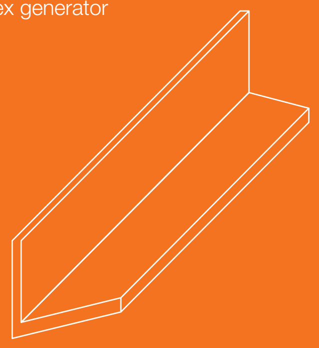


Figure 3: Improved vortex generators

The 777 PIP replaces all 32 vortex generators on the airplane's wings with a newly designed version that reduces drag.

Current vortex generator



737-size vortex generator

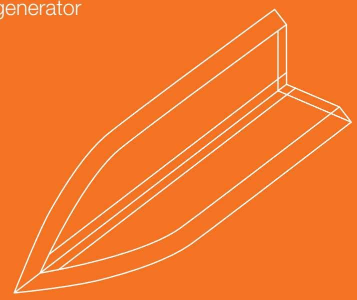
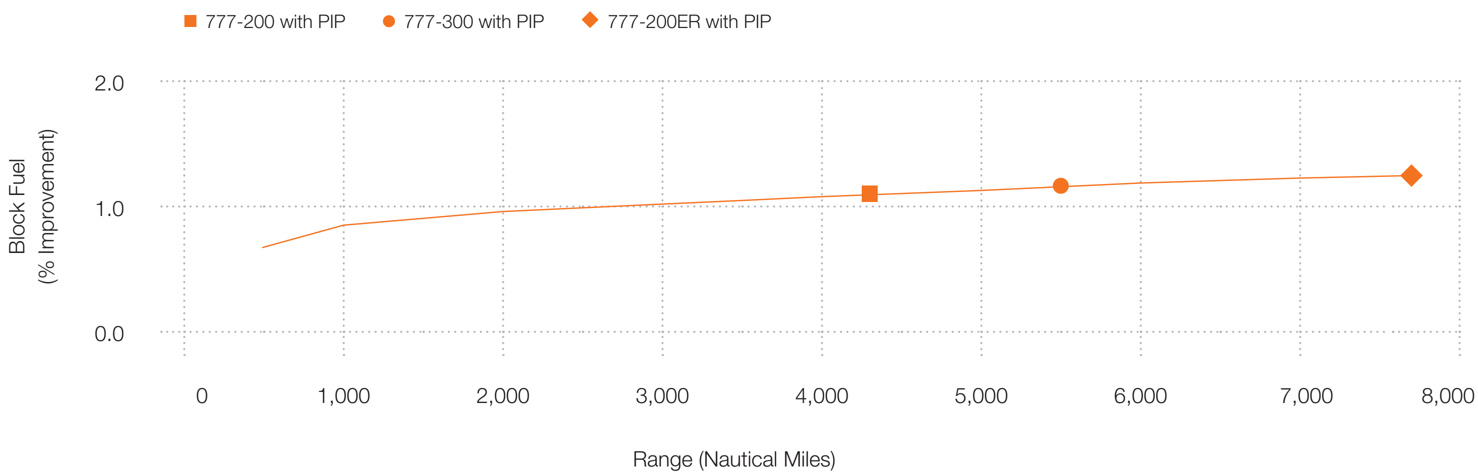


Figure 4: 777-200/-200ER/-300 block fuel vs. range

Boeing typical mission rules with 2,000-ft cruise steps, 210-lb passenger allowance, and standard day temperatures.



Resized vortex generators. Replacing the original 777 vortex generators with the smaller 737-type vortex generators reduces drag while maintaining the effectiveness of the original design (see fig. 3).

HOW THE 777 PIP IMPROVES PERFORMANCE

The 777 PIP makes possible three operational improvements to previously delivered 777 airplanes. These improvements are mutually exclusive — an operator can realize one effect per flight.

- For an operation carrying the same payload as a non-PIP airplane, the PIP-equipped airplane will fly farther.
- For an operation flying the same range as a non-PIP airplane, the PIP-equipped airplane will carry more payload.
- For an operation carrying the same payload and flying the same range as a non-PIP airplane, the PIP-equipped airplane will reduce fuel consumption as well as reducing CO_2 and NOx emissions commensurately (see fig. 4).

OPERATOR INFORMATION

The 777 PIP comprises three separate service bulletins, one for each of the elements in the PIP. While maximum performance gains are realized by equipping an airplane with all three elements, operators may choose to implement them separately in a way that corresponds to their maintenance schedule.

The drooped aileron is a software modification that can be accomplished within three hours. The vortex generators can be replaced overnight. Because the ram air system involves modifications to the airplane's environmental control system, it requires several days. As a result, operators may choose to perform this modification during a heavy maintenance check. The first two modifications alone will enable operators to realize about 60 percent of the total PIP benefit until the ram air modification can be scheduled.

In most cases, Boeing anticipates that operators should experience a 12- to 18-month payback period when implementing the full complement of PIP elements.

SUMMARY

Boeing is committed to improving existing, in-service airplanes. The 777 PIP package lowers operational costs and improves the environmental signature of the airplanes.

For more information, please contact Ken Thomson at kenneth.a.thomson@boeing.com or Terry Schulze at e.t.schulze@boeing.com.

Blended winglets are a proven way to reduce drag, save fuel, cut CO_2 and NOx emissions, and reduce community noise.

Blended Winglets Improve Performance

By William Freitag, Winglet Program Manager, Commercial Aviation Services; and
E. Terry Schulze, Manager, Aerodynamics

Blended winglets are wingtip devices that improve airplane performance by reducing drag. Boeing and Aviation Partners Boeing (APB) began making them available on the Boeing Business Jet (BBJ) and Next-Generation 737-800 in 2001. Flight test data demonstrate that blended winglets lower block fuel and carbon dioxide (CO_2) emissions by up to 4 percent on the 737 and up to 5 percent on the 757 and 767. Blended winglets also improve takeoff performance on the 737, 757, and 767, allowing deeper takeoff thrust derates that result in lower emissions and lower community noise.

Boeing offers blended winglets as standard equipment on the BBJ and as optional equipment on the 737-700, -800, and -900 Extended Range (ER). Blended winglets also are available as a retrofit installation from Aviation Partners Boeing for the 737-300/-500/-700/-800/-900, 757-200/-300, and 767-300ER (both passenger and freighter variants) commercial airplanes. More than 2,850 Boeing airplanes have been equipped with blended winglets.

The carbon-fiber composite winglets allow an airplane to save on fuel and thereby reduce emissions. The fuel burn improvement with blended winglets at the airplane's design range is 4 to 5 percent. For a 767 airplane, saving half a million U.S. gallons of jet fuel a year per airplane translates into an annual reduction of more than 4,790 tonnes of CO_2 for each airplane. The addition of winglets can also be used to increase the payload/range capability of the airplane instead of reducing the fuel consumption. Airplanes with blended winglets also show a significant reduction in takeoff and landing drag.

This article provides background about the development of blended winglets, describes the principle behind their operation, and outlines the types of performance improvements operators can expect from them.

THE DEVELOPMENT OF BLENDED WINGLETS

Blended winglets were initially investigated by Boeing in the mid-1980s and further developed in the early 1990s by Aviation Partners, Inc., a Seattle, Wash., corporation of aerospace professionals consisting primarily of aeronautical engineers and flight test department directors.

The blended winglet provides a transition region between the outboard wing, which is typically designed for a plain tip, and the winglet. Without this transition region, the outer wing would require aerodynamic redesign to allow for the interference between the wing and winglet surfaces.

Figure 1: Blended winglet retrofit certification history

Blended winglets are available for retrofit through APB on the 737, 757, and 767 models.

AIRPLANE MODEL	BLENDED WINGLET RETROFIT CERTIFICATION DATE
737-300	May 2003
757-200	May 2005
737-500	May 2007
737-900	October 2007
767-300ER	March 2009
757-300	July 2009

The first blended winglets were installed on Gulfstream II airplanes. The resulting improvements in range and fuel efficiency interested Boeing, and in 1999, Boeing formed the joint venture company APB with Aviation Partners, Inc., to develop blended winglets for Boeing airplanes. Boeing adopted the blended winglet technology as standard equipment for the BBJ in 2000 and APB certified the winglets for the 737-700 and 737-800 airplanes in 2001. Since then, APB has certified blended winglets for retrofit installation on other Boeing airplane models (see fig. 1). Blended winglets are also installed in production on Next-Generation 737-700/-800/-900ER models.

HOW BLENDED WINGLETS REDUCE DRAG

The motivation behind all wingtip devices is to reduce induced drag. Induced drag is the part of the airplane drag due to global effects of generating lift. In general, wings will produce air motion, called circulation, as a result of generating lift. This motion is characterized by downward flow between the wingtips and upward flow outboard of the wingtips (see fig. 2). As a result, the wing flies in a downdraft of its own making. The lift vector is thereby tilted slightly backward (see fig. 3). It is this backward component of lift that is felt as induced drag.

The magnitude of the induced drag is determined by the spanwise lift distribution and the resulting distribution of vortices (see fig. 4). The vortex cores that form are often referred to as "wingtip vortices," but as is shown, the entire wing span feeds the cores. Any significant reduction in induced drag requires a change in this global flow field to reduce the total kinetic energy. This can be accomplished by increasing the horizontal span of the lifting system or by introducing a nonplanar element that has a similar effect. (More information about the aerodynamic principles of blended winglets can be found in *AERO* 17, January 2002.)

Blended winglets are upward-swept extensions to airplane wings. They feature a large radius and a smooth chord variation in the transition section. This feature sacrifices some of the potential induced drag reduction in return for less viscous drag and less need for tailoring the sections locally.

Although winglets installed by retrofit can require significant changes to the wing structure, they are a viable solution when gate limitations make it impractical to add to wingspan with a device such as a raked wingtip.

BLENDED WINGLET PERFORMANCE IMPROVEMENTS

The drag reduction provided by blended winglets improves fuel efficiency and thereby reduces emissions (see fig. 5). Depending on the airplane, its cargo, the airline's routes, and other factors, blended winglets can:

- Lower operating costs by reducing block fuel burn by 4 to 5 percent on missions near the airplane's design range.
- Increase the payload/range capability of the airplane instead of reducing the fuel consumption.
- Reduce engine maintenance costs.
- Improve takeoff performance and obstacle clearance, allowing airlines to derate engine thrust.
- Increase optimum cruise altitude capability.

REDUCTION IN EMISSIONS AND COMMUNITY NOISE

Operators of blended winglets are able to gain the additional environmentally friendly benefit of reducing engine emissions and community noise. CO_2 emissions are reduced in direct proportion to fuel burn, so a 5 percent reduction in fuel burn will result in a 5 percent reduction in CO_2. Nitrogen oxide (NOx) emissions are reduced in percentages that are a function of the

Figure 2: Motion of the air behind a lifting wing

Without winglet

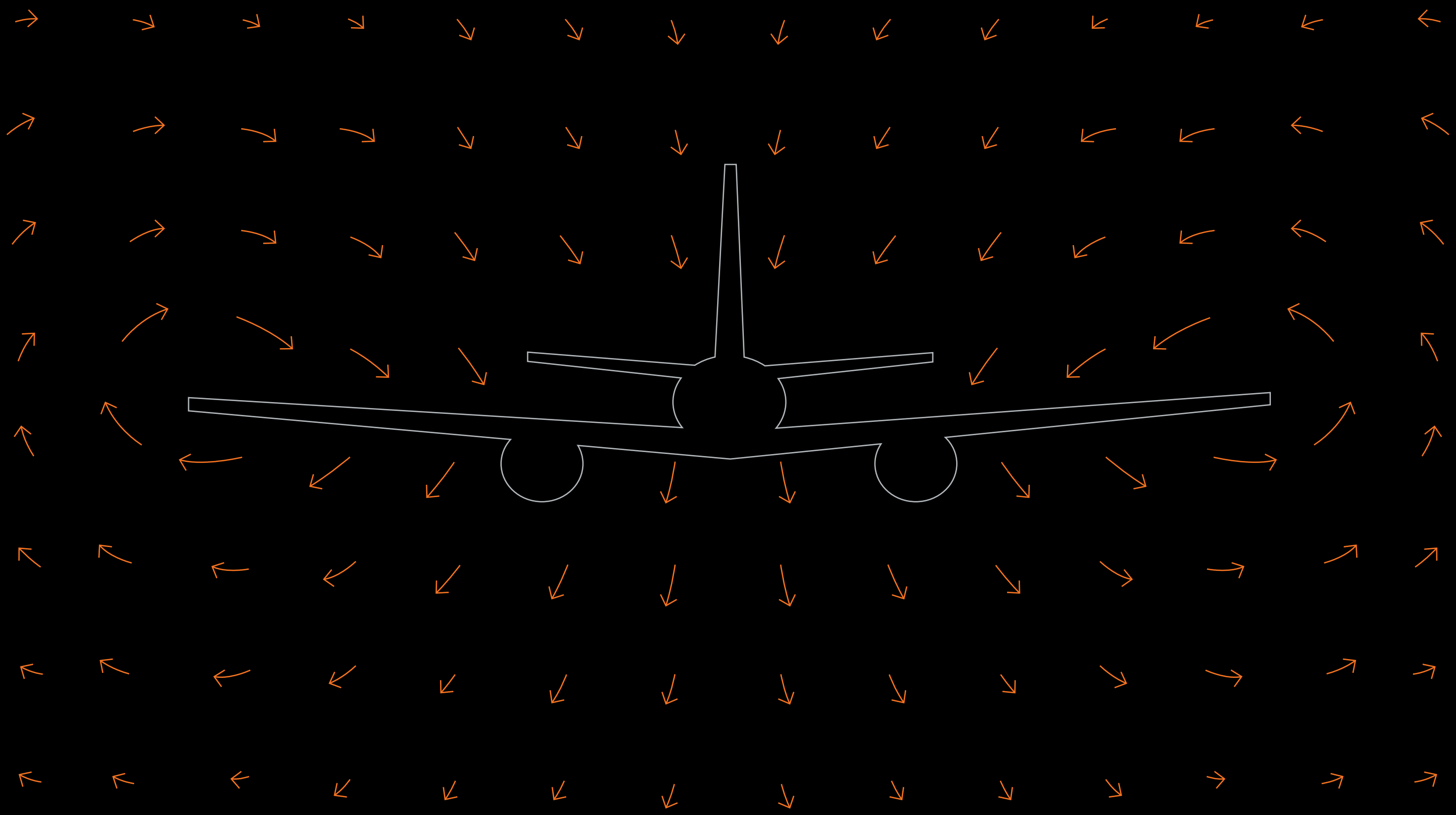


Figure 3: Blended winglets affect induced drag

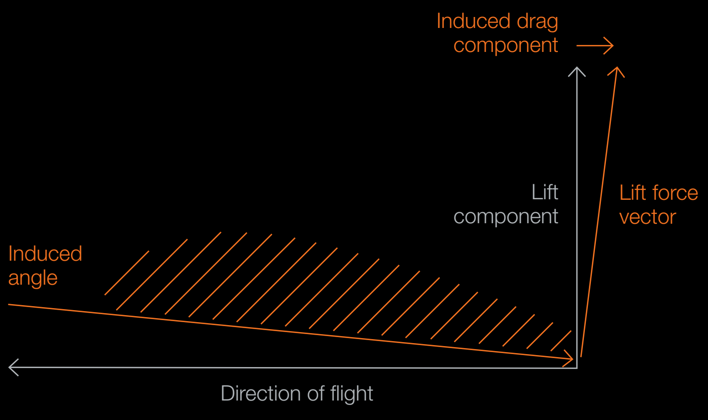


Figure 4: The vortex wake behind a lifting wing

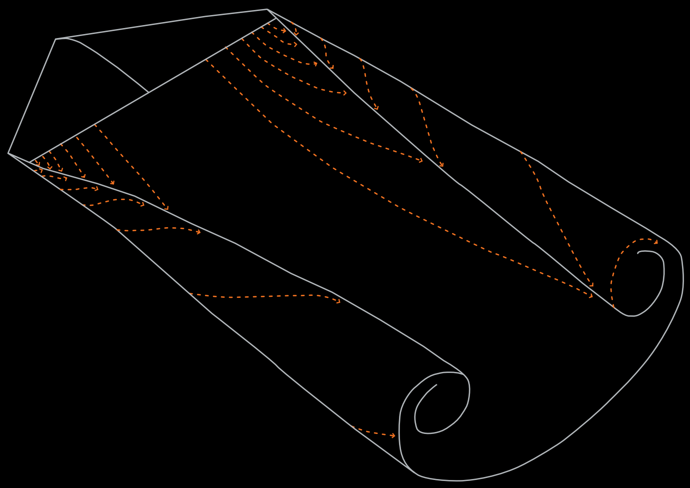


Figure 5: Estimated fuel savings on airplanes equipped with blended winglets

Estimate will vary depending on the mission parameters.

MODEL	LOAD (PASSENGERS)	MISSION (NAUTICAL MILES)	FUEL USE WITHOUT WINGLETS (LBS)	FUEL USE WITH WINGLETS (LBS)	ESTIMATED FUEL SAVINGS
737-800	162	500	7,499	7,316	2.5%
		1,000	13,386	12,911	3.5%
757-200	200	1,000	16,975	16,432	3.2%
767-300ER	218	3,000	65,288	62,419	4.4%

airplane, engine, and combustor configuration.

At airports that charge landing fees based on an airplane's noise profile, blended winglets can save airlines money every time they land. The noise affected area on takeoff can be reduced by up to 6.5 percent. With requirements pending in many European airports for airplanes to meet Stage 4/Chapter 4 noise limits, the addition of blended winglets may result in lower landing fees if the winglet noise reduction drops the airplane into a lower-charging noise category. The noise reduction offered by blended winglets can also help prevent airport fines for violating monitored noise limits.

BENEFITS FROM OPERATORS USING BLENDED WINGLETS

Airlines have been gathering operational data on blended winglets since they first began flying airplanes equipped with the modification in 2001. These benefits include:

- One operator flying 737-700s had three years of data showing a fuel savings of 3 percent.
- Another operator flying 737s also reports that blended winglets are helping reduce fuel consumption by 3 percent, or about 100,000 U.S. gallons of fuel a year, per airplane.

Other airlines are projecting results based on historical flight data about airplane models recently equipped with blended winglets:

- An operator with a fleet of 767-300ER airplanes estimates that installing blended winglets will save 300,000 U.S. gallons of fuel per airplane per year, reducing CO_2 emissions by more than 3,000 tonnes annually.
- An airline that recently began flying 767-300ERs with blended winglets anticipates that each airplane equipped with the winglets will save up to 500,000 U.S. gallons of fuel annually, depending on miles flown. The airline plans to install winglets on its entire 58-airplane fleet of 767-300ERs, which could result in a total savings of up to 29 million U.S. gallons of fuel per year and a reduction of up to 277,000 tonnes of CO_2 emissions annually.

SUMMARY

Blended winglets are a proven way to reduce drag, save fuel, cut CO_2 and NOx emissions, and reduce community noise. They can also extend an airplane's range and enable additional payload capability depending on the operator's needs. Depending on the airplane model, blended winglets are available either as standard or optional equipment through Boeing or for retrofit through Aviation Partners Boeing.

For more information on blended winglets and Stage 4/Chapter 4 noise certification, please contact Bill Freitag at william.j.freitag@boeing.com or Terry Schulze at e.t.schulze@boeing.com.

Crew Management Tools Improve Operating Efficiency

By Tomas Larsson, Product Manager, Fleet & Recovery, Jeppesen

Frequent changes in airlines' market situations make it challenging to maintain efficient operations. This can lead to an underutilized fleet and crew, or even worse, a shortage of resources. Boeing subsidiary Jeppesen helps airlines overcome these challenges by enabling them to optimize crew utilization in terms of cost, robustness, and crew quality of life.

Airline operations have three major cost drivers: airplanes, fuel, and crew. Advanced mathematical models to optimize crew utilization were introduced in the early 1990s and have evolved continually since then. Key to the long-term success of such models is their adaptability to changes in planning conditions and their ability to absorb advancements in technology. Because of the large numbers of crew employed by major airlines, even small changes in productivity can have a significant impact on an airline's profits: a single percent improvement can translate into several million dollars.

This article provides an overview of the crew management challenge that airlines face and illustrates the benefits of Jeppesen crew management software tools.

THE CREW MANAGEMENT CHALLENGE

Airlines want their crews to work as efficiently as possible within regulatory and contractual requirements. But an efficient plan also needs to be flexible enough to work under changes in real-world conditions. For example, it needs to easily accommodate the unexpected, such as sick crews or delayed flights.

What's more, airline crews quite naturally want to influence their work content. Therefore, crew preferences are important inputs in the crew planning process. The crew planner also needs to monitor such items as crew fatigue, hotel costs, and standby requirements and deliver a crew plan that meets the airline's objectives month after month.

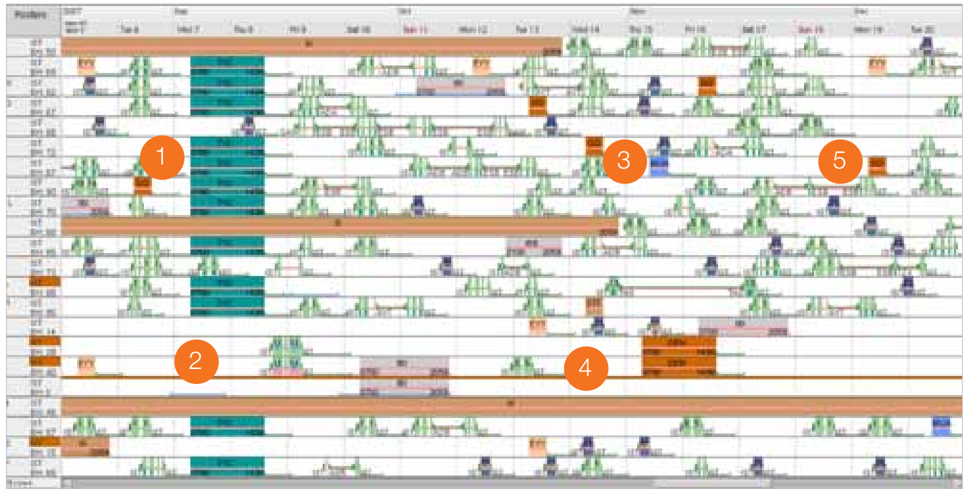
Additional complications include implementation of a new crew agreement or an entire new fleet of airplanes. The result is that crew planners need to consider a wide array of information (see fig. 1).

Jeppesen has developed a suite of software applications that streamlines crew management and automates the scheduling process (i.e., Carmen Crew Management). These tools help airlines manage dynamic flight schedules, crew member requirements, and complex logistical and contractual requirements. As a result, they deliver substantial savings in what usually is a major cost center for airlines. The following examples illustrate how airlines are using Jeppesen software tools.

Figure 1: Crew planning challenges

This crew management software computer screen shows the variety of often conflicting information crew planners must consider when assigning crews.

1 Classroom training
2 Day-off bid
3 Medical check
4 Minimum rest after duty
5 Simulator training



Use case No. 1: Optimizing preferential bidding

A major U.S. airline found its previous preferential bidding system inadequate because it left a large share of the flights unassigned and failed to meet contractual obligations with the pilot union. The airline's new Jeppesen-based system offers a number of improvements:

- It enables full compliance with the contractual agreements by providing the ability to guarantee a crew group a minimum level of assignment, which corresponds to pay.
- It reduces the amount of open time (unassigned production) by nearly 30 percent. Because any open time left after crew roster publication must be covered by reserves, this provides real productivity improvements. In addition, the system levels the distribution of open time, reducing the biggest peak in open time by 50 percent. This also has a positive impact on productivity as a single reserve can take on only one duty at a time.
- It awards crews more of their bids than the previous system. It was most important to the airline that this was achieved for the more senior crew members, but the new system also resulted in an overall improvement in the bid award ratio of 14 percent.

Use case No. 2: Coping with rapid growth

One of the world's fastest-growing airlines found its in-house solution for crew planning insufficient as it increased its revenue passenger kilometers (RPK) by about 20 percent per year for two consecutive years. The airline chose a more efficient Jeppesen solution to help it cope with its rapid growth.

In order to be operational with the system as quickly as possible, the airline and Jeppesen decided that Jeppesen would provide crew planning as a service while the software was being implemented. By using this approach, the airline could begin realizing savings within six weeks. The realized improvement in crew productivity was 12 percent.

After six months, the airline was running the system on its own. It also began using the new system's scenario capability. A scenario may be a new schedule, new rules for how to schedule crew, revised costs, revised resource availability, or any combination. One of the most promising scenarios was to allow cabin crew to mix fleets in their rosters. This resulted in nearly 5 percent of additional efficiency improvements.

Use case No. 3: Streamlining a union agreement

A planning system that is not visible to all of the parties involved is often perceived with skepticism by planners, management, and crew. In contrast, when all parties feel that they can control the system — rather than be controlled by it — the analytical power of the system can be leveraged effectively.

This was the case at an airline in a crisis when union agreement negotiations started. It was clear from the beginning that crew productivity needed to be improved; the question was how to achieve this improvement. The main obstacle to negotiations was an agreement that had grown to more than 200 pages through years of additions and modifications.

Because the changes that had been made over time resulted in an unnecessarily complicated agreement, the parties decided to take a fresh start, retaining only some fundamental rules and those related to regulatory issues. Then, in a brainstorming session, all ideas that were presented — good as well as bad — were implemented in the crew planning system and tested. Because the system was trusted by both parties, there was no dispute on whether the key performance indicators generated by the system were correct.

The result was a new union agreement that reduced crew costs by 15 to 20 percent. Such savings would not have been possible within the previous agreement without severely affecting crew pay. At the same time, the new union agreement went from 200 pages down to 15 pages. The agreement is seen as joint property by management and unions and is fully comprehensible by both parties. The system's ability to allow for advanced simulations, combined with both parties' trust in the system, facilitated a successful negotiation process.

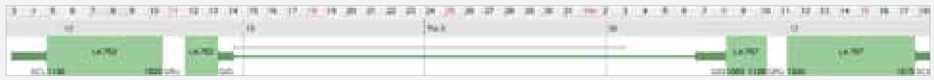
SUMMARY

Jeppesen Carmen Crew Management optimization software provides fast, high-quality solutions for large crew populations, including complex problems with a high number of conflicting objectives. By improving the efficiency of assigning and managing airline crews, this software can help enhance overall airline operational efficiency.

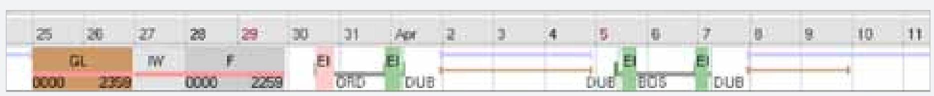
For more information, please contact Tomas Larsson at tomas.larsson@jeppesen.com. A

Definitions

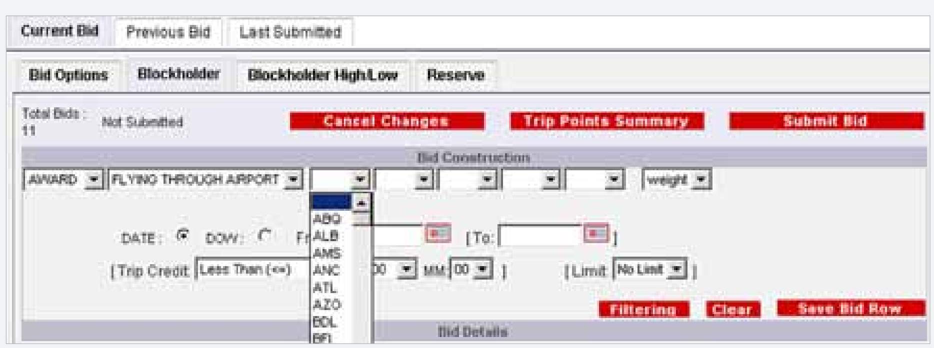
Pairing: A crew pairing is a sequence of flight legs from home base to home base. A pairing may cover one or many days. This is how a two-day pairing from Santiago to Rio de Janeiro via São Paulo and back is represented by Jeppesen crew management software.



Roster: A crew roster is a sequence of personal activities assigned to a crewmember. A roster contains not only pairings but also training, reserve duties, and other activities. Crew management typically provides rosters to crews monthly. Below is a depiction of a crewmember roster. The crewmember comes back from a sequence of ground activities. Those activities are followed by the crewmember traveling as a passenger from Dublin to Chicago, staying overnight, and flying back as an active duty. This is followed by three mandatory days off. Thereafter, the crewmember operates a round-trip from Dublin with a layover in Boston.



Preferential bidding system: With this system, the crewmember bids for specific assignments. How this is done varies by airline. The crewmember may bid for pairings or for pairing properties, such as layover station, length of pairing, or check-in time. In almost all cases, the crewmember can bid for days off. In North America, bids are awarded based on seniority. In the rest of the world, some type of adjustment criteria is usually used. In this example, the crewmember is about to enter a request to get a pairing flying through a particular airport. The crewmember may also specify the length and dates of the stay.



The lower weight of carbon brakes results in slightly lower fuel consumption, which can reduce CO_2 emissions.

Operational Advantages of Carbon Brakes

By Tim Allen, Program Integration Manager, Airplane Integration, 737 Programs;
Trent Miller, Lead Engineer, Wheels/Tires/Brakes Production Programs; and
Evan Preston, Engineer, Wheels/Tires/Brakes Production Programs

Carbon brakes offer a significant weight savings compared to steel brakes. This translates into a lighter airplane, which directly contributes to decreased fuel consumption and associated reductions in engine emissions.

Carbon brakes are a practical alternative to steel brakes. Advances in engineering and manufacturing mean that retrofitting carbon brakes onto existing airplanes can decrease fuel costs for certain models.

This article provides historical background about carbon brakes and outlines their operational advantages, including their positive environmental impact. It is important to note that this article does not address total cost of ownership topics such as usage and overhaul costs. Operators should weigh the decisions on brake type based on several considerations, including specific model usage, route utilization, and cost structure.

CARBON BRAKE HISTORY

Carbon brakes were originally used in high-performance military aircraft applications. The lower weight and higher energy absorption capability of carbon brakes justified their cost, which historically was higher than the cost of steel brakes. These cost considerations often resulted in the use of steel brakes on smaller, short-haul commercial airplanes and carbon brakes on larger, long-haul commercial airplanes. In the past, the higher cost of carbon brakes could more easily be justified for larger airplanes because of the cost savings associated with reduced weight and longer service life.

However, recent improvements in carbon brake manufacturing and overhaul

Figure 1: Carbon brakes offer high performance

A Next-Generation 737-900 Extended Range (ER) airplane performs a high-speed rejected takeoff test to verify that an airplane at maximum weight with greatly worn carbon brakes can stop safely after a refused takeoff decision.

Figure 2: Carbon brake weight savings

Weight comparison: steel vs. carbon brakes

AIRPLANE MODEL	WEIGHT SAVINGS IN LBS (KILOGRAMS)
737-600/-700	550 (250)*
737-600/-700/-700IGW/-800/-900/-900ER	700 (320)**
757	550 (249)
767	800 (363)
MD-10 Freighter	976 (443)

* Carbon brakes weigh 550 lbs (250 kg) less than standard-capacity steel brakes for 737-600 and -700 models.

** Carbon brakes weigh 700 lbs (320 kg) less than high-capacity steel brakes on 737-600/-700/-700 Increased Gross Weight/-800/-900/ and -900ER models.

procedures have reduced the per-landing cost of carbon brakes to the point that they are cost competitive with steel brakes. Carbon brake manufacturing has become more efficient and overhaul procedures now allow for optimal use of refurbished carbon material.

These improved operating economics — along with the weight savings and performance improvements offered by carbon brakes — have led to increased application of carbon brakes on commercial airplanes.

OPERATIONAL ADVANTAGES

Carbon brakes are well-suited to the high-performance braking demands of commercial airplanes (see fig. 1). Carbon brake material is characterized by high temperature stability, high thermal conductivity, and high specific heat. Carbon brakes have a number of operational advantages relative to steel brakes:

- *Longer life:* Carbon brakes offer up to twice as many landings per overhaul as steel brakes.
- *Cost effectiveness:* For most operations, the life-cycle costs of carbon brakes are now similar to those of steel brakes.
- *High performance:* Carbon brakes have greater energy absorption capability than steel brakes.
- *Lightweight:* Carbon brakes are significantly lighter than steel brakes.

ENVIRONMENTAL IMPACT

One of the primary benefits of carbon brakes is the amount of weight they remove from an airplane (see fig. 2). The lower weight of carbon brakes results in slightly lower fuel consumption, which reduces carbon dioxide (CO_2) emissions.

CARBON BRAKE AVAILABILITY

Carbon brakes became widely available for commercial airplanes in the 1980s. They are or were basic equipment on the Boeing 747-400 and -400ER, 757-300, 767, and 777 and the MD-11 and MD-90. They are basic equipment on the 787 Dreamliner and 747-8.

Carbon brakes are optional and will be available for retrofit for the Next-Generation 737 via no-charge service bulletins. They are also available for retrofit via master change service bulletins on the 757-200, 767-200, and 767-300 and MD-10 models.

SUMMARY

In addition to offering a number of operational advantages relative to steel brakes — including longer life and higher performance — carbon brakes save weight, which lowers fuel consumption and can reduce CO_2 emissions.

For more information, please contact Tim Allen at timothy.j.allen@boeing.com.

Taxi braking recommendations for carbon and steel brakes

Because the wear mechanisms are different between carbon and steel brakes, different taxi braking techniques are recommended for carbon brakes in order to maximize brake life.

Steel brake wear is directly proportional to the kinetic energy absorbed by the brakes. Maximum steel brake life can be achieved during taxi by using a large number of small, light brake applications, allowing some time for brake cooling between applications. High airplane gross weights and high brake application speeds tend to reduce steel brake life because they require the brakes to absorb a large amount of kinetic energy.

Carbon brake wear is primarily dependent on the total number of brake applications — one firm brake application causes less wear than several light applications. Maximum carbon brake life can be achieved during taxi by using a small number of long, moderately firm brake applications instead of numerous light brake applications. This can be achieved by allowing taxi speed to increase from below target speed to above target speed, then using a single firm brake application to reduce speed below the target and repeating if required, rather than maintaining a constant taxi speed using numerous brake applications. Carbon brake wear is much less sensitive to airplane weight and speed than steel brake wear.

These recommendations are intended as general taxi guidelines only. Safety and passenger comfort should remain the primary considerations.

Fuel Conservation Information on MyBoeingFleet

By James A. Johns and **Masud U. Khan,** Flight Operations Engineers, Commercial Aviation Services

MyBoeingFleet.com is a Web portal to a large repository of Boeing aviation information. The business-to-business site offers customers direct access to information on Boeing airplanes and enhances airlines' ability to work collaboratively with Boeing, suppliers, and each other. Boeing has added a section about fuel conservation to the portal. This new section allows customers to browse for general knowledge or query for specific information that can help them reduce fuel consumption and save money.

For more than 50 years, Boeing and McDonnell-Douglas have published articles and made technical presentations on fuel conservation. Because these articles and presentations were authored by different departments — such as marketing, maintenance, engineering, and flight operations — they were maintained and stored in numerous areas within the company.

In mid-2008, fuel prices increased approximately 91 percent, and customers were urgently in need of fuel conservation information. In response, Boeing consolidated fuel conservation information from across the company on a single Web site. The site includes all of the fuel conservation letters, documents, technical presentations, and data within Boeing and McDonnell-Douglas since the 1960s.

This article guides users through the new Fuel Conservation Web site, describes how to locate information, and outlines Boeing's plans for future additions to the site.

ACCESSING THE FLIGHT OPERATIONS FUEL CONSERVATION WEB SITE

To access the Fuel Conservation Web site, log on to the MyBoeingFleet customer Web portal by going to www.MyBoeingFleet.com. (Those who do not have a MyBoeingFleet user ID may contact their airline's MyBoeingFleet focal, who is authorized by Boeing to provide a user ID. Airlines that do not have a focal should contact Boeing Digital Data Customer Support by e-mailing ddcs@boeing.com.)

Logging on to MyBoeingFleet takes the user to a Welcome page that contains information specific to that user. Fuel conservation information is accessed from this page by clicking on the Flight Operations link, which is located in the My Products section. At the Flight Operations home page, the Fuel Conservation link provides access to the main page of the Fuel Conservation site.

Figure 1: Fuel Conservation Web site main page

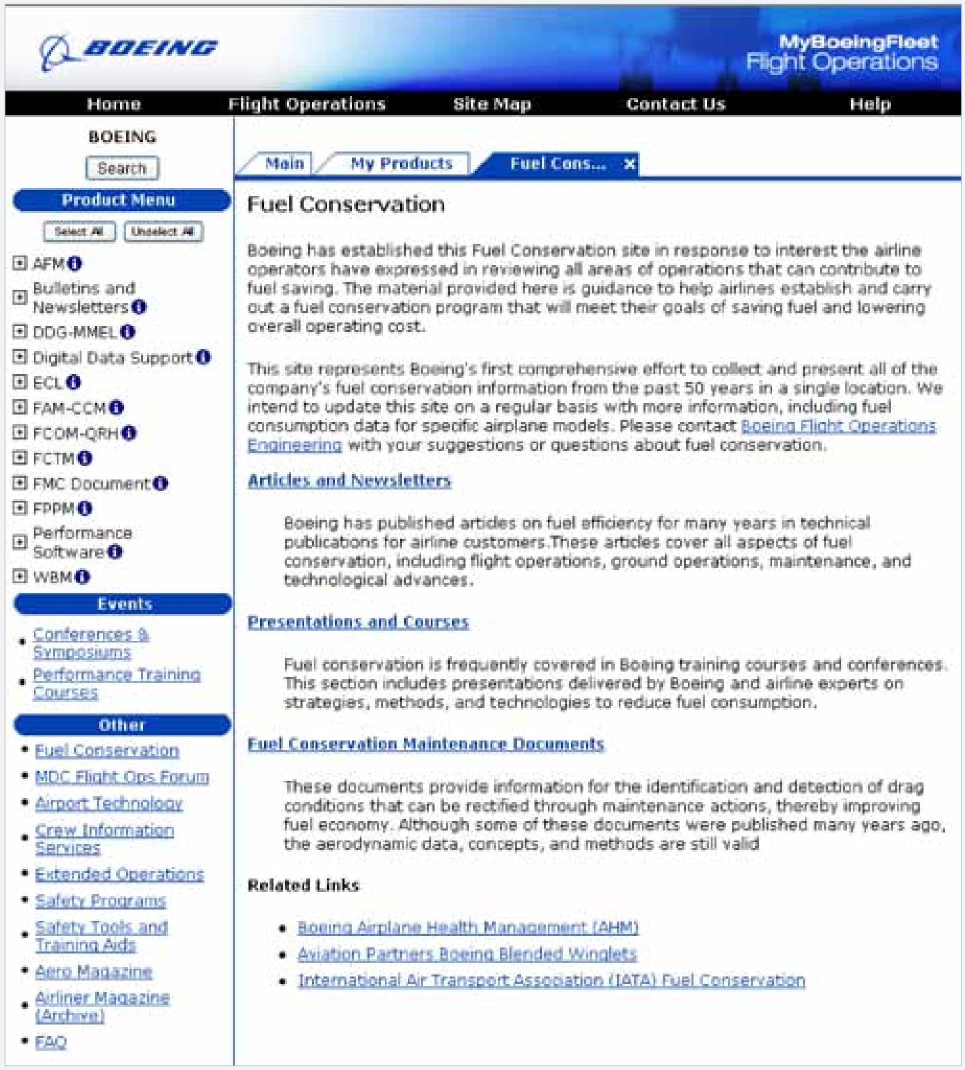
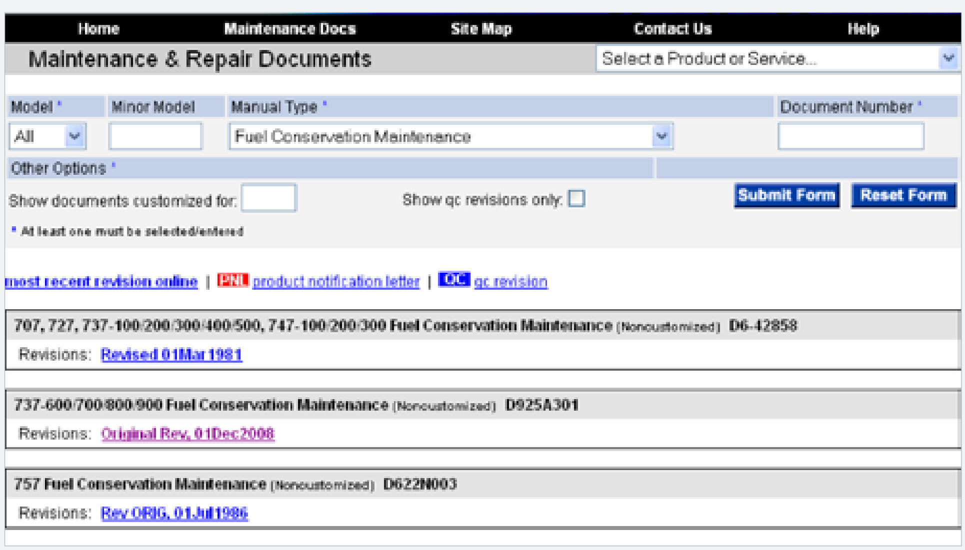


Figure 2: Fuel Conservation Web site Maintenance & Repair Documents page



INFORMATION ON THE FLIGHT OPERATIONS FUEL CONSERVATION WEB SITE

The Fuel Conservation Web site has three major sections: Articles and Newsletters, Presentations and Courses, and Maintenance Documents. A Related Links section provides access to Web sites both within and external to Boeing that have fuel conservation information (see fig. 1).

ARTICLES AND NEWSLETTERS

Boeing has published articles on fuel efficiency for many years in technical publications for airline customers. These articles cover all aspects of fuel conservation, including flight operations, ground operations, maintenance, and technological advances.

This section of the Web site contains the following:

- Relevant articles from *AERO* magazine since January 1999.
- Boeing *Fuel Conservation & Operations Newsletters* that were published from 1981 to 1997 (some of the data within these newsletters dates back to 1974 and earlier).
- Relevant articles from *AERO* magazine's predecessor, *Airliner*, from 1961 to 1992.

For example, the *Fuel Conservation & Operations Newsletter* from April–June 1990 addresses fuel conservation for the 747-400. The issue includes a table that shows the effect of cost indices, climb speed, optimum altitude, cruise speed, descent speed, takeoff flaps selection, and reduced climb thrust on trip fuel. Operators can use the information as a guide in determining how to reduce fuel burn and operational cost for 747 fleets.

PRESENTATIONS AND COURSES

The second section of the Fuel Conservation Web site includes presentations delivered by Boeing and airline experts on strategies, methods, and technologies to reduce fuel consumption. The material typically provides more in-depth information on fuel conservation than the Articles and Newsletters section.

Training course topics include cost index, cruise performance analysis, and the Boeing performance software Airplane Performance Monitoring (APM). The site includes detailed information on how operators can use the APM program for cruise performance analysis, especially for fuel consumption.

In addition to training materials, this section comprises presentations and white papers from Boeing Flight Operations conferences and symposia held since 2003. Topics range from continuous descent final approach to fuel efficiency gap analysis, wingtip devices, weight control, and cruise performance monitoring.

MAINTENANCE DOCUMENTS

Maintenance Documents is the most comprehensive section of the Fuel Conservation Web site. It contains all the fuel conservation maintenance documents that have been published to date by Boeing and McDonnell-Douglas (see fig. 2).

These documents provide information for the identification and detection of drag conditions that can be rectified through maintenance actions, thereby improving fuel economy. Although some of these documents were published many years ago, the aerodynamic data, concepts, and methods are still valid.

The Boeing documents contain fuel conservation information pertinent only to aerodynamics and maintenance of the airplane, while the McDonnell-Douglas documents include information on aerodynamics, flight operations, systems, and performance analysis.

FUTURE PLANS

Boeing plans to continue to add information and data to the Fuel Conservation site. The information will be a function of phase of flight, specific to the various Boeing airplane models, starting with the Next-Generation 737. The goal is to eventually provide model-specific fuel conservation information for the 717, 727, 757, 737 Classic, 747, 767, 777, DC-9, DC-10, MD-11, and future models. Information will cover all phases of flight: taxi out, takeoff, climb, cruise, descent, approach, and taxi in.

SUMMARY

Boeing has developed a Flight Operations Fuel Conservation Web site to help reduce the time and effort spent by customers searching for and retrieving information and data that can help them reduce overall operational costs.

For more information, please contact James A. Johns at james.a.johns@boeing.com or Masud U. Khan at masud.u.khan@boeing.com.

Monitoring Real-Time Environmental Performance

By John B. Maggiore, Senior Manager, Airplane Health Management, Aviation Information Services; and
David S. Kinney, Associate Technical Fellow, Airplane Health Management, Aviation Information Services

Through timely and streamlined identification and diagnosis of issues, Airplane Health Management (AHM) provides significant overall fuel and emission performance measures for individual airplanes, enabling operators to improve overall average fleet performance.

AHM is an information tool designed by Boeing and airline users that collects in-flight airplane information and relays it in real time to the ground. The Performance Monitoring module within AHM provides automated monitoring of fuel consumption and calculation of carbon dioxide (CO_2) emissions. Airlines can use this information to optimize the operation of individual airplanes as well as entire fleets.

This article provides background on the overall AHM tool, explains the goals of the Performance Monitoring module, and shows how automated monitoring of key indicators — such as fuel consumption and CO_2 emissions — can help airlines have a direct impact on the environment and improve their operational efficiency.

AHM BACKGROUND

AHM is a maintenance decision support capability provided through the MyBoeingFleet.com Web portal. AHM uses real-time airplane data to provide enhanced fault forwarding, troubleshooting, and historical fix success rates to reduce schedule interruptions and increase maintenance efficiency. It delivers relevant information whenever and wherever it's needed — data received directly from airplanes is delivered by Boeing within the MyBoeingFleet.com Web portal.

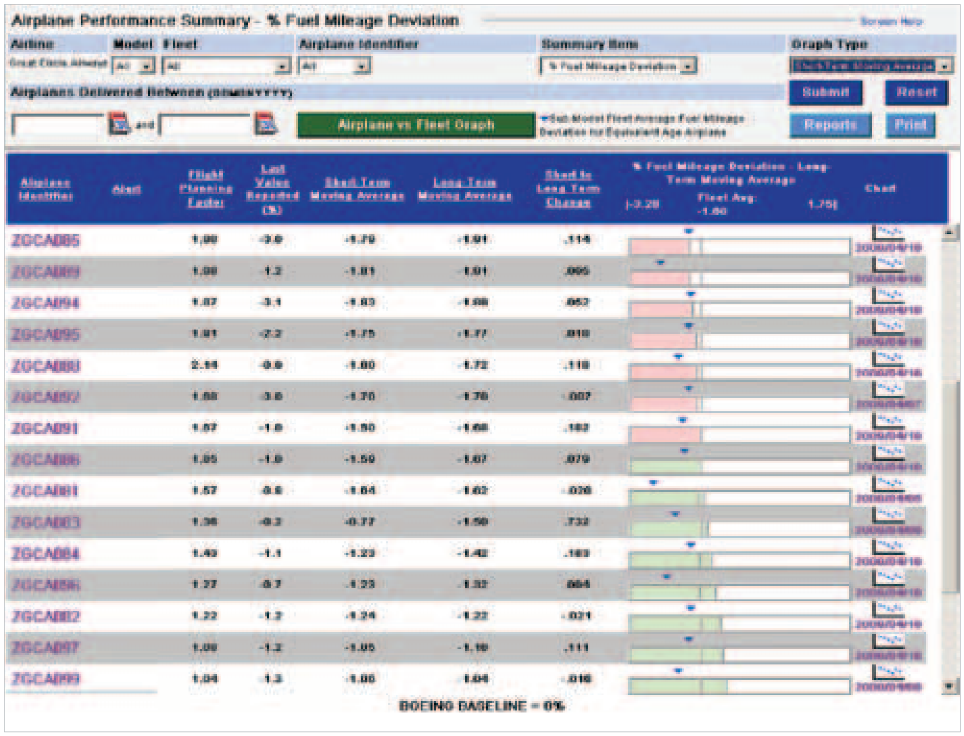
AHM integrates the remote monitoring, collection, and analysis of airplane data to determine the status of an airplane's current or future serviceability or performance. An airline's engineering and maintenance staff can use this data to make timely, economical, and repeatable maintenance decisions that can help improve overall fleet operation. (More information about AHM can be found in *AERO* third-quarter 2007, which outlines how AHM works, aircraft data used, and benefits to airlines.)

AHM is designed to be easy to implement and operate. The fee-based service requires no incremental cost for aircraft communications addressing and reporting system (ACARS) if the airline is already down-linking the related reports.

The Performance Monitoring module is one of three types of decision support available through AHM. (The others are Real-Time Fault Management and Service Monitoring.)

Figure 1: AHM provides performance information for a single airplane or an entire fleet

Through timely identification and diagnosis of in-service issues, Performance Monitoring provides significant overall fuel and emission performance measures for individual airplanes and, thus, improves overall average fleet performance.



PERFORMANCE MONITORING MODULE

The AHM Performance Monitoring module uses Boeing airplane performance monitoring (APM) and health management technology to provide automated monitoring of fuel consumption and CO_2 emissions. The module enhances viewing, managing and researching of, and acting on, airplane performance data to optimize airplane operation and support maintenance decision-making (see fig. 1). The module also provides a linkage between the performance and maintenance domains, allowing for a common toolset that addresses system's condition and fuel performance.

Specific data provided by the module includes:

- Performance comparisons across airline and the larger monitored Boeing fleet.
- Flight planning factors.
- Per-flight and fleet CO_2 emissions (e.g., emissions per seat-kilometer) (see figs. 2 and 3).
- Exception-based alerting.
- Integration with engine original equipment manufacturer condition-monitoring alerts.

The module can provide operators with timely alerts of difficult-to-detect performance degradation by clearly showing specific deviations within the fleet (see fig. 4).

PERFORMANCE MONITORING PROCESS

Much as airplane condition monitoring systems (ACMS) have facilitated more consistent, complete, and convenient collection of higher-quality data on board the airplane, AHM automates the time-consuming and tedious ground processing of the performance data. Many airlines have implemented a formal performance

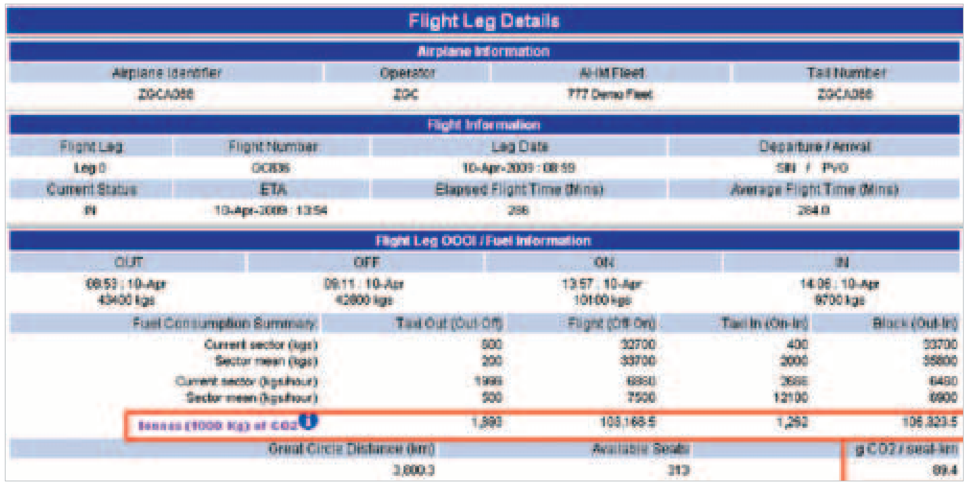


Figure 2: AHM collects fuel usage data and automatically calculates CO_2 emissions

Performance Monitoring automates remote monitoring of airplane CO_2 emissions via automatic calculation of fuel-used information. AHM uses an industry-accepted multiplier to then calculate resulting CO_2 emissions. Summary of emissions in metric tonnes for the flight and kilograms of CO_2 per seat-kilometer provide airline visibility to support environmental initiatives.

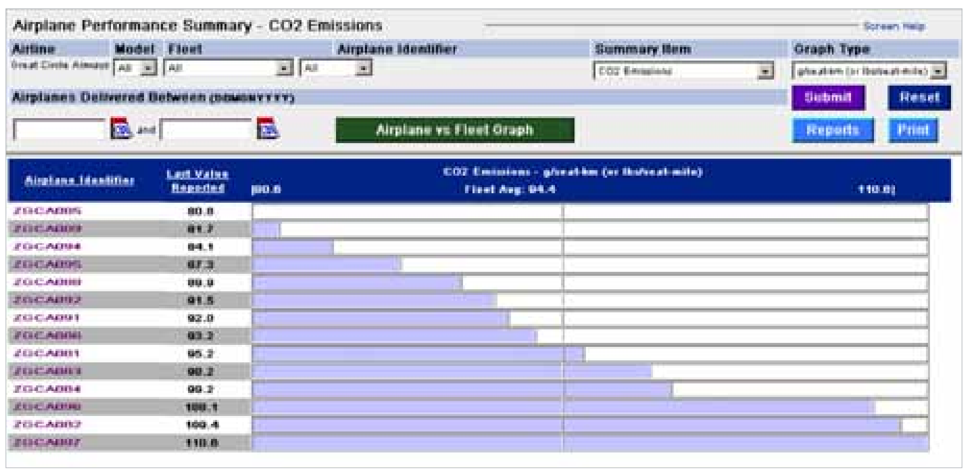


Figure 3: CO_2 emissions for individual flights and across the fleet

Summary reports provide airlines with total emissions for fleet or sectors, providing a complete picture of environmental performance relating to flights.

monitoring process. The typical performance monitoring process involves five steps:

1. Record cruise data.
   Once tight atmospheric and airplane criteria for stable cruise have been achieved, the ACMS records air data, engine, and airplane performance parameters over a period of several minutes. The resulting data can be sent to the ground via the ACARS in a summary report. Some airlines choose to store the summary reports on board the airplane (such as on the quick access recorder) for later retrieval and analysis.
   AHM receives and processes the ACARS data for each airplane model, airline, airplane, and flight within minutes of receiving it from the airplane.
2. Convert data to a format that can be read by Boeing APM software.
   The wide range of ACMS capabilities and summary report formats require translation of the data into the digital standard interface record format. Similarly, manually collected data must be converted to manual standard interface record format. These format standards are required for correct and complete computations.
   AHM ensures that the data interpretation and translation are complete and consistent across a wide range of ACMS reports.
3. Analyze data with Boeing APM software.
   APM applies off-nominal data adjustments to ensure the data and database are consistent, compares results for each data point to chosen baseline levels for the same flight conditions, and averages the results for all data points into selected time periods, observing deviation trends as functions of time.
   AHM presents the resulting performance deviation computations and trends in a banner across the top of the ACMS summary report (see fig. 4).
4. Interpret results.
   Once the deviations in fuel mileage, fuel flow, and thrust required have been computed, the airline's performance

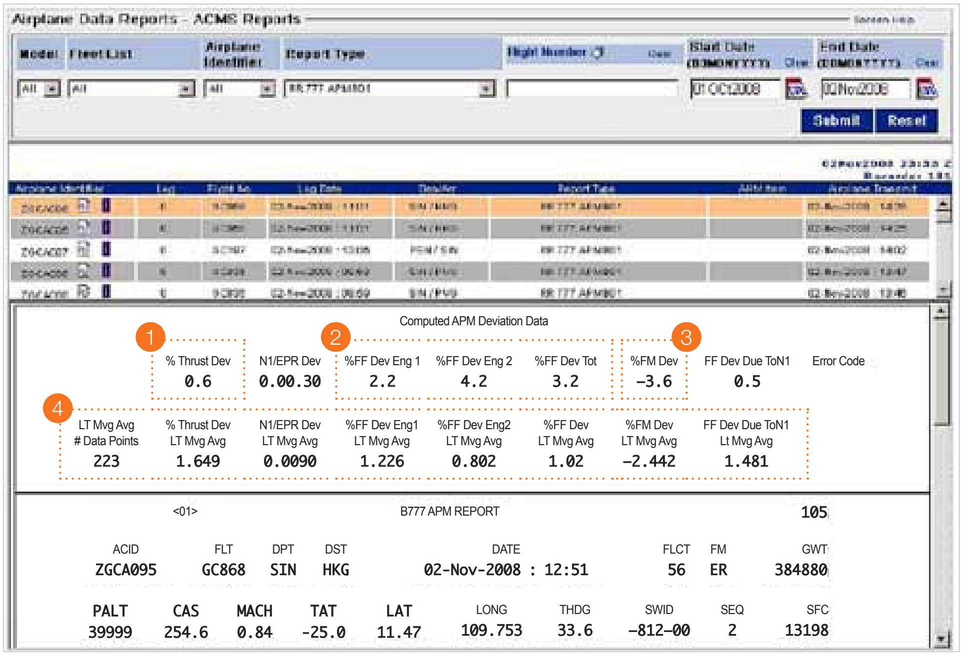


Figure 4: The Performance Monitoring module

Performance Monitoring automates remote monitoring of airplane fuel mileage and associated parameters through alerting of sudden changes as well as gradual degradation. This provides operators with information that can be used to adjust airplane performance factors, analyze performance issues, and make comparisons with other airplanes within the fleet.

1 % Thrust Required Deviation

2 % Fuel Flow Deviation — All Airplane Per Engine

3 % Fuel Mileage Deviation

4 Long-Term (90-Day) Moving Average Statistics

engineers can interpret the data. They assess the data for reasonableness and examine whether changes are required in flight planning and flight management computer (FMC) factors. These factors are key to ensuring that the proper amount of fuel is loaded for each flight and are fundamental in order to save fuel and reduce emissions.

AHM automatically assesses the data and reports any trends that exceed airline-defined thresholds. AHM also monitors the data for abrupt changes and isolates the cause so it can be corrected quickly. This advanced processing can identify problems long before traditional analysis methods.

5. Take appropriate action.
   With fully interpreted and updated performance information, airline performance engineers can update flight planning and FMC factors for improved reserve and total fuel loading. The performance information may also indicate a requirement for planning maintenance actions, such as engine compressor washes or flight control rigging checks.

SUMMARY

The AHM Performance Monitoring module enhances and automates the management of issues that affect fuel mileage and CO_2 performance. AHM enables an airline's performance professionals to initiate necessary actions within hours — rather than the weeks required by traditional analysis methods — saving time, fuel, resources, and, as a result, money.

AHM may also help automate operators' compliance with CO_2 requirements, such as the European Union Emission Trading System monitoring, reporting, and verification of tonne-kilometer data.

For more information on AHM, please contact John Maggiore at john.b.maggiore@boeing.com or Dave Kinney at david.s.kinney@boeing.com.

While flight plan calculations are necessary for safety and regulatory compliance, they also provide airlines with an opportunity for cost optimization.

Effective Flight Plans Can Help Airlines Economize

By Steve Altus, Ph.D., Senior Scientist, Airline Operations Product Development, Jeppesen

Every commercial airline flight begins with a flight plan. Over time, small adjustments to each flight plan can add up to substantial savings across a fleet. Optimal overall performance is influenced by many factors, including dynamic route optimization, accurate flight plans, optimal use of redispatch, and dynamic airborne replanning. While all airlines use computerized flight planning systems, investing in a higher-end system — and in the effort to use it to its full capability — has significant impact on both profitability and the environment.

An operational flight plan is required to ensure an airplane meets all of the operational regulations for a specific flight, to give the flight crew information to help them conduct the flight safely, and to coordinate with air traffic control (ATC).

Computerized systems for calculating flight plans have been widely used for decades, but not all systems are the same. There are advantages to selecting a more capable system and using all of its analytical and optimization capabilities. Using the flight planning process to reduce fuel not only saves money but also helps the environment: carbon dioxide (CO_2) emissions are directly proportional to fuel burn, with more than 20 pounds of CO_2 emitted per U.S. gallon of fuel burned.

This article provides a brief overview of flight planning and discusses ways that flight planning systems can be used to reduce operational costs and help the environment.

FLIGHT PLANNING FUNDAMENTALS

A flight plan includes the route the crew will fly and specifies altitudes and speeds. It also provides calculations for how much fuel the airplane will use and the additional fuel it will need to carry to meet various requirements for safety (see fig. 1).

By varying the route (i.e., ground track), altitudes, speeds, and amount of departure fuel, an effective flight plan can reduce fuel costs, time-based costs, overflight costs, and lost revenue from payload that can't be carried. These variations are subject to airplane performance, weather, allowed route and altitude structure, schedule constraints, and operational constraints.

OPTIMIZING FLIGHT PLANS

While flight plan calculations are necessary for safety and regulatory compliance, they also provide airlines with an opportunity for cost optimization by enabling them to determine the optimal route, altitudes, speeds, and amount of fuel to load on an airplane.

Optimization can be challenging because it involves a number of different elements. An optimized flight plan must not

Figure 1: Minimum information on an operational flight plan

By varying the parameters in a flight plan, flight planning systems can improve the efficiency of an airline's operations.

```
                              COMPUTER FLIGHT PLAN
SPEED SKD       CLB-250/340/.84       CRZ-CI40  (1)  DSC-.84/320/250

                FUEL     TIME
POA ZBAA  (2)  224000    10/31
ALT ZBTJ       006100    00/15
RESV           008500    00/30
CONT           011200    00/40
REQ            249800    11/56
XTR            000000    00/00
TOT       (3)  249800    11/56

KSEA..YVR J528 TRENA J488 UAB..YYD NCA34 YXY J515 FAI J502 OTZ B244
FRENK G902 ASBAT B337 URABI G212 DABMA W74 SABEM G332 GITUM GIT01A ZBAA (4)

FL  300/YVR   320/YYD   340/FRENK 348/BUMAT 381 (5)
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1 What speed to fly (possibly varying along the route)

2 How much fuel the airplane will burn ("trip fuel")

3 Total departure fuel, and how it is allocated – fuel to alternate, contingency fuel, and other allocations that vary between airlines and regulatory rules

4 What route (ground track) to fly

5 What profile (altitudes along the route) to fly

only take into account the correct physics (i.e., airplane performance and weather) but also route restrictions from ATC and all relevant regulatory restrictions. The mathematical nature of these constraints and the overall size of the calculation combine to make it a challenging problem, even by modern optimization standards. Some of the equations that describe the behavior are nonlinear and noncontinuous, and the airplane state is dynamic (i.e., it depends on how the airplane has gotten to a specific point, not just where it is). As a result, tens to hundreds of thousands of individual calculations are required for a single flight.

An optimal flight planning scenario for saving fuel and emissions involves calculating multiple routes or operating approaches for each flight, ranking these scenarios by total cost, choosing the scenario that best accomplishes the airline's cost objectives, and providing summaries of the other scenarios for operational flexibility (see fig. 2). While the scenario chosen by the system might be used most of the time, dispatchers and operations managers at an airline's control center may choose another scenario to meet the airline's operational goals, such as routing of airplanes, crews, and passengers. Because they are often making these decisions shortly before departure time, a user-friendly presentation of the relevant information is vital.

ROUTE OPTIMIZATION

The best route to fly depends on the actual conditions for each flight. These include the forecast upper air winds and temperatures, the amount of payload, and the time-based costs that day. The time-based costs are especially dynamic, driven by the value of the payload and the schedule and operational constraints for the crew and the airplane. Winds can have a significant impact on the optimal route: it can be very far from the great circle "direct" route (see fig. 3). Flight planning systems use wind forecasts from the U.S. National Weather Service and U.K. Meteorological Office, updated every one to six hours, to include the winds in every flight plan calculation.

While nearly all computer flight planning systems can optimize routes, many airlines still use fixed "company routes" most of the time. One reason adoption of dynamic route optimization has been limited is that ATC organizations, overflight permissions, and company policies place restrictions on routing in certain areas. An effective flight planning system contains models of all these restrictions, which are then applied as constraints in the numerical optimization process. This allows the flight plan to be optimized with the dynamic data on winds, temperatures, and costs while still complying with all restrictions.

One recent study by Boeing subsidiary Jeppesen considered the benefit of dynamic route optimization on an airline that used fixed company routes in its computer flight planning system. This airline, which had 60 single-aisle airplanes, used fixed routes developed with historical winds and experience about ATC requirements. The study determined that using routes optimized with the most recent forecast winds, with numerical constraints modeling ATC requirements, would save about 1 million U.S. gallons of fuel per year. This, in turn, would reduce annual CO_2 emissions by about 20 million pounds.

THE IMPORTANCE OF ACCURACY

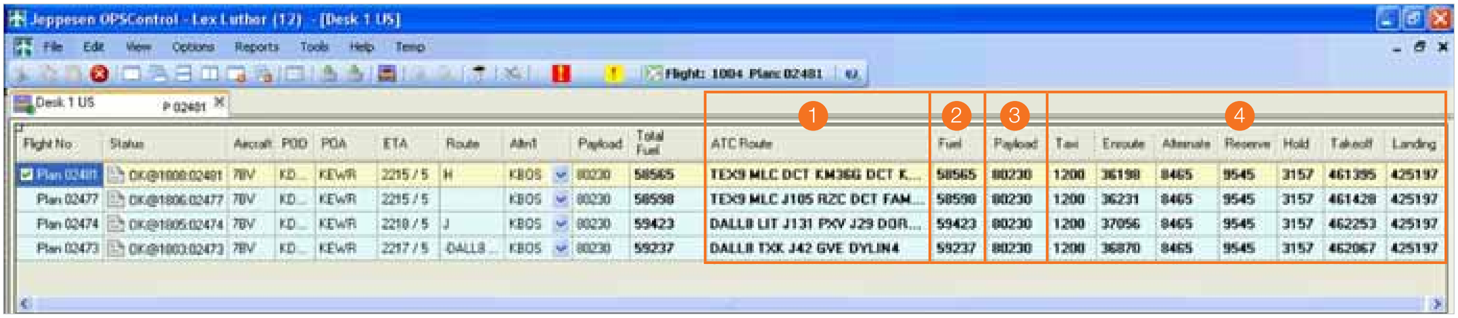
Airlines can reduce fuel consumption and costs by improving the accuracy of their flight plans. The flight crew and dispatcher can elect to add fuel they think might be needed to complete the flight as planned. But the heavier the airplane, the more fuel it will burn, so adding extra fuel — which adds weight — burns more fuel, increasing both operating costs and emissions.

Accurate flight plan calculations can minimize the additional fuel the flight crew adds. Accurate calculations are the result of several factors that combine engineering and information management. Some of the relevant factors require integration with other systems and data sources, both within and outside an airline.

For example, the basic airplane performance characteristics come directly from manufacturer data, but must be modified

Figure 2: Optimal flight planning using multiple routes for each flight

A user interface allows management of multiple possible scenarios for a single flight.



1 Multiple routing scenarios displayed simultaneously 2 Scenario sort by fuel 3 Scenario sort by payload 4 Scenario sort by any computed field

by active master minimum equipment list/configuration deviation list data (available in an operator's maintenance tracking system) and by measured deviations from baseline data, available from Boeing Airplane Performance Monitoring software. Up-to-the-minute payload predictions require integration with the reservation system, and time-based cost prediction is most accurate when it is integrated with operational control and crew tracking systems. Integration with convective weather and air traffic delay predictions helps to accurately predict possible airborne delays or deviations, rather than using rough guesses. Because an integrated, properly tuned flight planning system increases the accuracy of calculations used to develop flight plans, flight crews and dispatchers will feel confident reducing the amount of extra fuel they request.

Further study of the airline described in the "Route Optimization" section found that it carried an average of 300 U.S. gallons of extra fuel per flight. Analysis showed that the airline could save an *additional* million U.S. gallons of fuel per year by cutting that amount in half.

OPTIMAL REDISPATCH DECISION POINT

Another way to decrease total fuel carried is to reduce international contingency fuel required by using a redispatch technique. Contingency fuel (called "international reserve fuel" in the United States), which is defined by a percentage of flight time or planned fuel burn (varying by different regulators), can be reduced by splitting a flight plan into two different calculations: one from the departure airport to an airport that is closer than the intended destination, and another from a decision point on the route of flight to the planned destination. Each calculation requires contingency fuel over its entire distance, but each is less than the total that would be required for the entire flight to the planned destination. The actual flight must carry the greater of the contingency fuels for the two scenarios.

The optimal flight plan places the decision point in a location where the contingency fuels for the two scenarios are exactly equal; moving it in either direction increases the fuel required for one scenario or the other. While some general guidelines exist for a good location of the decision point, a flight planning system can calculate the optimal location automatically — and it can vary dramatically based on the relative locations of all the airports (see fig. 4).

DYNAMIC AIRBORNE REPLANNING

Winds, temperature, convective weather, and ATC congestion have a sizeable impact on the optimal 4D path for an airplane. Over the course of a long flight, this information can change significantly, and the predeparture flight plan may no longer be optimal.

An advanced flight planning system can reoptimize the flight plan while the airplane is in flight. The airline's operations center has more information about weather and traffic far ahead of the airplane, as well as the dynamic costs associated with other flights (related to crew, airplane, and passenger connections), so the flight planning system can find better solutions than the flight crew working with the flight management computer (FMC) alone. The new route and latest forecast winds can be uplinked directly to the FMC, minimizing crew workload.

TRENDS IN FLIGHT PLANNING

Airspace design and regulations are changing all the time, sometimes quite rapidly. Some recent innovations include continuous descent approaches, high-altitude redesign in the western United States, and new U.S. Federal Aviation Administration (FAA) extended-range twin-engine operational performance standards (ETOPS) rules. (Boeing can help operators make sure they're defining all of their ETOPS parameters and fuel analyses correctly.) These are in addition to less recent changes, such as the introduction of a reduced vertical separation minimum in different parts of the world.

However, not all operators can take advantage of the improvements right away because their flight planning software cannot be updated quickly enough. Those whose

Figure 4: Determining the optimal redispatch decision point

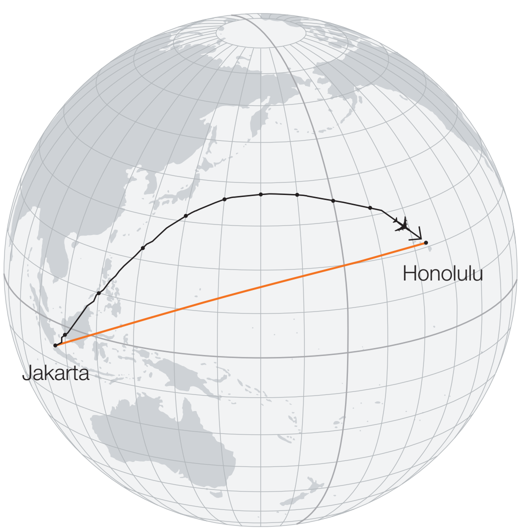
On this flight from Denver to Tokyo, the optimal decision point to redispatch changes based on the relative location of all the airports. In this first instance, the decision to turn back to Anchorage is made after the airplane is over Russia. In the second instance, the redispatch decision point occurs as the airplane approaches the coast of Japan. The diversion city is Sapporo.

Diversion Path

Diversion Cities

Figure 3: Forecast winds must be considered to find the optimal route

This flight from Jakarta to Honolulu illustrates that a wind-optimal flight path may be far from the great circle. This route is 11 percent longer than a great circle route, but is 2 percent faster and uses 3 percent less fuel.



Optimized Route

Great Circle

software is ready could take full advantage of the innovations, immediately reducing their fuel consumption and operating costs.

Further route, altitude, and speed optimization will be made possible by 4D trajectory-based approaches, such as the Next Generation Air Transportation System, which is the FAA's plan to modernize the national airspace system through 2025, and the Single European Sky Air Traffic Management Research Programme (SESAR). Ongoing research goes beyond compliance with new approaches, identifying opportunities for improved optimization that build on the changes to the global traffic management system.

Companies such as Jeppesen are also working on improved optimization scenarios designed to minimize fuel consumption, operational cost, and emissions. For instance, Jeppesen is developing a new optimization objective function for its flight planning system that is based on an atmospheric impact metric developed by airplane design researchers at Stanford University, taking many emission products into account, rather than just minimizing fuel as a means to minimize CO_2.

Another future trend in flight planning optimization is a close integration with other airplane operations efforts, such as disruption recovery, integrated operations control, and collaborative air traffic management. Current systems can already pick optimal cost index speeds if the cost of arriving at different times is available. This cost, however, is not independent for a single flight, but related to the decisions made for all an airline's flights because the cost for passengers, crew, and the airplane itself to arrive at a specific time depends on when their next flights will depart — which, in turn, depends on when all other flights arrive. By combining the different operational decisions and optimizing them together, better solutions that factor in all of the different costs and constraints can be attained.

SUMMARY

Accurate, optimized flight plans can save airlines millions of gallons of fuel every year — without forcing the airlines to compromise their schedules or service. Airlines can realize their benefits by investing in a higher-end flight planning system with advanced optimization capabilities and then ensuring accuracy by comparing flight plan values to actual flight data, identifying the cause of discrepancies, and using this information to update the parameters used in the flight plan calculation.

Current research in flight planning system development ensures that flight planning systems take full advantage of airspace and air traffic management liberalization and work together with other airline operations systems to produce the best overall solutions.

For more information, please contact Steve Altus at steve.altus@jeppesen.com.

AERO Readership Survey

Welcome to *AERO*'s 2009 reader survey. Please help us deliver the best content possible by sharing your opinions, insights, and ideas for *AERO*. Your participation is anonymous, and no information will be shared outside the given purpose of this survey. It should take less than five minutes to complete.

Feel free to fill out the survey using the questionnaire on the next page, and mail or fax it back to us using the contact details below. Or simply complete the survey online by visiting **www.AEROsurvey2009.com**. We appreciate your participation.

AERO Magazine
Boeing Commercial Airplanes
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98124-2207
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Fax: 206.766.2934

AERO Readership Survey

1. Where do you work? CHOOSE ONE

- ◯ Airline
- ◯ Maintenance, repair, and overhaul (MRO) organization
- ◯ Supplier
- ◯ Regulator
- ◯ School
- ◯ Library
- ◯ Trade association
- ◯ News media
- ◯ Boeing
- ◯ Other, specifically: ....

2. What is your primary area of expertise? CHOOSE ONE

- ◯ Engineering
- ◯ Flight
- ◯ Maintenance
- ◯ Management
- ◯ Regulatory
- ◯ Safety
- ◯ Other, specifically: ....

3. Where do you live? CHOOSE CONTINENT, FILL IN COUNTRY

- ◯ Africa ....
- ◯ Asia ....
- ◯ Australia ....
- ◯ Europe ....
- ◯ North America ....
- ◯ South America ....

4. When given a choice, do you prefer to read publications (including *AERO*) in print or on the Internet? CHOOSE ONE

- ◯ Printed
- ◯ Internet
- ◯ No preference

5. Which version of *AERO* magazine do you read the most? CHOOSE ONE

- ◯ Printed magazine only
- ◯ Internet version only
- ◯ Both printed and on the Internet
- ◯ Don't read either

5b. If you answered that you don't read *AERO*, please tell us why. CHOOSE ALL THAT APPLY

- ◯ No print copies available
- ◯ Poor Internet access
- ◯ Not fluent in English
- ◯ Articles of no interest
- ◯ Other, specifically: ....

6. *AERO* is published four times a year. How many issues do you read per year? CHOOSE ONE

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4

7. Which comment best explains how you read *AERO*? CHOOSE ONE

- ◯ I read the entire issue.
- ◯ I read only the articles that apply to my job.
- ◯ I skim the magazine.
- ◯ I only read articles recommended to me.

8. Overall, *AERO* contains valuable and timely technical information. CHOOSE ONE

- ◯ Strongly agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly disagree

9. Specifically, *AERO* provides useful information in the following categories:

	STRONGLY AGREE	AGREE	NO OPINION	DISAGREE	STRONGLY DISAGREE
Maintenance	◯	◯	◯	◯	◯
Engineering	◯	◯	◯	◯	◯
Flight	◯	◯	◯	◯	◯
Management	◯	◯	◯	◯	◯
Safety	◯	◯	◯	◯	◯
Regulatory	◯	◯	◯	◯	◯

10. Which comment best describes how easy it is to obtain a printed copy of *AERO*? CHOOSE ONE

- ◯ There are many copies of *AERO* magazine at my location.
- ◯ A few copies of the magazine are passed around.
- ◯ It is very difficult to get a copy of *AERO*.
- ◯ I have never seen a copy of *AERO*.

11. Which comment best explains how easy it is to access *AERO* on the Internet? CHOOSE ONE

- ◯ I can always access *AERO* on the Internet easily.
- ◯ I can sometimes access *AERO* on the Internet.
- ◯ I can never access *AERO* on the Internet.
- ◯ I did not know *AERO* is available on the Internet.

12. What kind of connection do you have to the Internet? CHOOSE ONE

- ◯ 28.8 Kbps modem
- ◯ 56 Kbps modem
- ◯ ISDN
- ◯ Cable modem
- ◯ DSL
- ◯ T1 or better
- ◯ Do not know

13. Which comment best describes your *AERO* experience on the Internet? CHOOSE ONE

- ◯ *AERO* on the Internet allows me to easily find and access articles, see photos and graphics, play videos, and access links.
- ◯ *AERO* on the Internet is sometimes difficult to navigate.

13b. If you answered that *AERO* is difficult to read on the Internet, please tell us why. CHOOSE ALL THAT APPLY

- ◯ Navigation confusing
- ◯ Pictures and graphics slow to load
- ◯ Videos do not play
- ◯ Links do not function
- ◯ Unable to access the Internet

14. Please let us know how we can improve *AERO*:

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You can complete our online reader survey at
www.AEROsurvey2009.com.


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