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AERO

Cover photo: *Inboard and outboard ends of two 737 wing panels.*

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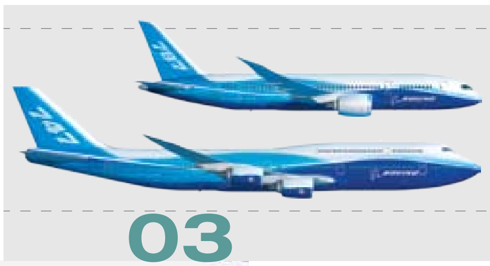

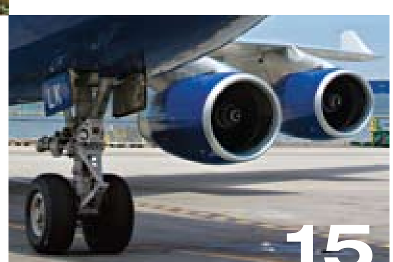

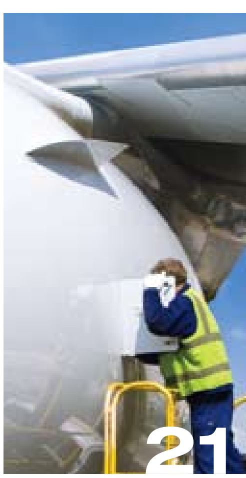

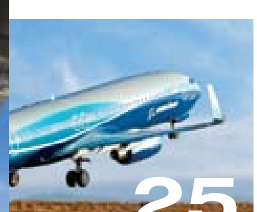

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AERO magazine is published quarterly by Boeing Commercial Airplanes and is distributed at no cost to operators of Boeing commercial airplanes. *AERO* provides operators with supplemental technical information to promote continuous safety and efficiency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

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Aviation and the Environment: Our Commitment to a Better Future

SCOTT CARSON
Executive Vice President,
The Boeing Company
President and Chief Executive Officer,
Boeing Commercial Airplanes

We all recognize that air transportation plays a vital role in continued global economic growth. Eight percent of the world's growth in gross domestic product can be directly attributed to air travel, making it essential to the global economy.

Our most immediate challenge is to continue to allow the global economy to prosper and to grow our industry responsibly, while minimizing impacts on the global ecosystem. Like our industry's approach to safety, this is an issue that beckons for global solutions, not regional ones. The challenge is to develop a framework that everyone can join — a framework that moves the industry forward.

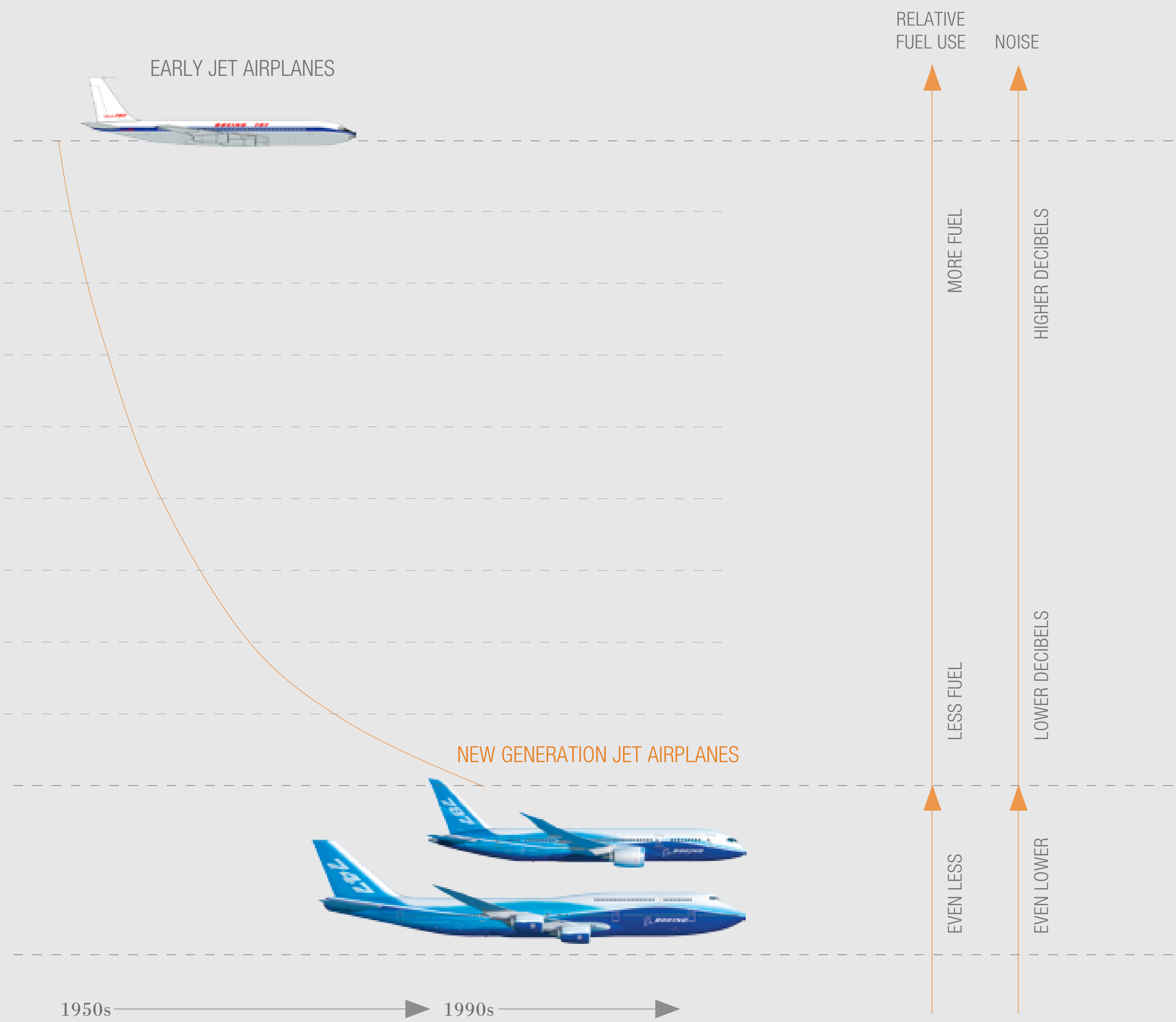
We know we can do it. We have a strong environmental track record as an industry. During the past 40 years, we've reduced noise by 75 percent. We've reduced carbon dioxide (CO_2) intensity by 70 percent. We've virtually eliminated hydrocarbon emissions and soot.

Still, aviation's carbon footprint today is 2 percent of global CO_2 emissions, according to the United Nations Intergovernmental Panel on Climate Change, and we must be part of a solution that addresses the environmental impact of our industry.

At Boeing Commercial Airplanes, we firmly believe that market demand and competition will continue to drive new product innovation and improved fuel efficiency, and that solutions based on technology and operational efficiency are the best path forward. To that end, we have adopted four guiding principles as we work both within Boeing and around the world with our colleagues, customers, and partners.

70%
Fuel Improvement and Reduced CO_2

90%
Reduction in Noise Footprint



Our Plan and Commitments

Pioneer new technologies

75%

Focus on improving fuel and CO_2 efficiency, reducing noise footprints, and developing low-carbon alternative fuels.

More than 75 percent of technology research and development will benefit environmental performance.

Relentlessly pursue manufacturing and life-cycle improvements

100%

Develop ISO 14001 certification plan for 100 percent of Boeing Commercial Airplanes' manufacturing sites.

Use Lean+ practices to reduce impact. Maximize recycling initiatives, including metals and composites.

Deliver progressive new products and services

15%

Each new airplane generation will deliver at least 15 percent improvement in CO_2 and fuel efficiency.

Continue our dedication to design innovation.

Improve performance of worldwide fleet operations

25%

Focus on efficiency improvements in worldwide fleet fuel use and CO_2 emissions by 2020.

Partner with customers to achieve performance.

- *First, we believe technology unlocks the future.* Much of our airplane development work — be it weight reduction or advanced aerodynamics — is focused on fuel efficiency. More than 75 percent of Boeing Commercial Airplanes' research and development effectively contributes to improving the environmental performance of our products. We also have developed alternative materials and processes for manufacturing and maintenance.
- *Second, CO_2 and fuel are the focus of our efforts.* We are committed to improving the fuel efficiency and CO_2 emissions for each new generation of airliners by at least 15 percent. Our newest airplanes, the 787 Dreamliner and the 747-8, exemplify our dedication to environmental design. Incorporating four innovative technologies — new engines, increased use of lightweight composite materials, high-efficiency systems applications, and modern aerodynamics — the 787 is designed to provide a 20 percent improvement in fuel use and an equivalent reduction in CO_2 emissions compared to today's similarly sized airplanes. The 747-8 offers a 16 percent improvement in fuel use and CO_2 emissions over the 747-400. We also continue to explore far-reaching projects, such as low-carbon alternative fuels for aviation use.
- *Third, we believe aviation system efficiency is essential.* Even the most fuel-efficient airplane can't achieve its highest efficiency levels if it is forced to fly indirect routes and to circle overhead waiting to land. Therefore, it is crucial that we do everything in our power to make improvements to the global air transportation system a priority and a reality. One example is Boeing's "Tailored Arrival" concept, which increases airplane arrival efficiency by establishing a predictable continuous descent rather than the current step-down descent. Trials have demonstrated that implementing these types of advanced arrival techniques can save up to 500 gallons of fuel per flight.
- *Fourth, a global approach involves and benefits everyone.* As I mentioned earlier, the environmental challenge is a global issue that demands global solutions, not regional ones. This means that continuous performance improvement and technological innovation must be accompanied by strong working partnerships among industry, academia, and governments. Together with our airline customers and other industry leaders, we are firmly committed to a pathway toward carbon-neutral growth and the aspiration of a carbon-free future.

Today, we have the very real opportunity to demonstrate our technical prowess as an industry and help define the legacy of flying for generations to come. Working together, we can identify solutions and approaches that will help our industry address environmental challenges regardless of geographical markets — and in the process build a healthier, more environmentally progressive aviation industry that delivers value to everyone who depends on the global air transportation system.

SCOTT CARSON
Executive Vice President,
The Boeing Company
President and Chief Executive Officer,
Boeing Commercial Airplanes

BOEING'S GOAL IS TO ACHIEVE 90 TO 95 PERCENT RECYCLABILITY OF THE WORLD'S FLEET BY 2012 BY TAKING ADVANTAGE OF INDUSTRY EXPERTISE AND NEW TECHNOLOGIES.

Airplane Recycling Efforts Benefit Boeing Operators

By William Carberry
Project Manager, Aircraft and Composite Recycling

Airplane life-cycle considerations are an important part of Boeing's strategic environmental efforts. In support of this strategy, Boeing initially conducted a field survey of companies involved in older fleet management and airplane scrapping. Boeing began to focus its efforts on older fleet management with a group of companies that shared a vision for the safe and environmentally progressive management of the world's aging airplane fleet.

These efforts evolved into the development of a nonprofit industry association called the Aircraft Fleet Recycling Association (AFRA), whose mission is to enable airlines to manage their retired airplanes in an environmentally responsible way while maximizing the value of aging commercial airplanes.

Environmental protection is more and more important around the world. AFRA was formed in 2006 partly in response to operators' desire for clear guidance on the most effective and efficient methods to retire their airplanes. In the two years since its inception, AFRA has produced a "Best Management Practice" document on the management of used airplanes, reclaimed parts, and defined minimum performance standards for companies that manage end-of-service airplanes. This article will explore AFRA's origins and objectives, provide examples of the best practices it has developed and the resulting accreditation program for airplane scrapping operations, and explain

The promise of recycled carbon fiber

The introduction of the largely composite Boeing 787 Dreamliner presents new opportunities in composite recycling. For the past several years, Boeing has been working with a number of third-party technology firms on the recycling of aerospace-grade composites. Boeing began these efforts in 2004 with the first tests using scrap carbon-fiber-reinforced-plastic (CFRP) composite from retired F-18A airplanes. More recent tests have used 777 and 787 composite manufacturing scrap. Boeing research has demonstrated not only that the carbon fibers in CFRP can be recovered, but that the fiber's surface characteristics, bond-ability with new resin, and overall quality are comparable to that of new fiber and suitable for use in high-end industrial manufacturing.

Recent Boeing research has focused on using recycled 777 and 787 CFRP in high-end industrial manufacturing applications that include electronics casings using required radio frequency shielding and high-end automobile parts. Boeing has started testing recycled carbon fiber in non-structural components of commercial airplanes and military aircraft.

The research has shown that the reclaimed fibers serve as a viable replacement for new fiber in many high-end industrial manufacturing processes, and offer a significant savings of money and carbon dioxide. Recycling carbon fiber can be done at approximately 70 percent of the cost and using less than 5 percent of the electricity required to make new carbon fiber (see fig. 1). If the 2 million pounds of carbon fiber scrap that commercial jet manufacturing is estimated to generate in 2014 is recovered, recycled, and substituted for virgin fiber in manufacturing applications, it will save enough electricity to power 175,000 typical homes a year.

the benefits to Boeing operators of working with AFRA-accredited companies when retiring airplanes from their Boeing fleets.

THE ECONOMICS OF AIRPLANE RECYCLING

Boeing's initial interest in airplane recycling began in the desert, where retired airplanes are typically parked. Boeing wanted to find out what happened to airplanes that had left revenue service and why operators often left the airplanes untouched.

The findings showed that most airplanes were parked for a variety of economic reasons. Without an effective airplane recycling program, operators were unaware of the value of recovered materials. In fact, they had a financial incentive to park airplanes when it became obvious they would never reenter revenue service.

For example, a twin-aisle transport that an airline grounds temporarily for economic reasons may have a book value of US$25 million. The owner looks for a buyer who could use the airplane for cargo. As time goes on and the airplane's appeal in the used airplane market decreases, the owner starts cutting back on costs, such as maintenance.

Eventually, the airplane deteriorates into a condition that makes it impractical to be returned to airworthiness. Yet the owner still has it valued at US$25 million for accounting purposes, and as soon as it is designated for scrap, it will immediately lose as much as 75 percent of its value. Although the airline may be able to recover US$5 million to US$7 million for the engines, rotable parts, and scrap metal, the remaining value must be written off. In essence, it is cheaper on an accounting basis to leave the airplane in the desert than it is to scrap and recycle it.

However, once an airplane is designated for scrapping, airlines have tended to choose the least expensive solution. To meet that demand, a business segment developed that focused on scrapping airplanes at a low cost with little or no consideration of recycling.

However, Boeing believed that airplanes could be recycled in a way that offered both economic advantages to operators and environmental benefits. Boeing's research showed that the most effective way to maximize airplane recycling would be to develop solutions in a collaborative fashion with companies that are already effectively engaged in that activity. By integrating and growing industry expertise and by advancing and accelerating promising new technologies, Boeing's goal is to achieve 90 to 95 percent recyclability of the world's fleet by 2012 with the materials recovered in these recycled airplanes directed toward high-value commercial manufacturing applications.

COMPARING VIRGIN AND RECYCLED CARBON FIBER
Figure 1

COST OF CARBON FIBER

	Cost to Manufacture	
	Materials	Energy
Virgin Carbon Fiber	US$15 – $30/pound (lb)	25 – 75 kilowatt hours (kWH)/lb
Recycled Carbon Fiber	US$8 – $12/lb	1.3 – 4.5 kWH/lb

Recycled chopped carbon fiber costs up to 70 percent less to produce and requires up to 98 percent less energy to manufacture than virgin chopped fiber. Yet, the performance of the two materials is comparable.

THE EVOLUTION OF AFRA

In 2006, Boeing and 10 other aerospace companies formed AFRA with a common commitment to improve the way older airplanes are managed. This international cooperative effort was facilitated by Boeing to leverage the experience of the founding members to develop and implement environmentally progressive recycling procedures. AFRA now has 34 members throughout the world, including France, Ireland, the Netherlands, South Africa, Switzerland, Turkey, the United Kingdom, and the United States. It is funded exclusively by its members and by revenue from its audit and accreditation program. AFRA membership is open to any company with a primary business focus on the world's aging fleet, and to university groups and technology companies that are developing improved airplane recycling processes.

AFRA's objectives include addressing the environmental concerns of retired airplanes and creating and sharing upgraded processes. AFRA provides owners of aging airplanes with audits of a company's performance relative to AFRA's "Best Management Practice" document to ensure that the company has the expertise and process fidelity to part-out and dismantle an airplane in a safe, environmentally progressive, economically beneficial manner that will maximize value and minimize risk to the owner.

These goals mesh with Boeing's objectives for airplane recycling, providing methods for safe parts recovery and environmentally responsible scrapping and recycling for airplanes that are not suitable for continued service (see fig. 2). The key is to greatly improve materials recovery from retired airplanes (and manufacturing scrap) and return that material to high-end manufacturing applications.

IMPROVING THE PROCESS OF RETIRING AIRPLANES

AFRA is dedicated to the concept that end-of-service is not end-of-life. Its mission is to help airlines achieve the best return for their retired airplanes while promoting responsible recycling and developing safe and sustainable solutions for the reuse of airplane parts and assemblies from older airplanes.

The AFRA network provides complete and clear guidance for airplane owners to use when selecting a company to manage their end-of-service equipment — now and in the future. The association's members share a commitment to improving older fleet asset management and fostering the recovery and the safe and environmentally progressive reuse of aerospace materials (see fig. 3).

FOCUS OF BOEING AIRPLANE RECYCLING
Figure 2

Facilitate the development and implementation of more efficient recycling processes that:

MAXIMIZE
the value of recovered materials

CHARACTERIZE
reclaimed materials so they can be used as a feedstock for high-grade manufacturing applications

CAPITALIZE
on opportunities to use reclaimed materials in aerospace manufacturing

Specifically, the group is dedicated to:

- Safe and environmentally responsible management of the world's aging and retired airplane fleet.
- Safe and economical return of airplanes, engines, and parts to revenue service.
- Safe return of engines and parts to the world fleet.
- Safe return of reclaimed materials (including composites, aluminum, and electronics) back into commercial manufacturing at maximum value.
- Safe scrapping of airplanes at dedicated sites with appropriate procedures, including parting out and decontamination (i.e., safely removing and managing the fluids that remain after an airplane has been parked for the last time).

Since AFRA's inception, member organizations have remarketed (i.e., returned to service) approximately 2,000 airplanes and scrapped more than 6,000 commercial airplanes and 1,000 military aircraft (including 800 tactical aircraft). AFRA members are currently processing 150 airplanes, containing 1,000 tons of airplane specialty alloys and 25,000 tons of airplane aluminum annually.

"BEST MANAGEMENT PRACTICE" PROVIDES EMPHASIS FOR RECYCLING

AFRA has published a document entitled "Best Management Practice for Management of Used Aircraft Parts and Assemblies" and has implemented an audit program that accredits companies that follow the minimum standards outlined in the document. The document and accreditation program outline specific guidelines to enhance the effective and responsible recycling of airplanes and provide a neutral third-party assessment of scrapping companies.

For example, to become accredited by AFRA, airplane recycling facilities must have several key components built into their operational model, including:

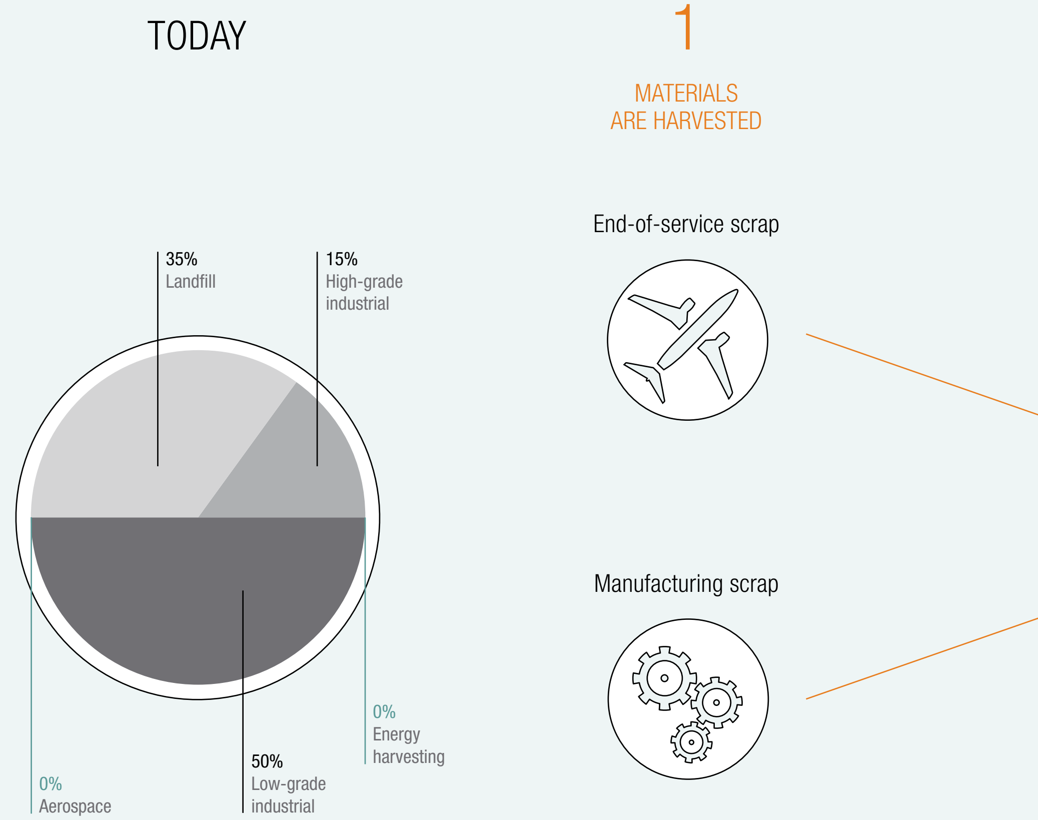
- Adequate systems, resources, and documentation to safely disassemble an airplane in an environmentally responsible manner:
  - Adequate containment for accidental spills.
  - Adequate space so that, if the facility handles more than one airplane at a time, each airplane can be disassembled so there is no mixing of parts among projects.
  - Designated areas to quarantine parts that are removed from an airplane before they can be inspected and properly tagged.
  - Designated areas that have adequate static discharge protection for parts that need that type of storage.
  - A sufficiently robust documentation and tagging system to track parts from the time they leave the airplane until they reach a used parts distributorship.

SAFE AND SUSTAINABLE SOLUTIONS
Figure 3

AFRA advocates an airplane recycling process that emphasizes safe and economical return of airplanes, engines, and parts to revenue service (top), safe scrapping of airplanes (center), and maximizing the value of reclaimed materials (bottom).

MOVING TOWARD A MORE EFFICIENT RECYCLING PROCESS
Figure 4

AFRA's goal is to achieve the highest possible commercial value for reclaimed materials, which would reduce the total cost of recycling airplanes for commercial airlines.



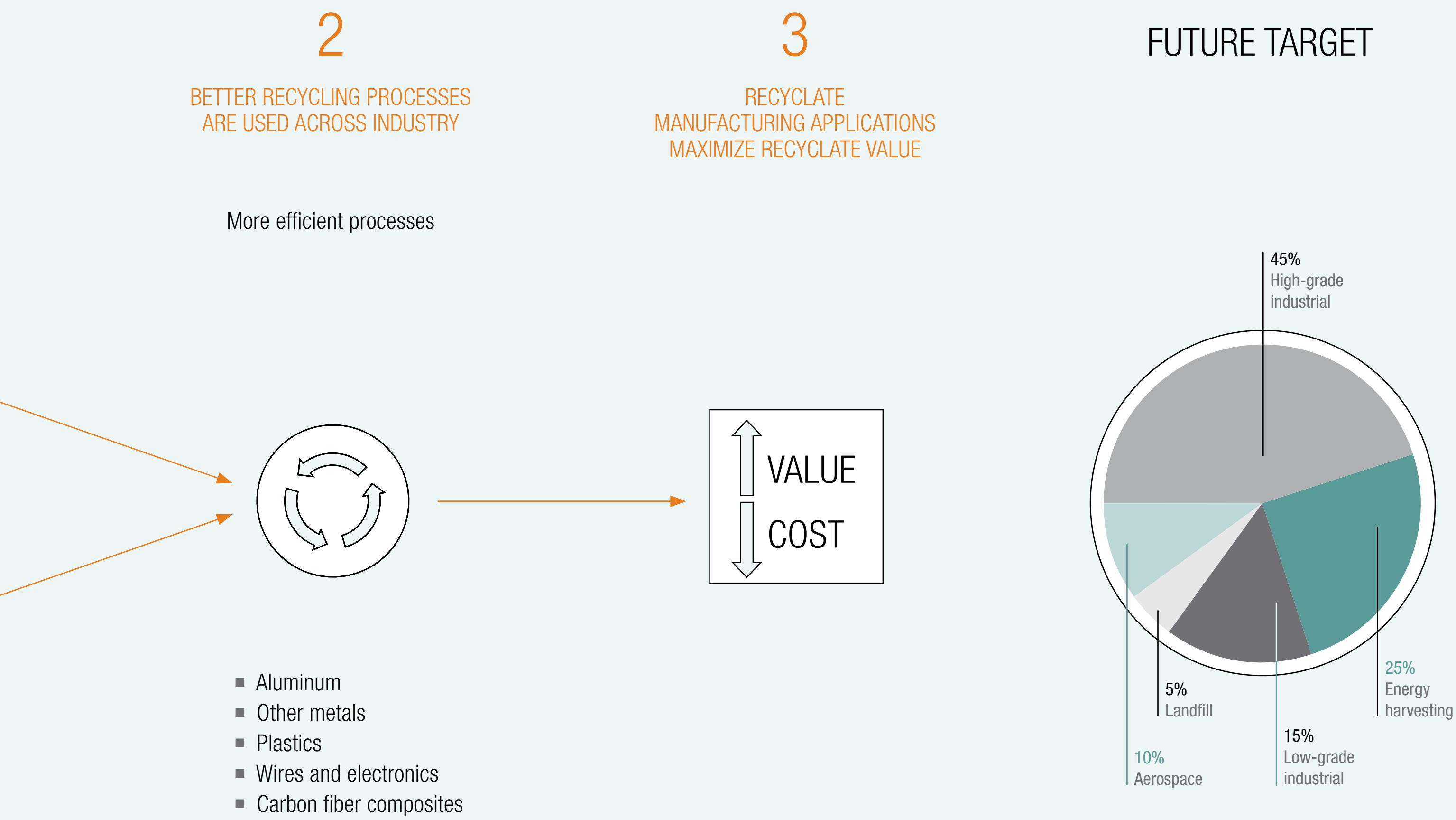
- Personnel to perform the disassembly who have been trained in the disassembly information from the manufacturer's technical manuals and who have access to the model-specific manuals and properly calibrated and maintained manufacturer-specified tools.
- Internal systems and an adequate internal audit program to ensure that removed parts are properly inventoried and stored and that relevant regulations are followed for the jurisdiction where the facility is located.
- Adequate procedures and safeguards to ensure that the asset is disassembled in an environmentally responsible manner and that materials recovered during the scrapping operation are recycled in accordance with the asset owner's wishes.
- AFRA has accredited five companies through July 2008: Air Salvage International (United Kingdom), Europe Aviation (France), P3 Aviation (United Kingdom), Southern California Aviation (United States), and Volvo Aero (United States).

AFRA plans to develop similar documents specifying end-of-service management procedures for engines and other major assemblies and define minimum requirements for written environmental and recycling plans.

BENEFITS FOR OPERATORS

AFRA has simplified the recycling process for airline customers seeking a responsible way to manage the airplanes that they retire by establishing minimum standards for how airplanes should be dismantled. By choosing an AFRA-accredited facility to scrap out their airplane, the airplane owner has an assurance that the facility has the expertise and processes to ensure that fewer parts are damaged by being removed and handled incorrectly and that the parts of the airplane that can't be reused are managed in an environmentally responsible manner. As a result, AFRA expects to maximize the value of reusable parts as airlines work to recertify used parts and install them in operational airplanes.

AFRA-accredited companies are independently audited and verified to use scrapping processes that maximize environmental responsibility. For example, AFRA's "Best Management Practice for Management of Used Aircraft Parts and Assemblies" specifies that "environmental concerns should be addressed through appropriate control technologies with sufficient capacity to handle largest



liquid storage tank/system" on the airplane. The AFRA document not only defines the minimum standard but also suggests control technologies a facility might employ to meet the standard. In this example suggested options include:

- Fully protected ground surface.
- Storm-water runoff pathways physically protected with spill barrier equipment (e.g., drains, culverts, channels).
- Pumping and storage capacity immediately accessible.
- Oil/water separator.
- Wastewater treatment with airplane fluid capabilities.
- Spill kits with sufficient absorptive materials.

Although there are additional costs involved with recycling airplanes in the manner dictated by AFRA, the group believes that these costs can be offset by the higher value of recyclates — recycled material that will be used to form new products — recovered by new recycling processes (see fig. 4). With Boeing expecting some 8,500 commercial airplanes to be retired by 2025, AFRA hopes its efforts will benefit both airlines faced with end-of-service airplanes and the environment by reducing the amount of airplane material that goes into landfills.

SUMMARY

Boeing continues to work with AFRA, which is focused on safe and sustainable solutions for the reuse of airplane parts, assemblies, and recovered materials from retired airplanes, with the ultimate goal of improving industry sustainability. AFRA's strong belief is that end-of-service airplane owners will preferentially seek out companies whose operators have been independently reviewed and accredited to embody the expertise and process fidelity that will realize greatest value at lowest risk. The organization publically distributes the information and processes it develops in a series of documents on its Web site: www.AFRAAssociation.org.

For more information, contact Bill Carberry at william.l.carberry@boeing.com.

AIRPLANE UTILIZATION AND TURN-TIME MODELS PROVIDE USEFUL INFORMATION FOR SCHEDULE, FLEET, AND OPERATIONS PLANNING.

Economic Impact of Airplane Turn-Times

By Mansoor Mirza
Regional Director,
Economic and Financial Analysis Group

Optimizing airplane utilization, which includes efficient airplane turn-time at the gates, can help an airline maximize the large capital investment it has made in its airplanes. Efficient airplane utilization requires close coordination among an airline's own fleet planning, schedules planning, passenger reservations, flight operations, ground operations, and airplane maintenance systems, as well as with air traffic controllers and airport authorities (see following article, "Improving Ramp/Terminal Operations for Shorter Turn-Times"). Even a small reduction in turnaround time at the gate can produce impressive benefits, particularly for short-haul carriers.

Airplane utilization is a key performance indicator for airline operations and a significant differentiator for some business models. Airplane utilization is a function of a number of elements, including airplane design features and characteristics, airline maintenance programs, airplane technical reliability, airline business philosophy, market demand characteristics, and availability of trained labor.

Traditionally, some carriers rely on more efficient airplane utilization based on point-to-point service and faster airplane turnaround at the gate. Improved airplane utilization helps spread fixed ownership costs over an increased number of trips, reducing costs per seat-mile or per trip.

AIRPLANE AVAILABILITY AND TURN-TIMES

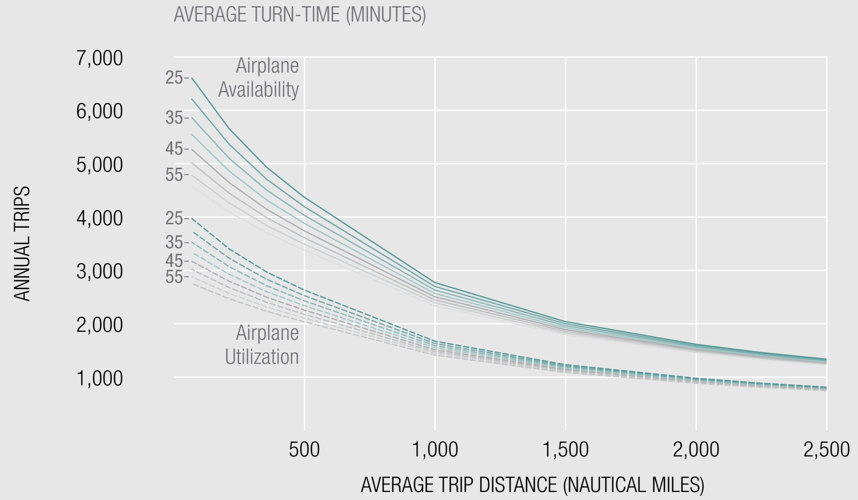
Airplane availability is the total number of days in a given period, less downtime required for airplane maintenance. Maintenance check intervals and check contents are key drivers for overall maintenance program efficiency, which in turn impacts airplane availability. Airplane systems and components reliability further influence the downtime required for additional maintenance. Airplane aging also leads to increased maintenance requirements and lower airplane availability.

For planning purposes, it is useful to convert airplane availability from number of days to number of trips. In order to simplify the analysis, assume that the airplane performs all trips at a specific trip distance. Based on airplane performance characteristics, average block time (defined as time from airplane pushback from the gate at origin to arrival at the gate at destination) for the trip can be estimated, using typical mission profile and speed schedule.

AIRPLANE AVAILABILITY AS A FUNCTION OF AVERAGE TRIP DISTANCE

Figure 1

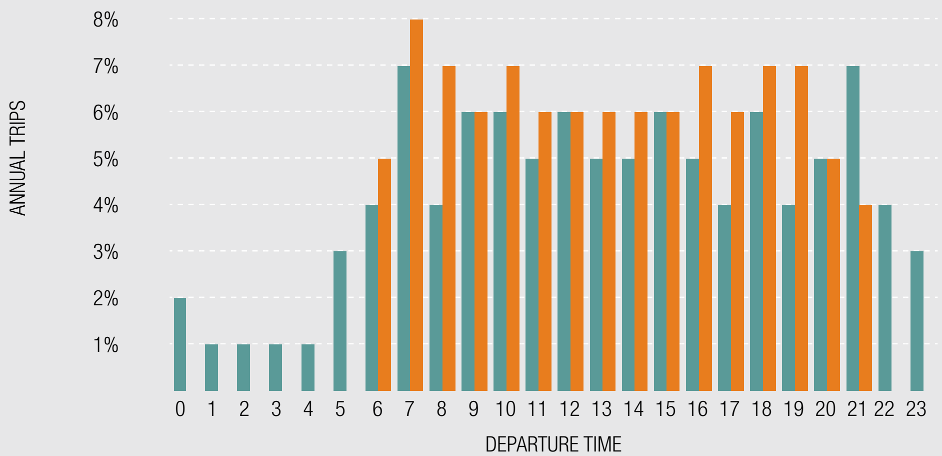
Airplane availability (in terms of number of trips) is quite sensitive to average turn-time for shorter average trip lengths. In this graphic, the solid lines represent the maximum number of annual trips for which an airplane is available as a function of average trip distance using various incremental turn-times. Additional operational factors further limit achievable airplane utilization which is captured in network efficiency factors. The dotted lines represent actual airplane utilization: airplane availability (maximum possible trips) multiplied by network efficiency (which is less than 100 percent by definition).



NETWORK EFFICIENCY IMPACTS AIRPLANE UTILIZATION

Figure 2

This graphic shows two examples of how different airline operating environments produce different network efficiency factors. In this example, one airline (orange bars) operates airplanes more intensively between 6 a.m. and 10 p.m. but has almost no utilization between 10 p.m. and 6 a.m. Another airline (turquoise bars) distributes departures relatively evenly throughout the 24-hour period, resulting in greater network efficiency.



Before an airplane can make another trip, it must remain at the gate to allow passengers to disembark, have cargo and baggage unloaded, have the airplane serviced, cargo and baggage loaded, and board passengers for the next trip. Averaged over a number of trips, this time at the gate is defined as average turn-time.

A typical hub-and-spoke system requires longer turn-times to allow for synchronization between the feeder network and trunk routes. This enables carriers to achieve higher load factors. On the other hand, carriers that typically rely on point-to-point service use a simplified fleet structure, fewer airplane types, and increased airplane utilization. With fewer airplane types, these carriers are better able to substitute airplanes in the event of an unplanned technical problem with an airplane. In order to optimize airplane utilization, point-to-point carriers operate with significantly faster turn-times at the gate. It's not unusual for a point-to-point carrier to operate with turn-times that are half as long as hub-and-spoke carriers because turn-times influence the number of trips an airplane can make in a given period of time.

Average block time for a given trip distance plus average turn-time constitutes average elapsed time per trip for the airplane. Dividing airplane availability by average elapsed time for a given trip distance provides the maximum number of trips an airplane can complete in any given period. Repeating these calculations for different trip distances using incremental turn-times in minutes provides a maximum number of trips for which an airplane is available, as a function of average trip distance (see solid lines in fig. 1).

Operators who would like to take advantage of the cost savings and efficiencies of increased airplane utilization may want to start by educating their workforces about the positive effects of reducing turn-times.

EFFECT OF NETWORK EFFICIENCY ON AIRPLANE AVAILABILITY

Airplane availability — maximum number of trips possible — represents an extreme condition and assumes no other constraints and unlimited traffic demand. In reality, traffic demand is unequally distributed around the clock. Lack of traffic demand and nighttime curfews limit airplane utilization at certain times of the day. Seasonality of demand implies less intense airplane utilization during certain months of the year. Traffic rights, arrival/departure slot restrictions, and other system limitations also restrict actual airplane utilization. All these factors combined create the network efficiency factor. Airplane availability (maximum possible trips) multiplied by the network efficiency factor (being less than 100 percent by definition) gives the actual airplane utilization (see dotted lines in fig. 1).

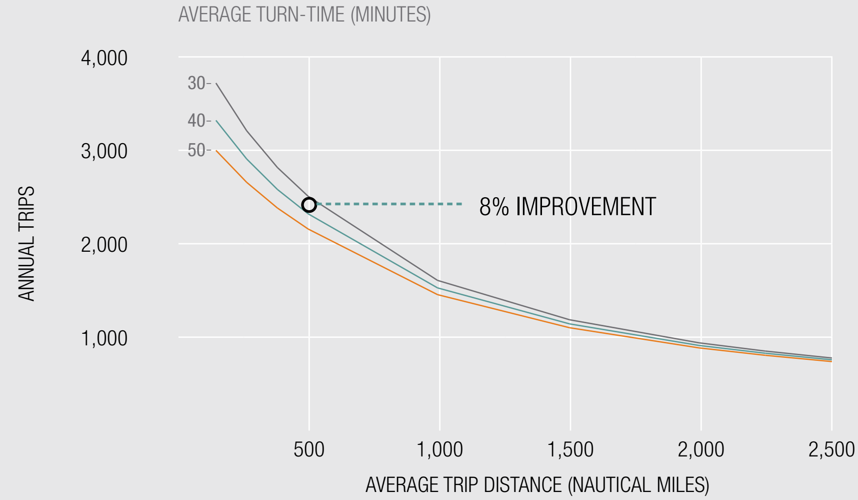
Flight departures may be distributed around the clock in very different ways, depending on the carrier (see fig. 2). For example, one airline may operate airplanes more intensively between 6 a.m. and 10 p.m. but have almost no utilization between 10 p.m. and 6 a.m. Another airline may distribute departures relatively evenly throughout the 24-hour period, resulting in a better network efficiency factor. This factor varies from operator to operator and by the business model the airline has adopted. Analysis of actual in-service data — such as annual utilization and average flight length — for a number of operators provides an opportunity to calibrate and benchmark the network efficiency factor for different business models.

In figure 1, the actual utilization levels as a function of average trip distance and turn-time are based on a 60 percent network efficiency factor, typical for most point-to-point carriers.

EFFECTS OF TURN-TIME REDUCTIONS ON AIRPLANE UTILIZATION

Figure 3

Reducing turn-time by 10 minutes with an average trip length of 500 nautical miles improves airplane utilization by 8 percent.



AIRPLANE UTILIZATION PROFILE

Figure 4

Point-to-point carriers have a significant advantage in airplane utilization compared to carriers operating on a typical hub-and-spoke system.

REAL-WORLD APPLICATIONS OF AIRPLANE UTILIZATION

Airplane utilization and turn-time models provide useful information for schedule planning, fleet planning, operations planning, and economic and financial analysis. For example, using the utilization/turn-time model for a point-to-point carrier with an average turn-time of 40 minutes gives an estimated utilization level of 2,304 trips per year with an average mission length of 500 nautical miles. Reducing the average turn-time by just 10 minutes — from 40 to 30 minutes — improves the utilization level to 2,491 trips per year, an increase of 8.1 percent (see fig. 3). This efficiency can enable a carrier to reduce the number of airplanes it needs to have in its fleet to make an equal number of trips.

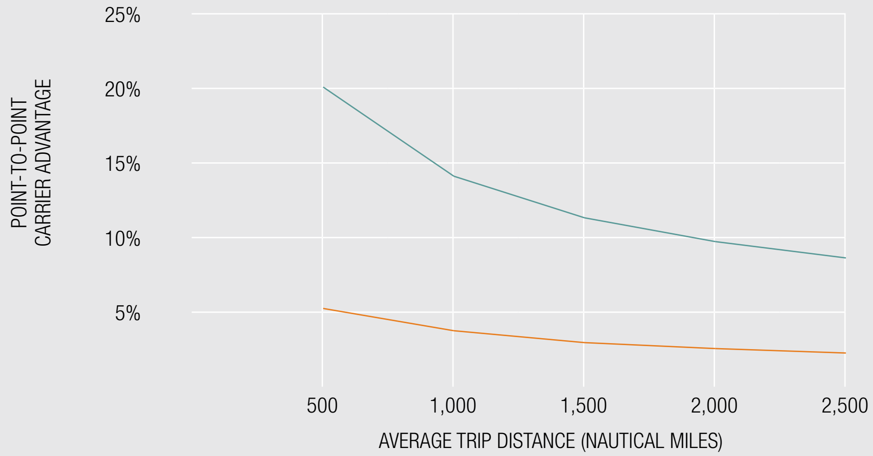
With increased average trip distance, airplane utilization in terms of flight hours increases but number of trips per year decreases, reducing the potential savings from shorter turn-times. Because of their average trip distances, point-to-point carriers can achieve greater airplane utilization than hub-and-spoke carriers (see fig. 4). The advantage is quite significant at around 20 percent for shorter mission lengths (approximately 500 miles) and reduces to about 10 percent for longer mission lengths (approximately 2,000 miles).

This increased utilization allows operators to distribute fixed ownership costs over higher number of trips, effectively lowering airplane-related operating costs (AROC) compared to hub-and-spoke carriers. Increasing airplane utilization by 20 percent effectively lowers AROC by about 5 percent, a significant reduction. As mission lengths increase, this advantage decreases (see fig. 5). In fact, the

AROC ADVANTAGE OF IMPROVED AIRPLANE UTILIZATION

Figure 5

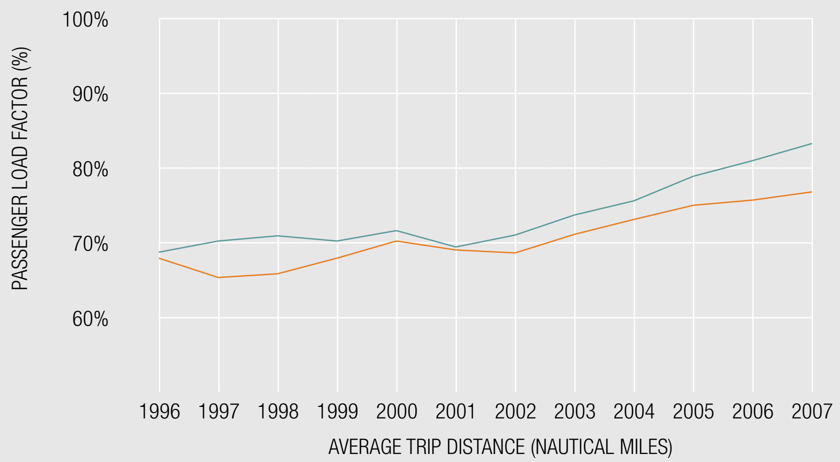
The greater airplane utilization that point-to-point carriers can achieve relative to hub-and-spoke carriers allows them to distribute fixed ownership costs over more trips, effectively lowering AROC. Increasing airplane utilization by 20 percent has the effect of lowering AROC by about 5 percent. As mission lengths increase, this advantage decreases due to fewer opportunities to save time at the gate.



PASSENGER LOAD FACTORS FOR HUB-AND-SPOKE AND POINT-TO-POINT CARRIERS

Figure 6

Although they have longer turn-times, hub-and-spoke carriers tend to have higher passenger load factors.



hub-and-spoke model, which requires relatively longer turn-times, offsets the disadvantage of lower airplane utilization by capturing higher load factors (see fig. 6).

HOW OPERATORS CAN INCREASE AIRPLANE UTILIZATION

Operators who would like to take advantage of the cost savings and efficiencies of increased airplane utilization may want to start by educating their workforces about the positive effects of reducing turn-times. For example, the airline may explain that saving 10 minutes on 2,000 trips per year means an additional 20,000 minutes — or more than 300 hours — available for additional flights. More flights mean more paying passengers and, ultimately, more revenue.

SUMMARY

Reducing airplane turn-times means more efficient airplane utilization, particularly for airlines that emphasize point-to-point routes. Benefits of shorter turn-times are significant for shorter average trip distances. For example, a 10-minute faster average turn-time can increase airplane utilization by 8 percent and lower AROC for a typical single-aisle airplane by 2 percent.

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BOEING ENGINEERS LOOK AT ALL ASPECTS OF AN AIRLINE'S RAMP PROCEDURES TO FIND OPPORTUNITIES TO IMPROVE SAFETY AND EFFICIENCY.

Improving Ramp/Terminal Operations for Shorter Turn-Times

By Troy Barnett
Principal Maintenance Engineer,
Maintenance and Ground Operations Systems

Efficient, dependable ramp operations not only directly affect passengers' satisfaction with an airline, but they also offer economic benefits, particularly for short-haul carriers (see preceding article, "Economic Impact of Airplane Turn-Times"). However, it can be difficult for airlines to achieve turn-time reductions if they don't fully understand the factors influencing airplane turnarounds. Boeing offers a service that analyzes turnarounds and provides recommendations to reduce turn-times and improve ramp safety.

Ramp/terminal operation engineers at Boeing are available to perform turn-time studies for airlines. This fee-based service is designed to increase operators' awareness of the latest and most successful ramp operations processes and procedures and to keep them up to date on developments in ramp and ground-support equipment (GSE).

This article provides an overview of these airplane turn-time studies, details the turn-time study process, and explains the benefits an operator can expect from a turn-time study.

TURN-TIME STUDY OVERVIEW

Boeing performs on-site ramp/terminal operational efficiency evaluations for its customers. These individual evaluations, or studies, are designed to:

- Help airlines benchmark their technical status in terms of ensuring their awareness of the latest and most successful ramp operation processes and procedures.
- Keep airlines current on developments in GSE.
- Identify areas of concern.
- Improve awareness of ramp safety.
- Recommend changes that can improve efficiency.
- Explore methods of implementing the recommended changes.

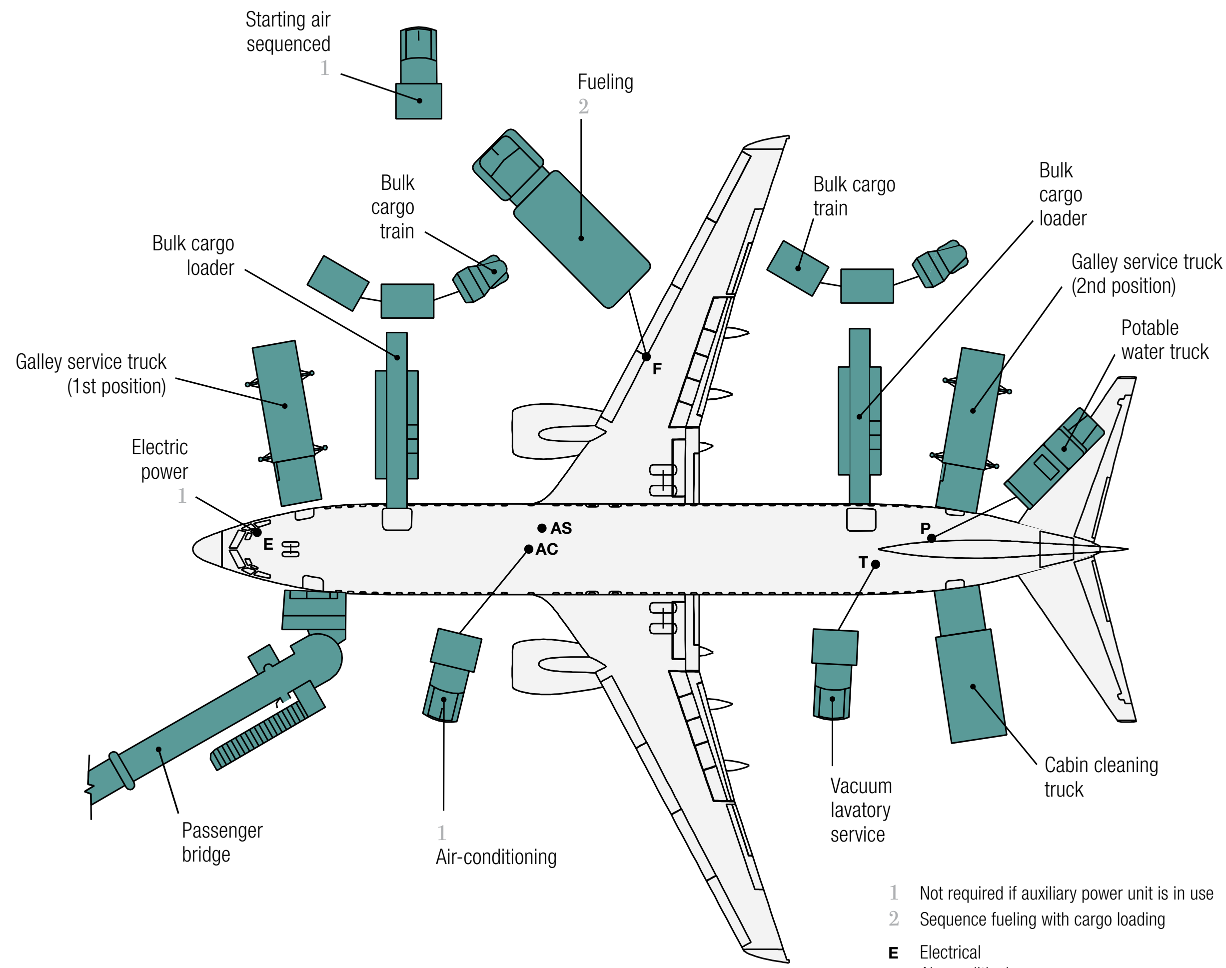
In performing an evaluation, Boeing engineers look at all aspects of an airline's ramp procedures to identify opportunities to improve safety and efficiency while attempting to eliminate the risk of damage to airplanes. The team assesses equipment, procedures, and the time required to turn an airplane. The goal is for the operator to achieve an efficient, economical, safe, and repeatable process.

Often, the solutions generated in an evaluation can be applied to other airplanes and other locations. Studies can be conducted for any airport and for all models of Boeing airplanes.

TYPICAL NEXT-GENERATION 737 TURN-TIME SERVICING ARRANGEMENT

Figure 1

A Boeing team analyzes an operator's ramp operations to help reduce average turn-times and increase airplane utilization.



TURN-TIME STUDY PROCESS

A turn-time study typically includes a review of the following areas, with the airline determining which activities may require special attention:

- Coordination and scheduling of labor.
- Line maintenance.
- Organizational structure.
- Outstation (as required).
- Quality assurance and control.
- Ramp safety.
- Ramp/terminal operations.
- Technical policies and procedures.
- Training.
- GSE.
- Ramp policies and procedures.
- Sequence of events.

A study begins with a visit by a Boeing team to an airline site and outstation to analyze detailed records on all aspects of the ramp operations (see fig. 1). Using analytical methods and standards, the team then identifies inefficiencies and opportunities for improvement in the following areas:

- Cabin grooming.
- Cargo loading and unloading.
- Fueling.
- Galley servicing.
- Meal and beverage provisioning.
- Passenger boarding and deplaning.
- Potable water replenishment.
- Preflight check.

The team also conducts detailed interviews with all levels of management and other ramp and terminal operations personnel. Topics addressed include organization and job descriptions; employed policies and procedures; maintenance and overhaul capabilities; and GSE, safety, and performance measurement methods.

The Boeing team uses a variety of criteria during the study, including the International Air Transportation Association's Airport Handling Manual, actual airline observations, Boeing-recommended practices and procedures, accepted industry standards, and knowledge of ramp handling operations and GSE requirements.

At the conclusion of a ramp/terminal operation analysis, the Boeing team verbally debriefs the airline's management on the significant findings. The airline also receives a written report approximately 30 days after the on-site evaluation. Reports typically range from 50 to 80 pages and provide detailed findings, observed and proposed timelines, and recommendations (see fig. 2). Airline findings are strictly treated as proprietary information and not shared with other airlines.

BENEFITS OF TURN-TIME STUDIES

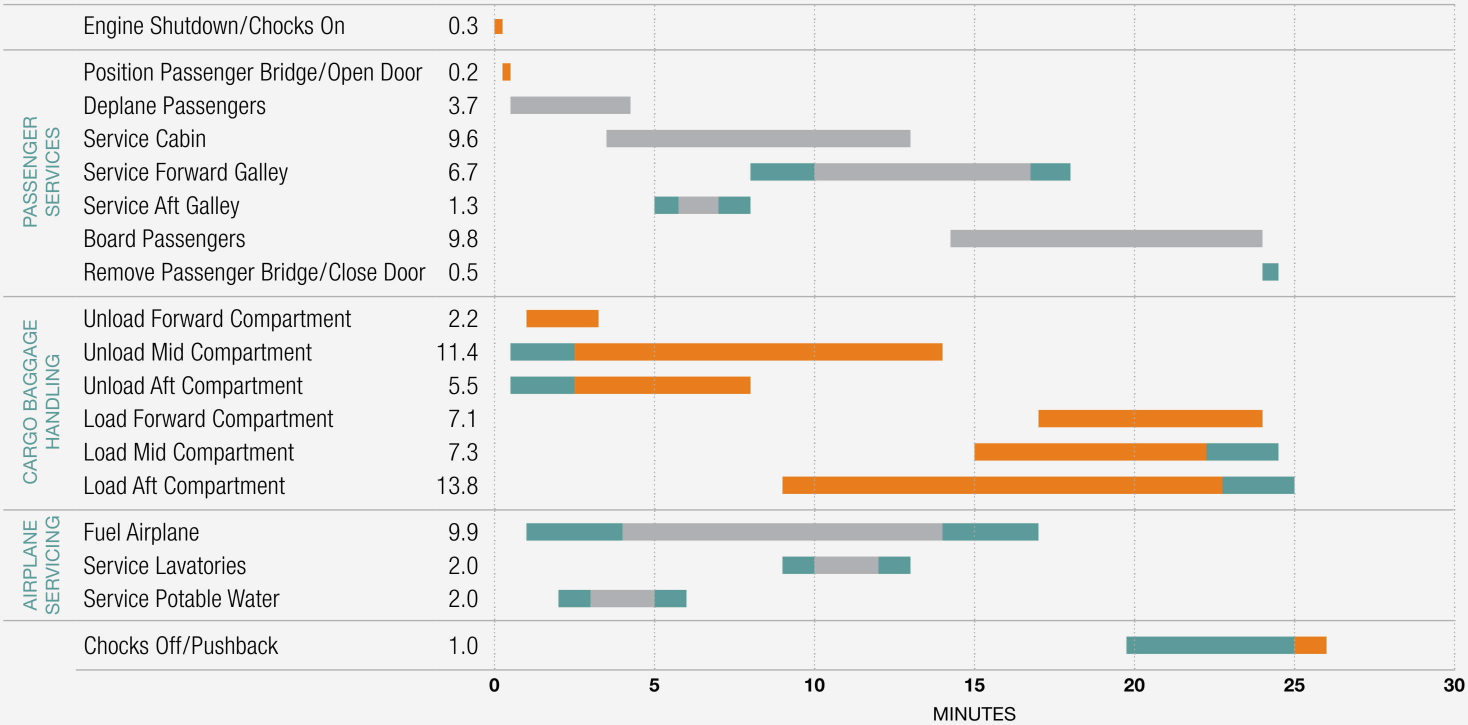
Turn-time studies provide operators with detailed recommendations on how individual tasks can be

DETAILED RECOMMENDATIONS TO IMPROVE TURN-TIME EFFICIENCY

Figure 2

Each turn-time study includes a detailed written report with specific recommendations, such as this flow chart, on how an airline can improve turn-times.

TYPICAL NEXT-GENERATION 737 TIMELINE



= Position Equipment = Critical Path

PARAMETERS

- *142 passengers off, 121 passengers on*
- *2 doors used to deplane and enplane*
- *1 galley service truck*
- *1 lavatory service truck*
- *1 potable water service truck*

NOTE

- *Belt loader used at cargo hold*
- *Aft galley, potable water, and lavatory service complete before passenger boarding*

improved and how multiple tasks can be coordinated to permit optimum ramp/terminal operations and improve airplane utilization. These studies enable airlines to compare their methods and performance to that of other operators, obtain an independent review of operations and processes, and identify problems and prioritize solutions. Airlines can realize a number of benefits from turn-time studies, including:

- Efficient, repeatable, and safe turnaround operation on the ramp and inside the airport terminal.
- Possibility of additional revenue and additional flights per day.
- Reduced "ramp rash" through safety awareness and recurrent training.
- Safer ramp/terminal infrastructure, equipment, and operations.
- Fuel savings through reduced auxiliary power unit usage.
- Reduced airplane scheduling conflicts on the ground and at the gates.
- Reduced gate time for airplanes during turnaround operations.
- Maximized gate usage during peak operational times.
- Improved passenger satisfaction.
- Proper use and availability of GSE.
- Better utilization of ramp personnel.
- Increased management awareness of ramp and terminal operations.

As outlined in the preceding article, "Economic Impact of Airplane Turn-Times," airplane turn-time studies can also help an airline keep airplanes earning revenue during a greater portion of their duty cycle. The time recovered may even allow an additional flight at the end of the day. In one actual case, Boeing helped an airline increase its number of quick turns (a turn accomplished in 30 minutes or less in most stations) by 33 percent.

SUMMARY

A Boeing team is available on-site to assist operators in optimizing their airplane turn-times by using analytical methods and standards to improve individual tasks and coordinate multiple events on the ramp. Boeing can perform this fee-based turn-time analysis for all models of Boeing airplanes. These studies incorporate airline maintenance, airline policy, government regulatory requirements, and GSE availability. At the conclusion, Boeing will provide the operator with a detailed written report documenting the findings and recommendations as well as an implementation plan to reduce overall turn-times.

For more information, please contact Troy Barnett at troy.a.barnett@boeing.com or view his Web site at http://www.boeing.com/commercial/ams/mss/brochures/turntime.html.

THE DIFFERENCE BETWEEN HIGHER AND LOWER FLAP SETTING CONFIGURATIONS MAY SEEM SMALL, BUT AT TODAY'S FUEL PRICES THE SAVINGS CAN BE SUBSTANTIAL.

Fuel Conservation Strategies: Takeoff and Climb

By William Roberson, Senior Safety Pilot, Flight Operations; and
James A. Johns, Flight Operations Engineer, Flight Operations Engineering

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

Every takeoff is an opportunity to save fuel. If each takeoff and climb is performed efficiently, an airline can realize significant savings over time. But what constitutes an efficient takeoff? How should a climb be executed for maximum fuel savings? The most efficient flights actually begin long before the airplane is cleared for takeoff.

This article discusses strategies for fuel savings during the takeoff and climb phases of flight. Subsequent articles in this series will deal with the descent, approach, and landing phases of flight, as well as auxiliary-power-unit usage strategies. The first article in this series, "Cost Index Explained," appeared in the second-quarter 2007 *AERO*. It was followed by "Cruise Flight" in the fourth-quarter 2007 issue.

TAKEOFF AND CLIMB FUEL CONSERVATION STRATEGIES

In the past, when the price of jet fuel increased by 20 to 30 cents per U.S. gallon, airlines did not concern themselves with fuel conservation in the takeoff and climb segment of the flight because it represents only 8 to 15 percent of the total time of a medium- to long-range flight.

But times have clearly changed. Jet fuel prices have increased over five times from 1990 to 2008. At this time, fuel is about 40 percent of a typical airline's total operating cost. As a result, airlines are reviewing all phases of flight to determine how fuel burn savings can be gained in each phase and in total.

This article examines the takeoff and climb phase for four types of commercial airplanes to illustrate various takeoff and climb scenarios and how they impact fuel usage. These analyses look at short-range (e.g., 717), medium-range (e.g., 737-800 with winglets), and long-range (e.g., 777-200 Extended Range and 747-400) airplanes.

An important consideration when seeking fuel savings in the takeoff and climb phase of flight is the takeoff flap setting. The lower the flap setting, the lower the drag, resulting in less fuel burned. Figure 1 shows the effect of takeoff flap setting on fuel burn from brake release to a pressure altitude of 10,000 feet (3,048 meters), assuming an acceleration altitude of 3,000 feet (914 meters) above ground level (AGL). In all cases, however, the flap setting must be appropriate for the situation to ensure airplane safety.

Higher flap setting configurations use more fuel than lower flap configurations. The difference is small, but at today's prices the savings can be substantial — especially for airplanes that fly a high number of cycles each day.

For example, an operator with a small fleet of 717s which flies approximately 10 total cycles per day could save 320 pounds (145 kilograms) of fuel per day by changing its normal takeoff flaps setting from 18 to 5 degrees. With a fuel price of US$3.70 per U.S. gallon, this would be approximately US$175 per day. Assuming each airplane

THE ROLE OF THE FLIGHT CREW IN FUEL CONSERVATION

Every area of an airline has a part to play in reducing the cost of the operation. But the flight crew has the most direct role in cutting the amount of fuel used on any given flight.

The flight crew has opportunities to affect the amount of fuel used in every phase of flight without compromising safety. These phases include planning, ground operations, taxi out, takeoff, climb, cruise, descent, approach, landing, taxi in, and maintenance debrief.

Top fuel conservation strategies for flight crews include:

- Take only the fuel you need.
- Minimize the use of the auxiliary power unit.
- Taxi as efficiently as possible.
- Take off and climb efficiently.
- Fly the airplane with minimal drag.
- Choose routing carefully.
- Strive to maintain optimum altitude.
- Fly the proper cruise speed.
- Descend at the appropriate point.
- Configure in a timely manner.

is flown 350 days per year, the airline could save approximately US$61,000 a year. If an airline makes this change to a fleet of 717 airplanes that averages 200 cycles a day, it could save more than US$1 million per year in fuel costs.

Using these same assumptions on fuel price, the potential fuel savings for an operator of a small fleet of 747-400s whose airplanes average a total of three cycles per day would be approximately 420 U.S. pounds (191 kilograms) of fuel per day, or approximately US$230. During a year, the operator could save approximately US$84,000. These savings are not as dramatic as the short-range transport airplane, but clearly they increase as the fleet size or number of cycles grows.

Operators need to determine whether their fleet size and cycles are such that the savings would make it worthwhile to change procedures and pilot training. Other important factors that determine whether or not it is advisable to change standard takeoff settings include obstacles clearance, runway length, airport noise, and departure procedures.

Another area in the takeoff and climb phase where airlines can reduce fuel burn is in the climb-out and cleanup operation. If the flight crew performs acceleration and flap retraction at a lower altitude than the typical 3,000 feet (914 meters), the fuel burn is reduced because the drag is being reduced earlier in the climb-out phase.

COMPARING THE FUEL USAGE OF TWO STANDARD CLIMB PROFILES

Figure 2 shows two standard climb profiles for each airplane. These simplified profiles are based on the International Civil Aviation Organization (ICAO) Procedures for Air Navigation Services Aircraft Operations (PANS-OPS) Noise Abatement Departure Procedures (NADP) NADP 1 and NADP 2 profiles. Profile 1 is a climb with acceleration and flap retraction beginning at 3,000 feet (914 meters) AGL, which is the noise climb-out procedure for close-in noise monitors. Profile 2 is a climb with acceleration to flap retraction speed beginning at 1,000 feet (305 meters) AGL, which is the noise climb-out procedure for far-out noise monitors. As a general rule, when airplanes fly Profile 2,

IMPACT OF TAKEOFF FLAPS SELECTION ON FUEL BURN
Figure 1

AIRPLANE MODEL	TAKEOFF FLAP SETTING	TAKEOFF GROSS WEIGHT *Pounds (kilograms)*	FUEL USED *Pounds (kilograms)*	FUEL DIFFERENTIAL *Pounds (kilograms)*
717-200	5	113,000 (51,256)	933 (423)	–
	13		950 (431)	17 (8)
	18		965 (438)	32 (15)
737-800 Winglets	5	160,000 (72,575)	1,274 (578)	–
	10		1,291 (586)	17 (8)
	15		1,297 (588)	23 (10)
777-200 Extended Range	5	555,000 (249,476)	3,605 (1,635)	–
	10		3,677 (1,668)	72 (33)
	20		3,730 (1,692)	125 (57)
747-400	10	725,000 (328,855)	5,633 (2,555)	–
	20		5,772 (2,618)	139 (63)
747-400 Freighter	10	790,000 (358,338)	6,389 (2,898)	–
	20		6,539 (2,966)	150 (68)

FUEL-SAVING POTENTIAL OF TWO CLIMB PROFILES
Figure 2

AIRPLANE MODEL	TAKEOFF GROSS WEIGHT *Pounds (kilograms)*	PROFILE TYPE	TAKEOFF FLAP SETTING	FUEL USED *Pounds (kilograms)*	FUEL DIFFERENTIAL *Pounds (kilograms)*
717-200	113,000 (51,256)	1	13	4,025 (1,826)	–
		2		3,880 (1,760)	145 (66)
737-800 Winglets	160,000 (72,575)	1	10	5,234 (2,374)	–
		2		5,086 (2,307)	148 (67)
777-200 Extended Range	555,000 (249,476)	1	15	14,513 (6,583)	–
		2		14,078 (6,386)	435 (197)
747-400	725,000 (328,855)	1	10	21,052 (9,549)	–
		2		20,532 (9,313)	520 (236)
747-400 Freighter	790,000 (358,338)	1	10	23,081 (10,469)	–
		2		22,472 (10,193)	609 (276)

EFFECT OF COMBINING TAKEOFF AND CLIMB STRATEGIES
Figure 3

AIRPLANE MODEL	TAKEOFF GROSS WEIGHT *Pounds (kilograms)*	PROFILE TYPE	TAKEOFF FLAP SETTING	FUEL USED *Pounds (kilograms)*	FUEL DIFFERENTIAL *Pounds (kilograms)*
717-200	113,000 (51,256)	1	18	4,061 (1,842)	–
		2	5	3,859 (1,750)	202 (92)
737-800 Winglets	160,000 (72,575)	1	15	5,273 (2,392)	–
		2	5	5,069 (2,299)	204 (93)
777-200 Extended Range	555,000 (249,476)	1	20	14,710 (6,672)	–
		2	5	14,018 (6,358)	692 (314)
747-400	725,000 (328,855)	1	20	21,419 (9,715)	–
		2	10	20,532 (9,313)	887 (403)
747-400 Freighter	790,000 (358,338)	1	20	23,558 (10,686)	–
		2	10	22,472 (10,193)	1,086 (493)

they use 3 to 4 percent less fuel than when flying Profile 1.

Figure 3 shows the combined effect of using a lower takeoff flap setting and flying Profile 2, compared to using a higher takeoff flap setting and flying Profile 1. Combining a lower takeoff flap setting with Profile 2 saves approximately 4 to 5 percent fuel compared to the higher takeoff flap setting and Profile 1.

Once the flaps are retracted, the crew should accelerate to maximum rate of climb speed. The 737s with flight management computers (FMC) provide this speed directly via the FMC control display unit. All Boeing flight crew training manuals provide guidance for maximum rate of climb speed. It can also be achieved by entering a cost index of zero in the FMC. (See “Cost Index Explained” in the second-quarter 2007 *AERO*.)

OTHER CONSIDERATIONS

From a fuel consumption perspective, a full-thrust takeoff and a full-thrust climb profile offer the most fuel economy for an unrestricted climb. However, from an airline’s cost perspective, this must be balanced with engine degradation and time between overhauls, as well as guidance from the engine manufacturer. The airline’s engineering department must perform the analysis and provide direction to flight crews to minimize overall cost of operation when using takeoff derates or assumed temperature takeoffs and climbs.

SUMMARY

In a time when airlines are scrutinizing every aspect of flight to locate possible opportunities to save fuel, the takeoff and climb phases of flight should be considered as part of an overall fuel savings effort. The impact of incorporating fuel saving strategies into every phase of the operation can result in considerable cost reductions.

Boeing Flight Operations Engineering assists airlines’ flight operations departments in determining appropriate takeoff and climb profiles specific to their airplane models. For more information, please contact FlightOps.Engineering@boeing.com

NEWS WITHOUT THE NOISE.

THE NEW 747-8 INTERCONTINENTAL.

The new 747-8 is great news for everyone. In addition to lowering operating costs for airlines and setting new standards of comfort for passengers, the 747-8 will also be a welcome sight for airport communities—significantly reducing noise and environmental impact. It's a cleaner flying, quieter 747. Great news that's easy on your ears.

BOEING