



*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

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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, rotatable 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).

Figure 2

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



- 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).*

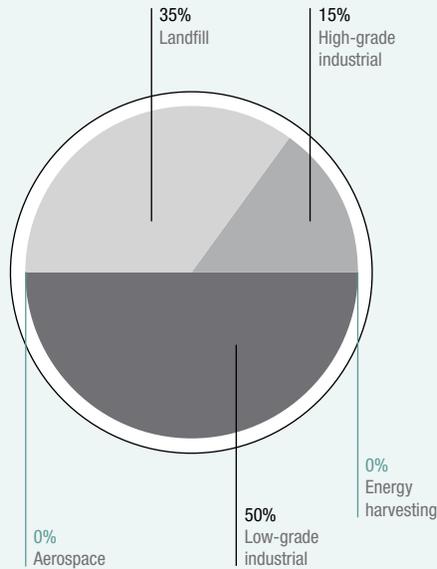


**MOVING TOWARD A MORE EFFICIENT RECYCLING PROCESS**

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.*

**TODAY**



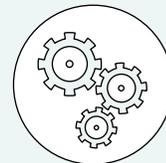
**1**

**MATERIALS ARE HARVESTED**

End-of-service scrap



Manufacturing scrap



- 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

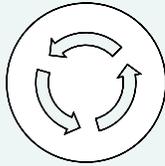
should be dismantled. By choosing an AFRA-accredited facility to scrap out their airplane, the airplane owner has an assurance that the facility has the expertise and processes to ensure that fewer parts are damaged by being removed and handled incorrectly and that the parts of the airplane that can't 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

## 2

BETTER RECYCLING PROCESSES  
ARE USED ACROSS INDUSTRY

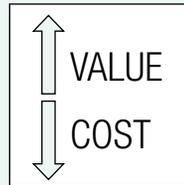
More efficient processes



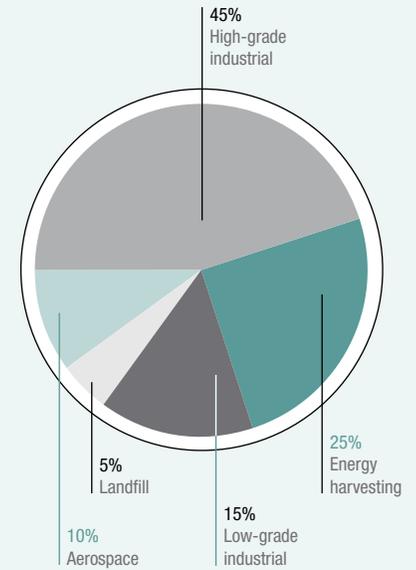
- Aluminum
- Other metals
- Plastics
- Wires and electronics
- Carbon fiber composites

## 3

RECYCLATE  
MANUFACTURING APPLICATIONS  
MAXIMIZE RECYCLATE VALUE



## FUTURE TARGET



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](http://www.AFRAAssociation.org).

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