



TAUBER INSTITUTE  
FOR GLOBAL OPERATIONS  
UNIVERSITY OF MICHIGAN

## Pioneering Carbon Fiber Recycling at Boeing



Founded in 1916 in Seattle and now headquartered in Chicago, The Boeing Company is a multinational corporation that designs, manufactures, and sells airplanes, rotorcraft, rockets, and satellites along with providing leasing and product support services. With 2015 revenue of \$96.11 billion, Boeing is among the largest global aircraft manufacturers, the second-largest defense contractor in the world, and the largest exporter in the United States by dollar value. To help improve its recycling processes, it brought in a team from the Tauber Institute for Global Operations.

Based in Renton, Washington with more than 83,000 employees, Boeing Commercial Airplanes (BCA) is one of The Boeing Company's five primary divisions. Along with designing, assembling, marketing, and selling jet airliners and business jets, BCA provides product-related maintenance and training to customers worldwide.

Boeing is one of the largest consumers of carbon fiber reinforced plastic (CFRP) in the U.S. and is therefore also a significant producer of CFRP waste. Boeing currently creates 1.1 million pounds of CFRP waste annually and sends, at great expense, more than 95 percent of this waste to specialized landfills because of the nascent recycling industry and unavailability of material handling processes.

Boeing is currently building the 777X Composite Wing Center (CWC), which will increase total CFRP waste to 1.8 million pounds annually. Recognizing the importance of developing the CFRP recycling and reuse industry, it has launched a zero waste-to-landfill (ZW2L) initiative.

In order to jumpstart and explore the implementation of a CFRP ZW2L facility, Boeing brought in a student team from the Tauber Institute for Global Operations at the University of Michigan. This team consisted of two MSE in industrial and operations engineering students, **Akul Bali** and **Martha Neubauer**, and **Kelsea Ballantyne**, pursuing a Master of Business Administration and MS in natural resources and environment.

"The greatest challenge of our project is related to its uniqueness. Since we were dealing with a nascent industry, there were a lot of unknowns and variability. The recycling technology is also still developing and improving, so the carbon fiber waste volume companies can process and the cost of processing were only estimates," said Neubauer.

"To overcome these challenges, we developed a robust solution with different options based on the most probable future

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"Carbon fiber recycling is in its infancy and we were challenged to create a solution for both Boeing and the market."

— Kelsea Ballantyne.

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scenarios. In this way, Boeing will be able to achieve zero waste to landfill no matter what changes in the future," she added.

In addition to achieving ZW2L, the Tauber team defined decreasing costs, increasing revenues, and constructing planes with recycled CFRP as key solution drivers. Using a systems thinking approach, the team developed a plan to match operational waste outputs to market demand.

They first conducted a market analysis by visiting and interviewing viable CFRP recyclers and reusers. Following this analysis, the team developed a market material preferences table and a business case analysis on closing the loop. "To make the case for recycling and reusing, we needed to find ways to maintain the value of scrap



*Kelsea Ballantyne and Akul Bali (photo from student teams)*

carbon fiber,” said Neubauer. Previously, Boeing operators would ball up carbon fiber scrap pieces and mix them with other waste. This makes the material lose value, because it is stuck to itself and other pieces of trash.”

Next, the Tauber team created the Tauber Waste Discovery Method to estimate volumes and types of CFRP waste potentially generated. This allowed for assessment of Boeing’s proposed baseline material handling process. The simulation highlighted key shortfalls in the process that have resulted in missed opportunities to sell to reusers and recyclers. To address these issues, the team piloted point-of-use waste segregation and prototyped a material handling bolt tool with operators.

“These innovations cost less in time and money than the baseline process and created waste material in a form that reusers and recyclers would purchase,” said Ballantyne.

“Our bolt tool allows the operator to quickly consolidate scrap into a bolt, similar to a bolt of fabric, which is cost effective for shipping. Because of our methods, Boeing will be able to profit from its scrap carbon fiber, instead of paying for it to be disposed of safely.”

The Tauber team created a model that integrated engineering, operational, and market variables to test 14 scenarios. They then tested each scenario against its ability to fulfill the key solution drivers.

“We brought together five departments that had not collaborated prior, thus creating a holistic solution,” said Ballantyne. “These departments will be integrating into the new facility.”

In order to implement the best scenario, the team recommended a comprehensive market-building and operations approach ensuring Boeing had the incentives and tools to create and supply CFRP waste materials to the market as well as effectively develop the market through technologies.

These recommendations created a scenario with the ability to achieve revenues of \$5.4 million NPV over 10 years and ultimately accomplish the ZW2L objective. The team was also able to tailor its recommendations to Boeing’s 10 other CFRP waste producing sites, providing the company capacity to become CFRP ZW2L company-wide.

“The project was very different from typical Tauber projects,” said Neubauer. “Our focus was not saving money, making a manufacturing site leaner, or streamlining a supply chain. Instead, it was to decrease the environmental impact of airplane manufacturing and set a precedent in the industry for carbon fiber recycling.”

### The Challenge

The Tauber Boeing Commercial Airplanes-PD Team will create and pilot a plan to enable the new 777X Composite Wing Center to become a zero waste-to-landfill production facility. This plan includes determining the types and volumes of carbon fiber waste, creating a collection and segregation process, and piloting current and future reduction and recycling opportunities through both internal and external markets. The use of carbon fiber at Boeing and in other industries is increasing rapidly as the material cost falls due to its commoditization. Unlike metals, it does not have an established recycling industry. Thus, the team’s work is crucial in contributing to the overall best practices and standards of carbon fiber recycling at Boeing and beyond.

### Student Team

Akul Bali  
*EGL (BSE Electrical Engineering/MSE Industrial and Operations Engineering)*

Kelsea Ballantyne  
*Dual (MBA & Master of Science in Natural Resources & Environment)*

Martha Neubauer  
*EGL (BSE Chemical Engineering/MSE Industrial and Operations Engineering)*

### Project Sponsors

Tia H Benson Tolle  
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L to R: Three Boeing sponsored 2016 Tauber teams in Seattle (photo from student teams)

### Faculty Advisors

Erdogan Gulari  
*College of Engineering*

Peter Lenk  
*Ross School of Business*

### About Tauber Team Projects

Each two to three person Tauber Team consists of graduate Engineering, MBA, and/or MSCM students. Along with receiving high-level corporate support from the sponsoring company, each team is advised by a College of Engineering and a Ross School of Business faculty member and overseen by a Tauber Institute co-director. The projects begin on-site in May and continue for 14 weeks. Students present the results of their projects and compete for over \$40,000 in scholarships at the U-M Tauber Institute’s annual *Spotlight!* event, held each September in Ann Arbor, Michigan. *Spotlight!* provides outstanding opportunities for students and corporate partners to establish relationships while exploring innovations in operations and manufacturing. The 2015 Tauber Team Projects resulted in \$500 million in savings according to sponsoring company calculations, an average of \$14.3 million per project over three years.

To learn more about the Tauber Institute for Global Operations, visit [tauber.umich.edu](http://tauber.umich.edu) or contact us at (734) 647-1333.

