

# Frontiers

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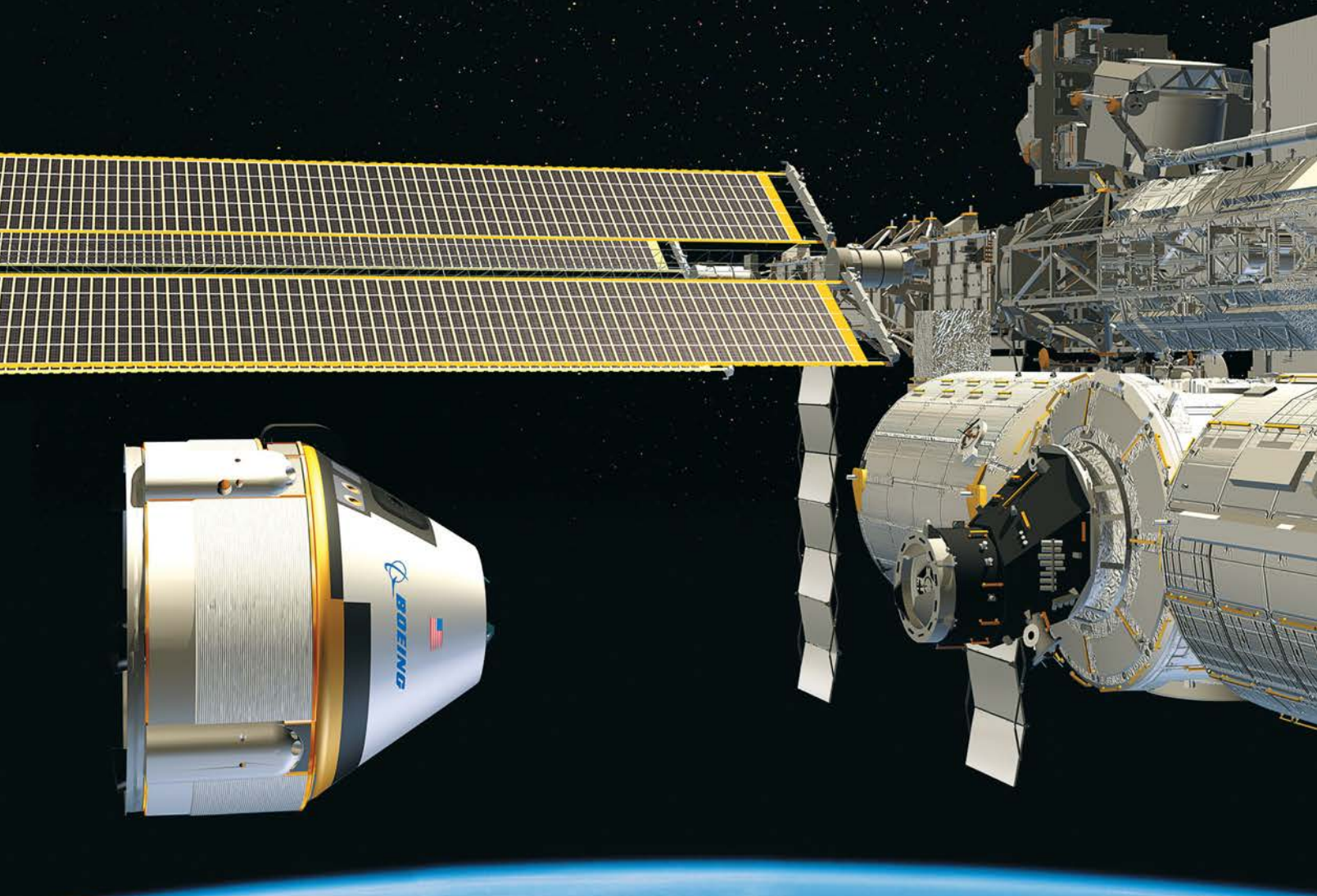
JULY 2012 / Volume XI, Issue III

## Shaping the future

Wind tunnel testing helps  
Boeing shape 737 MAX—  
and the future of flight







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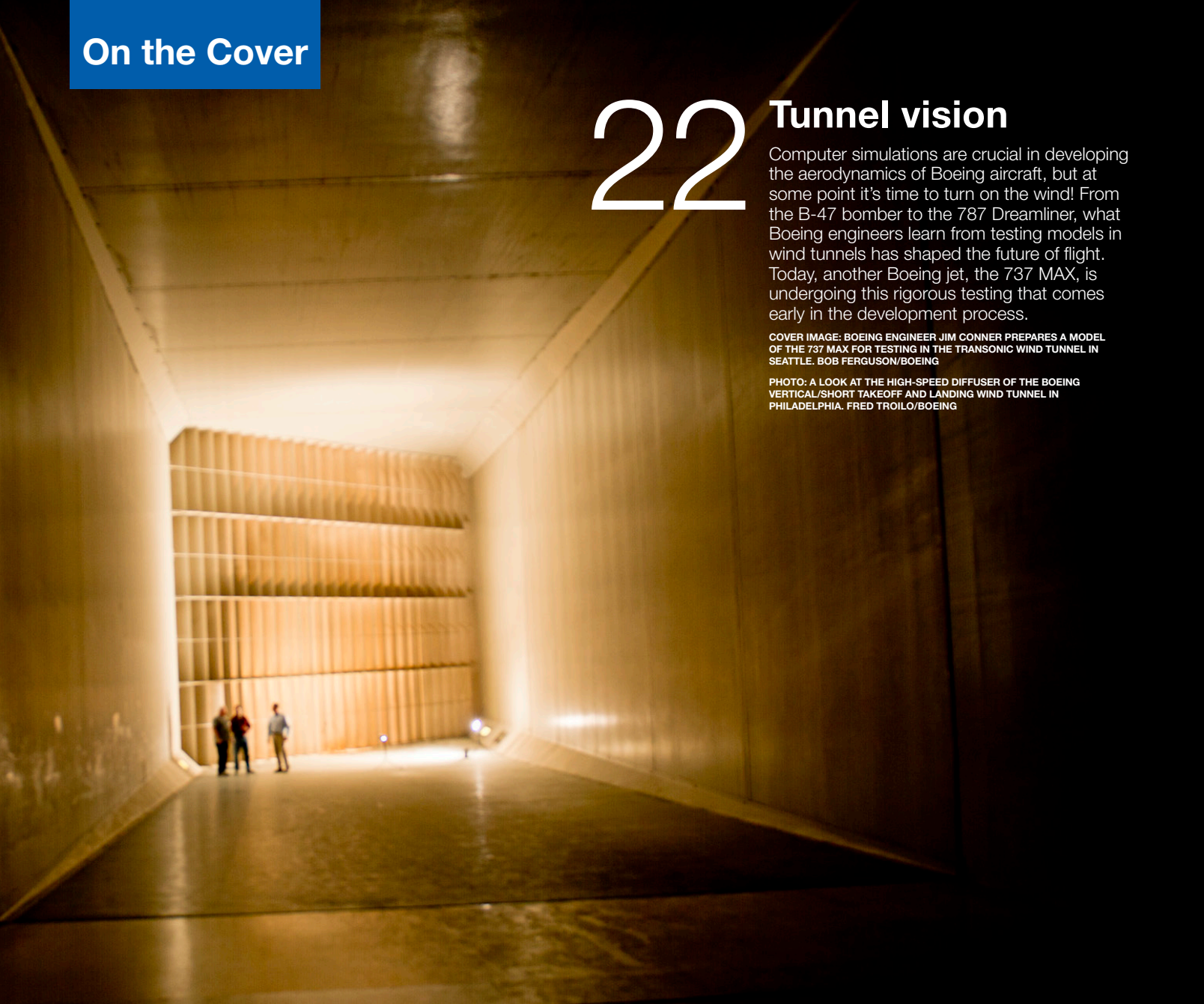


# 22 Tunnel vision

Computer simulations are crucial in developing the aerodynamics of Boeing aircraft, but at some point it's time to turn on the wind! From the B-47 bomber to the 787 Dreamliner, what Boeing engineers learn from testing models in wind tunnels has shaped the future of flight. Today, another Boeing jet, the 737 MAX, is undergoing this rigorous testing that comes early in the development process.

**COVER IMAGE: BOEING ENGINEER JIM CONNER PREPARES A MODEL OF THE 737 MAX FOR TESTING IN THE TRANSONIC WIND TUNNEL IN SEATTLE. BOB FERGUSON/BOEING**

**PHOTO: A LOOK AT THE HIGH-SPEED DIFFUSER OF THE BOEING VERTICAL/SHORT TAKEOFF AND LANDING WIND TUNNEL IN PHILADELPHIA. FRED TROILO/BOEING**



## Ad watch

The stories behind the ads in this issue of *Frontiers*.

### Inside cover:



This ad was created to highlight Boeing's Commercial Crew Development System, a reliable, cost-effective and low-risk solution for commercial space transportation. The ad is running in trade publications.

### Page 6:



This ad for the new 747-8 Intercontinental is running in Chinese trade and business publications and *Aviation Week*. The headline speaks to the airplane's striking beauty (new Boeing Sky Interior), classic elegance (new wing) and power (new engines).

### Back cover:



Every July, the Boeing Store commemorates Boeing's anniversary with a weeklong celebration, offering special merchandise, gifts and free birthday cake in the stores. This ad for the 2012 celebration features the

Model 40, Boeing's first passenger airplane, sharing the sky with the 787 Dreamliner.



# Frontiers

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Phantom Eye, a feat of Boeing engineering and innovation that pushes the envelope of unmanned aerial vehicles, flew for the first time last month in the high desert of California—and *Frontiers* has exclusive photos. Powered by clean-burning hydrogen, Phantom Eye is designed to fly at very high altitudes for days at a time. PHOTO: BOB FERGUSON/BOEING



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## Your move

For Boeing employees around the world, the six-week physical challenge known as Boeing on the Move is an opportunity to improve their health through exercise, regardless of the activity. The number of participants increases every year—as do the health benefits. Employees share some success stories in this article.

PHOTO: MIKHAIL MELNIKOV





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## 36 This is how we roll

It's a sight that has thrilled air show crowds for 66 years—the U.S. Navy Blue Angels flight demonstration team painting the sky with its precision maneuvers. As the Blue Angels prepare for their annual Seattle Seafair show next month, this photo essay captures their magic from the ground up. PHOTO: U.S. NAVY PHOTO

BY MC1 RACHEL MCMARR



## INSIDE

### 07 Leadership Message

This month the aerospace world gathers at the biennial Farnborough International Airshow in the United Kingdom, where Boeing will be showcasing its latest products and services. The show also is a great venue for Boeing to highlight its commitment to global collaboration and partnerships, says Shep Hill, president of Boeing International and senior vice president for Business Development and Strategy.

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### Boeing in the U.K.

Boeing has a long history in the United Kingdom, which today is one of the biggest markets for Boeing's commercial and military products. The U.K. also is a valuable supplier and partner, including U.K. universities working with Boeing on cutting-edge technology and research.

PHOTO: SHUTTERSTOCK





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 **BOEING**



# A world of ideas

Farnborough Airshow is a perfect venue to showcase Boeing's commitment to global collaboration and partnership

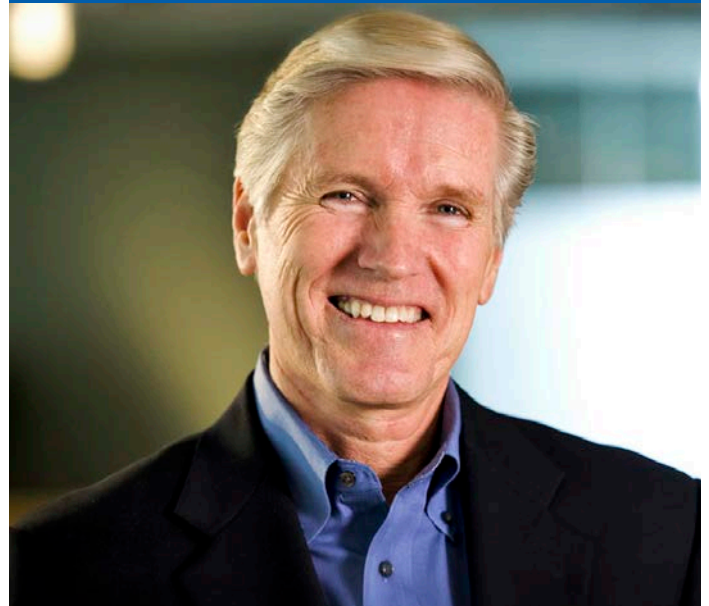
Every two years, the aerospace community gathers at the Farnborough International Airshow in the United Kingdom. It's a great place to fully appreciate the global nature and impact of our industry. In 2010, some 70 delegations from 44 countries attended. We expect a similar turnout this year, allowing Boeing representatives to engage with customers, partners and suppliers from around the world.

This global gathering of people, products and services also highlights the innovative nature of the aerospace industry. As in the past, Boeing will showcase our latest products and services. Commercial Airplanes will spotlight the 787 Dreamliner and Boeing Edge, while providing a closer look at what to expect from the 737 MAX. Defense, Space & Security will focus on the F/A-18 Super Hornet, Insitu unmanned vehicles and C4ISR (Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance) capabilities.

Innovation has always defined Boeing and, in a world of growing market competition, will continue to be our key differentiator. But the essence of innovation is collaboration and partnership, which bring new ideas, perspectives and experiences to focus on the technical and business challenges facing our customers and our world. Challenges that include enabling aviation to grow while also reducing its carbon footprint; enabling more aircraft to fly safely and efficiently by developing air traffic management systems; and developing highly capable yet affordable military products designed to protect and defend the interests of the United States and its allies.

Fortunately, the depth and breadth of Boeing's global engagement allows Commercial Airplanes, BDS, Boeing Capital Corporation, and Engineering, Operations & Technology to partner with the world's best. In so doing, we provide customers with industry-leading technologies, products and services while increasing shareholder value and expanding aerospace employment opportunities everywhere.

It is with this collaborative mindset and an eye on innovation and technology that Boeing International works closely with Boeing Research & Technology and its strategic alliances with major research organizations around the world. These alliances include companies, governmental labs, universities and technical institutions in Australia, Brazil, China, Germany, India, Russia,



“At Boeing, we are committed to developing ideas and innovation through a global team approach.”

— Shep Hill

*President, Boeing International  
Senior vice president, Business Development and Strategy*

PHOTO: BOB FERGUSON/BOEING

Spain, the Netherlands and the United Kingdom.

At the BR&T-Europe center in Madrid, we are working on environmental and air traffic technologies in partnership with European universities and research agencies. In 2008, this team accomplished an incredible aviation breakthrough when for the first time a manned airplane flew powered solely by hydrogen fuel cells, emitting only water vapor. This milestone was accomplished with help from industry partners in Austria, France, Germany, Spain, the United Kingdom and the United States.

Innovation has always been a global process. In fact, more than 100 years ago a Seattle lumberman traveled south to California to visit what was billed as America's first international air show. There, Bill Boeing met with international aviators and fell in love with the idea of manned flight, returning to Seattle determined to get into the airplane business. As he foresaw, the future belongs to those who can envision and create it, to those who savor the challenge and embrace the best ideas and solutions from wherever they may come.

At Boeing, we are committed to developing ideas and innovation through a global team approach. We have dedicated ourselves, in the words of author Richard Bach, to becoming “creatures of excellence and intelligence and skill.” The Farnborough Airshow is a perfect venue to share our progress. ■





**INTERCONTINENTAL SALUTE:** A Lufthansa 747-8 Intercontinental receives a water cannon salute at Dulles International Airport near Washington, D.C., on June 1 after completing the first commercial passenger flight of the new jetliner. The flight from Frankfurt, Germany, carried more than 350 passengers including Boeing and Lufthansa executives and media. The bigger and more fuel-efficient 747 is the longest passenger jetliner Boeing has ever built. PHOTO: FRED TROILO/BOEING

## Quotables

“Eventually, we envision an unmanned vehicle that can fly to any spot on Earth and stay overhead for days at a time.”

– Drew Mallow, program manager for Boeing’s hydrogen-powered drone Phantom Eye, which made its first flight in June. See story, Page 14.

“The coolest airplane in the sky.”

– United Chief Executive Jeff Smisek describing the 787 Dreamliner, which the airline has ordered and plans to use on a new Denver-Tokyo route next year. Denver Post, May 23.





# Turning the tide

Many will benefit from cleanup and restoration of this Seattle waterway

By *Brian Anderson*

Boeing is working with businesses and government agencies to clean up the Duwamish Waterway in Seattle. This includes restoring fish habitat near the Plant 2 area, where aircraft were built in support of World War II. In this *Frontiers* series that profiles employees talking about their jobs, Brian Anderson, Duwamish restoration project leader, discusses his passion for this cleanup effort.

PHOTO: MARIAN LOCKHART/BOEING

**T**he Lower Duwamish Waterway in Seattle is the gateway to salmon runs, industrial manufacturing, transportation and local recreation—all coexisting. Unfortunately, runoff from the industrial and residential metropolitan area has taken a toll on the natural environment.

I'm a geologist and a member of the team that's working to clean up legacy contamination in and along the waterway. Right now we're installing stormwater treatment systems to reduce future impacts to the waterway. In late fall we'll begin removing more than 200,000 cubic yards (153,000 cubic meters) of contaminated sediments from the waterway bed adjacent to Boeing property. That's enough to fill 4,000 rail cars. We'll be restoring the waterway bank habitat for migrating salmon, also home to native birds and other wildlife. And, in partnership with others, we are evaluating alternatives for the future cleanup of the lower 5-mile (8-kilometer) stretch of the waterway.

A big part of what I enjoy about my job is the chance to work with an awesome team of Boeing engineers and scientists, our county, city and port cleanup partners and regulatory agencies—all

dedicated to restoring the Duwamish. I couldn't find a better team to focus on making our workplace and this community a better place.

I also appreciate the opportunity to educate local residents and businesses so they understand and support the project, despite the short-term inconveniences it may create. So far, the folks we've spoken with from the nearby South Park area have been supportive of our plan. To minimize interference with tribal fishing, we work within "fish windows," or specified times that do not interfere with salmon runs. Restoration of the waterway adjacent to Plant 2 could take around three years to complete, so we are taking the extra steps to minimize any impact to local communities.

Everyone who lives, works or commutes in the nearly 500-square-mile (1,300-square-kilometer) watershed plays a part in the long-term success of this investment. I am excited about the vision of an urban waterway that supports the economic vitality of the region, is home to thriving native species, and is a resource for local communities. The Duwamish will once again be a flourishing waterway for all. I'm grateful that I get to help make it a reality. ■

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# The shape of things to come

A 1945 discovery in Boeing's high-speed wind tunnel led to historic change in jet design

*By Mike Lombardi*



**PHOTOS: (Top)** The High Speed Wind Tunnel's 16-blade, 24-foot (7.3-meter) diameter fan was built from spruce by Boeing craftsmen. Its large hub fairing was designed to eliminate turbulence. **(Above)** The swept-wing XB-47 bomber, which would serve as the model for large subsonic jets that followed. **BOEING ARCHIVES**

On Dec. 17, 1947, the 44th anniversary of the Wright brothers' historic first flight of a powered aircraft at Kitty Hawk, N.C., another flight took place at Seattle's Boeing Field that ranks as one of the most important in aviation.

Boeing's B-47 Stratojet bomber flew for the first time that day—and changed the shape of jet aircraft.

The B-47 was America's, and arguably the world's, first large swept-wing jet.

Seemingly forgotten in history, the Stratojet's revolutionary design was the first to pair swept wings with jet engines suspended from the wings in podded nacelles. Discovered in the Boeing High Speed Wind Tunnel in 1945, this basic design is still the model for all jets built today by Boeing, Airbus and others.

For Boeing, the journey to become the pioneer of large swept-wing jets began in April 1939 when the company hired famed test pilot Edmund T. "Eddie" Allen to head its new Flight and Research organization. A respected scientist, Allen was accorded the freedom to do whatever was necessary to advance Boeing's flight research efforts—and that included building a private wind tunnel.

At the time aircraft manufacturers did not have their own wind tunnels and the fierce competition to use the few operated by NACA (forerunner of NASA) and a handful of universities resulted in Boeing falling behind the competition.

Based on a recommendation by world-leading aerodynamic theoretician Theodore von Karman, Allen championed the idea of a company-owned wind tunnel, capable

of near-transonic (approaching the speed of sound) speeds. The estimated cost of \$1 million represented a huge risk for Boeing at the time. But it also was a great opportunity, and in August 1941 Boeing President P.G. Johnson authorized construction of a high-speed wind tunnel capable of speeds of Mach .9 (625 mph, or 1,000 kilometers per hour).

The design of the new tunnel, located at Plant 2 in Seattle, was guided by Boeing aerodynamicists William Cook and Bob Withington, and in April 1944 the honor of giving the tunnel its first breath was bestowed to Allen's wife on behalf of her late husband, who had died with 10 other Boeing employees when the XB-29 bomber crashed on approach to Boeing Field during a test flight.

The B-47 was the first full design tested in the new wind tunnel.

The swept-wing concept had first come to Boeing in May 1945 by way of a letter sent from Germany by the company's leading aerodynamicist, George Schairer, who was serving on Air Force Gen. "Hap" Arnold's Scientific Advisory Group. That group was tasked with securing German aircraft and rocket research. Boeing engineers subsequently saw dramatic results during wind tunnel tests of Schairer's swept-wing data, but they also discovered that the wings had to remain "clean" to achieve the high-speed benefits. And this presented a problem since the standard design for multi-engine airplanes at the time was to mount the engines on the wings.

As he puzzled over the problem during a

train ride back from Wright Field, Ohio (today known as Wright-Patterson AFB), Boeing Chief Engineer Ed Wells came up with the idea of engine pods mounted off the wings. The concept was tested in the Boeing wind tunnel by mounting model engine nacelles on the end of a pole (the "broomstick" test) and moving the nacelles around the wing until the optimal position was discovered—forward and below the wing.

These discoveries all came together in the Boeing wind tunnel as the optimal design for a subsonic jet—and resulted in the revolutionary XB-47 that rolled out of Boeing Plant 2 in September 1947—only two years after Schairer sent his note from Germany.

Just as building their own low-speed wind tunnel was critical to the success of the Wright brothers, so too was the wind tunnel key to success for Boeing and the B-47. Improved over the years, the now-transonic wind tunnel has tested some of the best-known airplanes in aviation history and continues its work today with jets such as the 737 MAX.

Boeing was fortunate that a leader arrived at the right time to set a course for success by not only pioneering the organization that continues today as Boeing Test & Evaluation but also insisting the company build its own wind tunnel. The Edmund T. Allen Memorial Aeronautical Laboratories are named in his honor. ■

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*See Page 22 for related stories about wind tunnel testing.*

Just as building their own low-speed wind tunnel was critical to the success of the Wright brothers, so too was the wind tunnel key to success for Boeing and the B-47.



**PHOTO:** Rollout at Plant 2 in Seattle of the swept-wing XB-47 bomber. **BOEING ARCHIVES**



**PHOTO:** Eddie Allen boards the Boeing 307 Stratoliner for a test flight. **BOEING ARCHIVES**



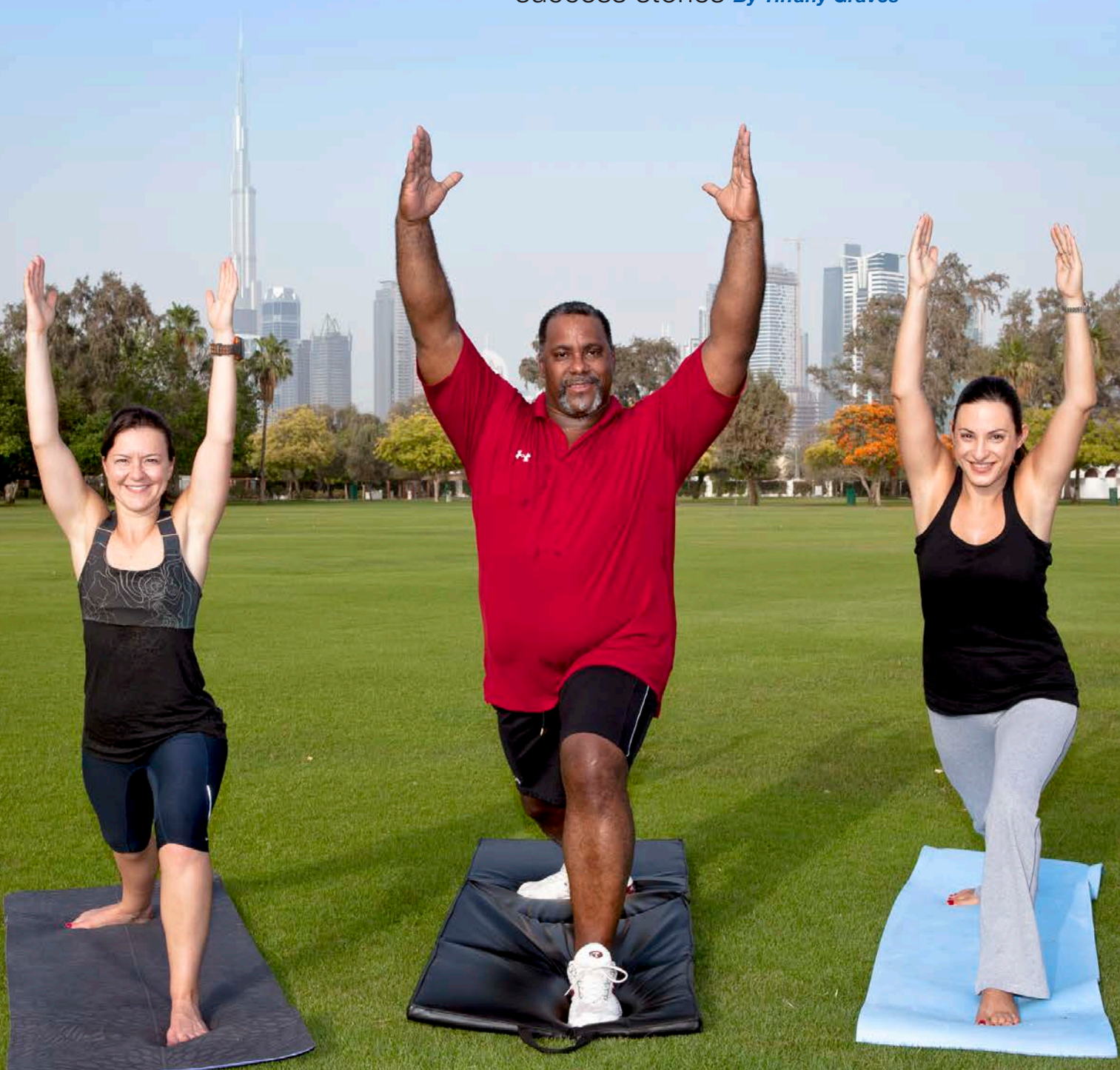
**PHOTO:** These models show the evolution of the B-47 design from a conventional straight-wing airplane to a radical swept-wing bomber with innovative podded engines. **BOEING ARCHIVES**



# On the move

## around the world

Employees share Boeing on the Move success stories *By Tiffany Graves*







**PHOTOS: (Far left)** Boeing on the Move motivates Dubai employees (from left) Denise Faulhaber, Horace Vinegar Jr. and Nadine Fattouhi to keep up their yoga. **MASLOW MEDIA GROUP (Insets, from left)** Terri Conrardy, an Alternative Dispute Resolution case manager in Seattle, has significantly improved her health through exercise and changes to her diet. **JESSICA OYANAGI/BOEING** The program inspired Srimeska Fernando, an office administrator in Singapore, to get active again with sports such as badminton. **NAPOLEON FELWA/BOEING** Boeing on the Move helped Cheri McFarland, an inventory and modeling technician in Huntington Beach, Calif., stay active and positive during chemotherapy. **PAUL PINNER/BOEING**

**A**s an Alternative Dispute Resolution case manager for Global Diversity and Employee Rights, Terri Conrardy travels often from Seattle to manage cases throughout the eastern United States. The travel can be demanding, but that hasn't stopped her from making huge strides in improving her health through exercise and diet.

"In early 2011, I was overweight, and I was not getting good results in managing my diabetes. Finally my doctor asked me to see a nutritionist," Conrardy said.

She made changes in her diet and began feeling better almost immediately. She decided to use Boeing on the Move to track her physical activity the same way she tracked her eating. She intensified her workouts at her fitness center and joined a friend doing Zumba Fitness, a fast-paced Latin-dance-inspired exercise program, converting the activities into steps on the Boeing on the Move website.

"With increased activity and healthy eating, I dropped 40 pounds, and my blood sugar went down dramatically," she said. "I had been taking five shots of insulin a day at the beginning of last year, and now I'm down to one shot at a low dose."

She and thousands of other Boeing employees are using Boeing on the Move to make significant improvements in their health and diet. It was first offered in 2010 and more than 40,000 employees signed up that year. Numbers increased to more than 58,000 in 2011.

Boeing on the Move is a six-week physical activity challenge offered to all Boeing employees around the world through July 29, 2012. Using pedometers, employees track the number of steps they take daily and record that information online. Activity other than walking can be converted into steps using the online conversion tool.

New this year: Employees who participate will be eligible to win either a \$50 or a \$100 gift card to purchase new athletic shoes, apparel or accessories.

Conrardy will be participating in the challenge again this year.

"I feel fantastic," she said. "Getting healthier has helped me to be a more productive employee. I'm more focused and happier. Finding that it was fun was an added benefit."

Other employees have similar stories.

Srimeska Fernando, an office administrator for Boeing Training

and Flight Services in Singapore, credits Boeing on the Move with helping her get active again after a decade on the sidelines.

In school, Fernando was an enthusiastic runner, sprinter and hurdler. When she injured an ankle, her doctor advised her to stop all sports activities for a few months. Fearing additional injury, she reluctantly gave up exercising and focused on her studies and work for the next 10 years. When Fernando heard about Boeing on the Move, she decided to join.

"It was amazing," Fernando said. "I had so much fun with my colleagues playing badminton, doing yoga and running. The best part is that I did not fear injury any longer. Boeing on the Move helped me get over that psychological hurdle."

Cheri McFarland has also faced health hurdles.

A former body builder and fitness trainer, McFarland is an inventory and modeling technician on the C-17 Globemaster III program in Huntington Beach, Calif. But staying active took on a whole new meaning in December 2010 when she was diagnosed with stage IV inflammatory breast cancer. Chemotherapy and other treatments followed.

An avid cyclist, she had met her steps goal in 2010 with 50-mile (80-kilometer) bike rides, spinning classes and rounds of golf. McFarland participated in Boeing on the Move again last summer, only this time had to scale her activities.

"While I was undergoing chemo, I felt like I was wearing ski boots. Everything I did was an effort," she said. "I had to find activities that didn't take a lot of steam out of me, like stretching and core exercises, hot yoga and walking my dog. The challenge was a wonderful reminder to keep moving."

McFarland has responded well to treatment and is currently on medical leave, recovering from surgery earlier this year. She remains relentlessly positive, planning for a return to work and a Hawaiian vacation.

"I haven't been able to get back on my bike yet, but that's my goal!" she said. ■

*tiffany.l.graves@boeing.com*

*To learn more about the challenge, go to Boeing TotalAccess and click on "My Well Being."*

**10,000 STEPS TO BETTER HEALTH** Becoming physically active is one of the best things individuals can do for their health and well-being, and a minimum of 10,000 steps a day is ideal for maintaining fitness, according to health experts. Activities such as biking (equivalent to about 157 steps for each minute of activity), swimming (118 steps per minute), gardening (78 steps per minute) and yoga (49 steps per minute) add steps, variety and fun to a daily exercise routine—key factors in staying motivated.



# Fresh eyes

Boeing blazes a new trail in aerospace with first flight of hydrogen-powered Phantom Eye

By Diane Stratman

Photos by Bob Ferguson

It's 2 a.m. and at that hour, the late spring air in Southern California's high desert is crisp and cool as Brad Shaw begins the drive toward Edwards Air Force Base. He's headed for the NASA Dryden Flight Research Center hangar where a marvel of Boeing engineering is parked. A steaming hot thermos of coffee helps him stay alert as he drives mile after mile on the road to the hangar.

In just a few hours, a unique Boeing aircraft will stretch its wings on the dry lake bed. This is the day, June 1, 2012, that Phantom Eye takes to the air on its first flight, and Shaw is the program's chief engineer. He's excited, nervous and incredibly proud.

At 6:22 a.m., against the backdrop of a fiery California sunrise, the unmanned vehicle, whose engines are powered only by hydrogen, begins its takeoff roll and soars into the sky over the Mojave Desert lake bed. Twenty-eight minutes later, Phantom Eye touches down on the ground. After years of work and months of preparation, this first flight—despite some damage sustained when the aircraft's landing gear dug into the lake bed—is considered a success.

"Watching four years of hard work take off and fly was a powerful experience," Shaw said later. "The guidance, flight control, propulsion, and fuel and performance of Phantom Eye were exceptional."

Just as railroads shaped ground warfare in the 19th century, and aviation redefined combat in the past 100 years, unmanned aerial vehicles are transforming modern warfare. And Boeing's Phantom Eye represents a major push for the company in the



**PHOTOS: (Above)** As the sun rises over NASA's Dryden Flight Research Center at Edwards Air Force Base, Calif., Boeing teammates work diligently to prepare Phantom Eye for first flight. **(Inset left)** Brad Shaw, left, and Bill Norby.





***“Phantom Eye’s ability to maintain uninterrupted surveillance will enable smarter, faster decision-making at all levels of command.”***

*– Darryl Davis, president of Phantom Works*







***“Phantom Eye is a whole different animal, a hydrogen-powered glider with a 150-foot wingspan that takes flight from a cart! A fantastic challenge!”***

*– Teri Finchamp, engineer*





**PHOTOS:** Phantom Eye's massive 150-foot (46-meter) wingspan is one feature that allows it to stay on station at altitudes up to 65,000 feet (19,800 meters).

unmanned aerial vehicle, or UAV, market, one of the fastest-growing areas in aerospace.

Designed to perform battlefield and border observation, port security and telecommunications at high altitudes for up to four days, Phantom Eye could open an entirely new market, according to Darryl Davis, president of Phantom Works.

"Its intelligence, surveillance and reconnaissance capabilities over long periods offer game-changing opportunities for our military, civil and commercial customers," he said. "Phantom Eye's ability to maintain uninterrupted surveillance will enable smarter, faster decision-making at all levels of command."

Besides military applications, the aircraft could be used for a variety of commercial and civil requirements, added Drew Mallow, Phantom Eye program manager. For instance, it could help scientists track weather patterns and predict where hurricanes or tornadoes might hit. It could also be used to monitor disaster areas and relay critical data to ground crews who can then prioritize and dispatch resources quickly and efficiently.

The huge drone, with its 150-foot (46-meter) wingspan—nearly the width of a football field—is designed to cruise at altitudes of up to 65,000 feet (19,800 meters) for up to four days at about 250 mph (400 kilometers per hour) as it scans the terrain, collecting intelligence, reconnaissance, surveillance and communications data.

"Eventually, we envision an unmanned vehicle that can fly to any spot on Earth and stay overhead for days at a time," Mallow said.

Flying high is critical to Phantom Eye's intended missions.

"An altitude of 65,000 feet is a much calmer, benign environment for the lightweight, glider-like aircraft to operate," Mallow explained. Commercial jetliners operate below 45,000 feet (13,700 meters). And satellites operate much higher.

Phantom Eye has a distinctive way of taking off and landing, an approach adopted to reduce weight, which in turn increases mission endurance. For takeoff, the vehicle is propelled from a moving launch cart. Once there's enough lift on the wings, it separates from the cart, which then rolls to a stop on the runway while Phantom Eye soars to its intended altitude. When the aircraft is ready to land, it comes in at a relatively slow 70 mph (110 kilometers per hour). But rather than using conventional landing gear, it lands



on a lightweight main landing skid like a glider and has a nose wheel for steering.

Last month's maiden flight demonstrated Phantom Eye's initial handling and maneuverability capabilities, as well as its environmentally progressive liquid-hydrogen propulsion system. As the vehicle lifted to 4,080 feet (1 kilometer), then cruised for 28 minutes, the only byproduct created by its hydrogen-powered engines was water. Using hydrogen as a power source will eventually keep Phantom Eye in the air for up to four days without refueling.

"This flight puts Boeing on a path to accomplish another aerospace first—the capability of four days of unrefueled, autonomous flight," Davis said.

Robert Horton was the Phantom Eye program pilot who monitored and gave commands to the aircraft from the ground.

"For a flight tester, I can't think of anything more exciting than to have helped launch this incredible aircraft on its maiden flight," Horton said. "Milestones like this are so rare. I am definitely savoring the moment."

Paul Pillar, Phantom Eye test conductor, said he's loved each day on the project.

"Every morning," Pillar said, "I think what a fortunate man I am to be able to come to work and live out a childhood dream; to be part of one of the coolest, leading-edge technology projects on the planet!"

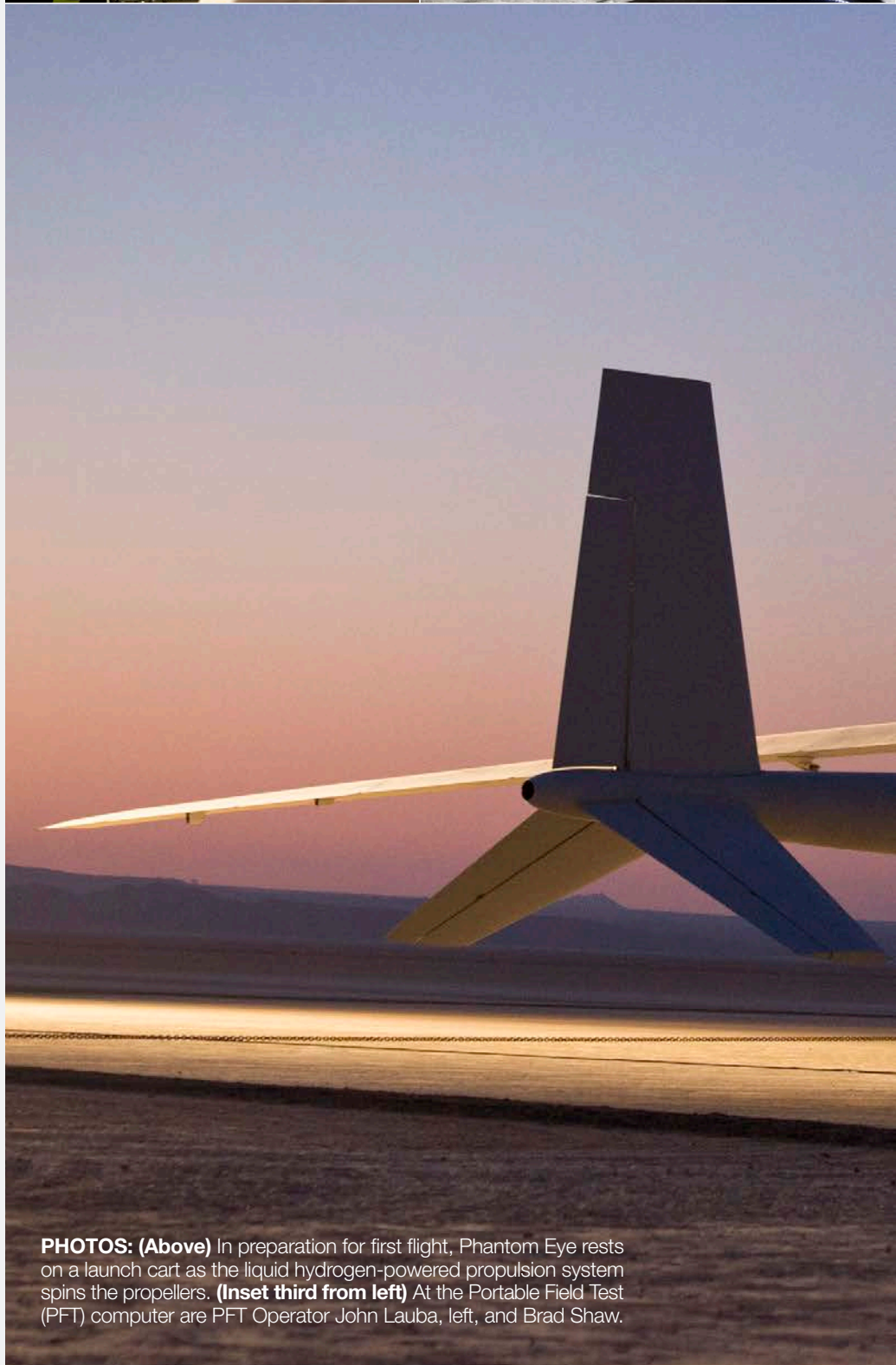
Following the successful flight, engineer Teri Finchamp marveled at the Phantom Eye team's accomplishment.

"How rewarding to watch a revolutionary aircraft that you helped manufacture take flight!" she said. "I've known the excitement of manufacturing huge fighter aircraft. But Phantom Eye is a whole different animal, a hydrogen-powered glider with a 150-foot wingspan that takes flight from a cart! A fantastic challenge!"

Phantom Eye's hydrogen propulsion system, according to Mallow, is what sets the aircraft apart. It runs on nothing more than two Ford Ranger truck engines converted to burn gaseous hydrogen.

"The use of hydrogen for power gives Phantom Eye a significantly reduced carbon footprint, since the only substance produced when it's in flight is water," Mallow said. "Because of hydrogen's efficiency and low density, using it will give the aircraft the level of endurance it needs to fly to any spot on Earth and orbit for long periods."

Also key to the aircraft's ability to conduct



**PHOTOS: (Above)** In preparation for first flight, Phantom Eye rests on a launch cart as the liquid hydrogen-powered propulsion system spins the propellers. **(Inset third from left)** At the Portable Field Test (PFT) computer are PFT Operator John Lauba, left, and Brad Shaw.





***“For a flight tester, I can’t think of anything more exciting than to have helped launch this incredible aircraft on its maiden flight.”***

*– Robert Horton, Phantom Eye test pilot*





***“We’ve had to constantly discipline ourselves to choose between what’s nice to have versus what’s absolutely needed to reach a single objective ... the safe demonstration of hydrogen propulsion in a flight environment.”***

*– Steve Degroote, engineer*







**PHOTO:** Phantom Eye lifts off the runway as it begins its first flight, soaring to an altitude of 4,080 feet (1,245 meters).

extensive missions is the material it's made of.

Just as commercial jets such as the Boeing 787 Dreamliner are being built with composites for fuel efficiency, Phantom Eye is dependent on lightweight composite materials to be able to operate efficiently for days at a time, Mallow said.

The Phantom Eye project is funded by Boeing. But Mallow said the go-it-alone investment is worth the risk because of the craft's capabilities.

"There are numerous customers across the military, civil and commercial sectors who've been eagerly awaiting a successful first flight," he said. "We believe that once the enabling technology (hydrogen propulsion) is proven, new markets will emerge that address customers' needs for affordable persistence in mission areas related to intelligence, surveillance and reconnaissance."

Horton, the test pilot, added that "a lot of people depended on us to get this right. There is great satisfaction in knowing that this technology will significantly impact the future of high-altitude long-endurance missions."

The go-it-alone approach has been challenging.

"With limited funds, we've had to constantly discipline ourselves to choose between what's nice to have versus what's absolutely needed to reach a single objective," said Steve Degroote, an engineer who considers a project such as Phantom Eye an engineer's dream job. And that goal, he explained, is the safe demonstration of hydrogen propulsion in a flight environment.

"The propulsion system was particularly challenging," Mallow said. "From a test perspective, the team worked through a number of issues associated with maturing an autonomous vehicle with a nontraditional fuel and propulsion system. And then there was the ever-changing weather in the high desert that's particularly challenging for a lightweight aircraft."

The Phantom Works team is now re-designing the nose wheel and repairing the vehicle. When Phantom Eye re-enters testing, it will move into higher and more demanding envelopes of high-altitude flight. ■

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# MAXimum advantage

How Boeing engineers perfected the Advanced Technology  
winglet for the 737 MAX

*By Lauren Penning*





**D**ino Roman and John Vassberg, both Technical Fellows for Boeing in Huntington Beach, Calif., had experience going back some 20 years working on concepts for winglets that help airplanes fly more efficiently and burn less fuel.

It's what brought the team developing Boeing's 737 MAX to Huntington Beach—an engineering quest to find just the right winglet that, when combined with new engines and other improvements, will give the MAX a significant leap in efficiency over the single-aisle jetliners flying today.

"When the MAX study got under way, we were glad they invited us to the party," Vassberg said.

It was a party that eventually spanned across Boeing.

"We were told from MAX leadership to 'unleash the power of the enterprise' and that's what we did," said Brian Johnson, 737 MAX Wing Structures manager.

The result was a striking winglet design that is one of the most distinguishing features of the new airplane.

"The MAX program is all about bringing customers superior fuel efficiency in the single-aisle market," said Bob Feldmann, vice president and general manager, 737 MAX. "In addition to the engine, we were interested in aerodynamic improvements we could make to the airplane that would have a substantial benefit on fuel burn—with little risk to our program schedule."

Known as the AT winglet, short for Advanced Technology, it's an up-down design, but one that is far more advanced than the similar up-down concepts Roman and Vassberg worked on years ago for Douglas Aircraft. The latest computer tools, using what's known as computational fluid dynamics, or CFD, allowed engineers to optimize the configuration in ways never before imagined.

"Ever since the whole wingtip effort got under way, I've been working with Huntington Beach on the designs using CFD," said Adam Malachowski, aerodynamicist from Boeing's commercial Product Development organization based in Everett, Wash.

But Boeing Product Development also brought concepts to



**PHOTOS: (Far left)** Tom Butler, left, and Dan Goering ensure the proper parts are installed on an airplane model and the configuration is appropriate for a wind tunnel test. **(Insets, clockwise from top right)** Cari Paskan, Richard Bowman, Mike Nangle, Dave Holler, Jeff Housekeeper and Travis Watson are part of the Boeing Transonic Wind Tunnel team in Seattle.

BOB FERGUSON/BOEING





**PHOTOS: (Opposite page)** An airplane model awaits a wind tunnel test. **(Insets, clockwise from top left)** Among the members of the Boeing wind tunnel team in Seattle are Taunya Backus, left, and Cari Paskan; John Mashak, left, and Richard Bowman; Danny Minalia, from left, Kwangwoo An and Bryan Deatherage; and Carey Northam. **BOB FERGUSON/BOEING**

## MAXimum advantage

the table that had been developed for other Boeing projects, such as raked-tip technology used on the 737 and 747-8. Combining the expertise of Roman and Vassberg with Boeing's commercial Product Development organization proved powerful.

"We can't create designs alone. It affects so many different areas, we have to interact closely with other groups," said Chris Vegter, an aerodynamicist from Product Development.

For example, the weight of a new winglet had to be considered, as well as the aerodynamic loads on the wing. And there were airport infrastructure constraints that limited what the team could do. The wingspan of the MAX had to fit into existing airport gates.

The Advanced Technology winglet's dual-feature design

uniquely balances span between the upper and lower parts. And while the MAX winglet will fit within today's airport infrastructure, it flexes in flight to provide more wingspan, giving operators additional fuel-burn improvement.

Designing the shape for the winglet was done by tailoring the airfoils to create the best surface to interact with airflow. The team started with a number of concepts and narrowed them down based on existing design constraints. Using computational fluid dynamics, engineers optimized the efficiency of the most promising concepts for when the 737 MAX was at cruise altitude, which showed a 1.5 percent fuel-burn improvement over today's wingtip technology.

"We have a well-rounded group of talented people, which was



## ■ Wind blows, data flow

Computer simulations go far, then it's time to turn on the wind

From the B-47 bomber to the 787 jetliner, wind tunnels have played important roles in helping Boeing shape the future of flight.

Wind tunnel testing comes early in the process of developing an aircraft and can demonstrate which concepts are worth pursuing. The rigorous testing undertaken by Boeing Test & Evaluation personnel in tunnels that can generate winds of up to Mach 5.5—or 5.5 times the speed of sound—helps Boeing create well-designed and highly efficient products that meet the needs of emerging markets.

“We’re a factory and our product is data,” explained Kevin Watson, lead engineer for wind tunnel calibration and validation. “Our product is not the model or the wind tunnel itself. Our product is the data, information and knowledge that are gathered during the tests and provided to the customer. These data are used to design better, more efficient airplanes.”

Boeing has been operating wind tunnels

continuously since 1944. In the 1940s the only accurate way to test an aircraft design was to put a scale model in the wind tunnel. Since then, there have been significant advances in testing that have complemented the development of new aircraft design. When Boeing was designing the 767, more than 70 wing configurations were tested in the wind tunnel. On recent programs only six configurations needed wind tunnel testing as product development aerodynamicists used advanced computers and computational fluid dynamics, or CFD, to predict which configurations would offer the most efficient performance.

Although computer simulations predicting how air will flow over an airplane have come a long way since the 1980s, they can’t do it all. There are times when computational fluid dynamics is the right tool for the job and times when only wind tunnel testing will do, said Robert Gregg, chief engineer of Flight Sciences Product

Development & Technology. Computational fluid dynamics is very accurate at predicting how the air will act around a model at cruise conditions, he explained. But when the model approaches the extremes of the flight performance envelope, wind tunnel data are much more accurate at predicting the interactions of air and plane. This is why it is so important that the teams and tools work well together.

“The wind tunnel team is a value-added part of the development process,” said Walt Howard, a product development manager specializing in aerodynamics and a lead on the 737 MAX development team. “In our case they redesigned the model to facilitate the many configuration changes required during the test. Thinking like that makes the Boeing Transonic Wind Tunnel [in Seattle] one of the most efficient production wind tunnels out there.”

— Jennifer Hawton

## By the numbers

800

Approximate number of pressure ports on the body, tails and wing of the 737 MAX wind tunnel model during testing in the Boeing Transonic Wind Tunnel

7,500

Approximate force, measured in pounds per square feet (359.1 kilopascals), that can be created in wind tunnels

500,000

Approximate number of data points collected in one test series

5.5

Highest speed, in terms of Mach, at a Boeing wind tunnel; at sea level, Mach 1 (the speed of sound) is 761.2 mph (1,225 kilometers per hour)

— Jennifer Hawton





## MAXimum advantage

important to ensure an integrated design," Malachowski said.

Even though computational fluid dynamics has evolved over the years to provide engineers with very accurate performance data, the final winglet concepts still had to be tested in wind tunnels.

"The wind tunnel is able to provide a lot better data on adverse design conditions," Roman explained. "For safety and handling characteristics of the airplane, wind tunnel testing is very important." The concepts were scaled down to fit in the low-speed wind tunnel at Boeing supplier QinetiQ in Farnborough, United Kingdom, as well as the Boeing Transonic Wind Tunnel in Seattle. The wind tunnels allowed the team to run a series of different scenarios every few minutes just by adjusting the settings. Out of these wind tunnel tests

emerged one concept that worked the best.

"It was really gratifying to see the test validate our work," Malachowski said. But the MAX team still had fundamental decisions to make before they could recommend going forward with the radically new design for the MAX.

"We had a shape, but how do you build it?" Johnson said.

In March, the team held the first of what's known as a non-advocate review, or NAR, for the winglet design. These reviews, according to Johnson, are about people 'checking egos at the door.'

"You start peeling back the layers," he said. "It's buildable, but is it producible at rate? What about certification issues?"

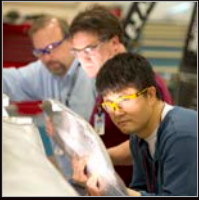
These questions were tackled in the non-advocate review



**PHOTOS: (Opposite page)** Mike Nangle, left, and Jim Conner ready the 737 MAX with Advanced Technology winglets for high-speed wind testing at the Boeing Transonic Wind Tunnel in Seattle. **KEVIN BROWN/BOEING (Above)** Pictured are employees Jim Conner (left and right) and John Mashak. **(Far left)** From left, a close-up of pressure port lines on the model wing that give information about airflow at those points; a wind tunnel teammate monitors a test. **BOB FERGUSON/BOEING**

## ■ Testing 1, 2, 3 ...

Wind tunnel testing involves several rigorous steps. They are:



1. Boeing Test & Evaluation's wind tunnel team meets with the customer, usually a Boeing business program, to determine the test and data requirements. After customer requirements and test configuration are finalized, the experimental hardware design group designs a model of the air vehicle or structure being tested, then fabrication of the model begins. Meanwhile, the testing team works on test plan development, a key component of which is a safety plan for each facility.



2. Test article preparation begins. Although model components have been machined, finish handwork must be done to meet the extremely tight tolerances and requirements of wind tunnel testing. Each model goes through a process of being machined, hand-finished and assembled to test for fit. Then it is taken apart and instrumented with up to thousands of pressure ports to collect the amount of data needed. A single model can contain up to 12,000 feet (3,650 meters) of instrumentation tubing no bigger than a bundle of six human hairs. The customer reviews all test configurations to ensure they meet test requirements.



3. Before a test, the wind tunnel requires a thorough review including maintenance, calibration and validation. After the facility is judged ready, the model is installed for testing. The final step before turning on the power is the Test Readiness Review, where the customer and wind tunnel teams perform a final readiness check.



4. It's time to turn on the wind! The test series starts and data pour in—up to half a million data points per test sequence. The duration of a test can range from a few days to several months, depending on data requirements.



5. Raw data are converted to a format the customers use to analyze the configuration and prepare for the next iteration. Following test completion, the customer and wind tunnel test team take time to share "lessons learned" so they can continue to improve test processes.

PHOTOS: BOB FERGUSON/BOEING

— Jennifer Hawton







## MAXimum advantage

process, allowing the team to pull from experts around the enterprise. The Boeing Gated Process for product development helped provide a structure for the team to work together. The gated process is a series of well-established steps that address engineering questions and decisions about new products.

“We knew that many voices were better than one, and the gated process gave us access to key executives and talent within the company to make this decision,” Johnson said.

Ultimately, the team agreed to move forward with the AT winglet for the MAX.

Bringing the right tools, talent, technology and expertise

together from across the Boeing enterprise, and a disciplined process of development, is the competitive advantage “One Boeing” provides.

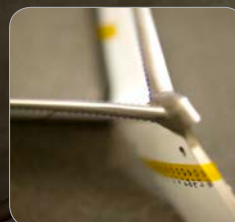
Indeed, for Vassberg and Roman, being physically separated from the rest of the team in the Puget Sound area was a challenge.

“There are cultural differences,” Vassberg acknowledged. But, overall, this is also a strength for the company because it brings together more diversity of ideas, he added.

“Once groups like this can come together and open up to listening to one another,” Vassberg said, “we can fuse technology—and that’s what we’ve done with these winglets. ■

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**PHOTOS: (Opposite page, bottom right)** The size of the 737 MAX model is optimized to tunnel capability. **KEVIN BROWN/BOEING** **(This page, clockwise from bottom left)** The Seattle Transonic Wind Tunnel team includes Tom Butler, left, and Dan Goering; Mike Nangle; Dave Holler; and Chris Stewart; a close-up of the new winglet for the MAX. **BOB FERGUSON/BOEING**





## ■ Where the wind blows

Boeing has three major aerodynamic wind tunnel facilities, each focusing on a different aspect of testing, along with three dedicated specialty tunnels. The company can test almost anything in its wind tunnels.



The Vertical/Short Takeoff and Landing Wind Tunnel in Philadelphia supports low-speed testing and has the largest cross-section of any Boeing tunnel. Although built mainly for helicopter and rotorcraft testing, it also supports certain military aircraft and commercial aircraft tests.

PHOTO: FRED TROILO/BOEING



The Transonic Wind Tunnel in Seattle focuses on testing at commercial jetliner cruise speeds. Airplanes spend most of a flight at cruise speeds, so this testing offers a significant opportunity to improve an airplane's efficiency.

PHOTO: BOB FERGUSON/BOEING



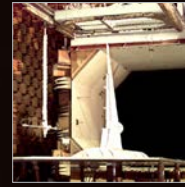
The Polysonic Wind Tunnel in St. Louis performs a combination of transonic (approaching supersonic) and supersonic testing, with a focus on defense products. Since the physics of flight changes at supersonic speeds, it is important to understand stability and control characteristics at these high speeds. Typically the Polysonic Wind Tunnel tests fighters, missiles and rockets.

PHOTO: RICHARD RAU/BOEING



The Icing Tunnel in Seattle confirms the performance of an aircraft's de-icing systems and analyzes ice buildup on an aircraft.

PHOTO: ED TURNER/BOEING



The Low-speed Aeroacoustic Tunnel in Seattle is used to test aircraft noise and ways to reduce it. These tests generally focus on noise generated by engines or airframes, which have a large impact on noise the airport community may experience.

PHOTO: BOEING



The Low-speed Propulsion Wind Tunnel in Seattle was built to focus on how airplane inlets, thrust reversers and exhaust systems perform at low speeds. This lab focuses on commercial aircraft.

PHOTO: BOEING

— Jennifer Hawton







**PHOTOS: (Below)** Tower Bridge in the heart of London. **SHUTTERSTOCK (Insets, clockwise from top left)** A British Army Apache and Royal Air Force Chinook operating off the coast of Libya on the deck of HMS *Ocean*. **UK MINISTRY OF DEFENCE** Thomson Airways will be the first U.K. airline to operate the 787. **THOMSON AIRWAYS** The eighth C-17 delivered to the Royal Air Force in May 2012. **BOEING** Sir Roger Bone, president, Boeing UK, outside the Houses of Parliament. **ASSOCIATED PRESS**



# 'A magnificent market'



The United Kingdom is one of Boeing's biggest markets

Stories by Bill Seil

**B**oeing's 70-year relationship with the United Kingdom soared to new heights in 2008 when the company established a major new subsidiary based in London.

Since the consolidation of all Boeing Defense, Space & Security activity in Boeing Defence UK and the addition of several other subsidiaries, Boeing employment in the United Kingdom has nearly doubled. Boeing Commercial Airplanes has also increased its business ties in the U.K. by making greater use of suppliers. And Boeing UK has formed research and development alliances across the country.

"The United Kingdom is a magnificent market for both the commercial and military sides of our business," said Shep Hill, president, Boeing International, and senior vice president, Business Development and Strategy. "We have wonderful customers and partners in the U.K., as well as some great technology associates and collaborators."

Hill said the creation of Boeing Defence UK was in response to the 2005 Defence Industrial Strategy published by the UK Ministry of Defence. It emphasized the need for defense contractors to create U.K. business entities headquartered within the country and develop intellectual property.

Boeing Defence UK has experienced strong growth, including the creation in January 2009 of Boeing UK Rotorcraft Support. Similarly, following the November 2010 win of the Future Logistic Information



***"The U.K. is the second-largest aerospace manufacturing nation in the world ... its capabilities are across the board."***

— Sir Roger Bone, president, Boeing UK

Services contract, Boeing Information Technology has been leading the transformation of the U.K. military's logistics system and integrated logistics software, in what is now called LogNEC (Logistics Network-Enabled Capability).

"The fact that through Boeing Defence UK we were able to win that contract shows the depth of confidence the U.K. government has in Boeing, and the real sense that Boeing is indigenous to the U.K.," Hill said.

Boeing's long history with the U.K. dates back to the late 1930s, when the British government bought North American "Harvards" for aerial reconnaissance and pilot training, and Pan American inaugurated regular transatlantic passenger

service from New York to Southampton, U.K., using Boeing's 314 Clipper.

The U.K. remains an important airline hub, serving as a waypoint to Europe, the Middle East, the Far East and the United States, and Boeing has a long and mutually beneficial relationship with Britain's airlines.

"The U.K. has always been one of Boeing's biggest markets," said Sir Roger Bone, president, Boeing UK. "We serve as the company's European regional hub for commercial airplane sales, and the UK Armed Forces have always been a key customer for our products. In addition, the company relies on its U.K. supply base."

Boeing employment in the U.K. has reached more than 1,200, including a strong Information Technology presence to support key programs like LogNEC. The company's U.K. employment continues to rise, with a strong group of subsidiaries based throughout the country—starting with Boeing Defence UK and including Jeppesen UK, Boeing Flight Services, Continental DataGraphics and Aviall UK. Narus UK offers cybersecurity services, and a joint venture with AgustaWestland, Aviation Training International Limited, provides training for British Army Apache aircrew, ground crew and maintenance personnel.

The U.K. has long been at or near the top of the list of Boeing's non-U.S. suppliers. The company's total U.K. supply chain purchases—averaging about \$1 billion a year over the past decade—are divided





equally between defense and commercial airplane programs.

In addition to being an important supplier to Boeing Commercial Airplanes, the U.K. is also a major customer.

“There is a vibrant commercial airline business here in the U.K.,” said David Longridge, one of three Commercial Airplanes sales directors for the U.K. “It represents all the different business models that we see in the commercial airplane world.”

The nation’s flag carrier, British Airways, has purchased nearly every jetliner model Boeing has produced. It is the company’s largest customer for the 747 and one of the largest customers for the 777.

Another major international carrier, Virgin Atlantic, got its start in the U.K. and has since spread its brand to other parts of the world. The first airplane it purchased was a Boeing 747.

The U.K. also is a leader in the “inclusive tour” market, in which one company arranges a holiday trip, plus flights to and

from the destination. Two of the world’s leading inclusive tour companies, TUI Travel and Thomas Cook, are headquartered in the U.K. TUI operates in Britain under its U.K. brand, Thomson Airways.

British Airways—alongside Virgin and Thomson Airways—has ordered the 787 Dreamliner. Longridge believes Boeing’s new fuel-efficient 737 MAX will prove to be a strong competitor in attracting low-cost carriers.

Boeing Defence UK, while headquartered at Boeing International offices in London, has employees and facilities at nearly 30 locations around the country. Mike Kurth has served as managing director of the subsidiary since it was consolidated four years ago.

“The UK Ministry of Defence is a bellwether customer for us,” Kurth said. “When they buy something, other countries decide to buy it, too. And the U.K. military knows what it wants. We don’t really sell; it’s more like they buy.”

Boeing equipment used by the British Armed Forces includes C-17 transports, Apache and Chinook helicopters, Airborne Warning & Control System aircraft, and Harpoon missiles.

In December 2011, Boeing Defence UK opened the Boeing Portal, which is located in Fleet, Hampshire, southwest of London. The facility offers customers advanced experimentation and analysis services for strategic planning and problem-solving.

“With the growth of Boeing Defence UK, we are well-positioned to meet requirements when the U.K. conducts its next strategic defense review in 2015,” Kurth said. “This will create opportunities for the sale of other products and services.” ■

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**PHOTOS: (Below)** British Airways operates more than 50 Boeing 747-400s. **BRITISH AIRWAYS (Insets, from left)** A Virgin Atlantic 747-400. **VIRGIN ATLANTIC AIRWAYS** The Chinook is the workhorse of the Royal Air Force fleet and plays a crucial role in U.K. operations in Afghanistan. **UK MINISTRY OF DEFENCE** Jet2 operates a fleet of 737s based at Leeds-Bradford Airport. **FLIGHTAWARE**



## U.K. aircraft fleet data

### British Airways

Headquarters: Heathrow

Fleet: 235 airplanes in service, with fleet including 19 737-400s, four 757-200s, 21 767-300s, 46 777-200s, six 777-300s and 52 747-400s

British Airways has two 777-300s, eight 787-8s and 16 787-9s on order.

### DHL Air

Headquarters: Hounslow

Fleet: 28 airplanes made up of 22 757-200 Freighters and six 767-300ER (Extended Range) Freighters

### Global Supply System

Headquarters: Stansted

Fleet: Three 747-8 Freighters

### Jet2.com

Headquarters: Leeds

Fleet: 42 airplanes including seven 737-300 QC (Quick Change)

### Monarch Airlines

Headquarters: Luton

Fleet: 32 aircraft in service including three 757-200s

### Thomas Cook Airlines

Headquarters: Peterborough

Fleet: 27 airplanes including 15 757/767s

### Thomson Airways

Headquarters: Luton

Fleet: 63 airplanes including 24 737-800s

U.K. launch customer for the 787. Across Thompson's parent, the TUI Group, Boeing has 21 Next-Generation 737s to deliver.

### Titan Airways

Headquarters: Stansted

Fleet: 11 airplanes including three 737-300s, one 737-300

Freighter, three 757-200s and one 767-300

### Virgin Atlantic Airways

Headquarters: Crawley

Fleet: 37 aircraft in service including 12 747-400s

Virgin Atlantic has 16 787-9s on order.

## U.K. military fleet data

### British Army

Headquarters: Warminster, Wiltshire

Fleet: 67 Apache AH-Mk.1 attack helicopters based at Wattisham Air Station

### Royal Air Force

Headquarters: High Wycombe, Buckinghamshire

Fleet: Eight C-17 transports based at RAF Brize Norton; 46 Chinook Mk2, Mk3 and Mk4 helicopters based at RAF Odiham, expecting 14 additional Mk6 aircraft between 2013 and 2015





## Build a plane—and a career

Starting with parts in a kit and finishing with a light airplane that flies with a pilot, students in U.K. secondary schools are learning how to build airplanes—with Boeing's help.

The hands-on experience takes students through principles of flight, assembly and project management, and seeing the aircraft fly. Aeronautics professionals, active and retired, including Boeing employees, work with the students.

Boeing partners with the Royal Aeronautical Society to support the Schools Build a Plane Challenge.

"We attach a lot of importance to this program," said Sir Roger Bone, president, Boeing UK. "We work with students aged 12 to 16 years—it helps capture their imaginations in the field of aerospace and all the technologies and skills it represents."

Aimed to motivate young people in the areas of science, technology, engineering and math, the program is but one of the many ways Boeing participates in U.K. civic and charitable activities. The company also supports a Boeing Aviation Studies Certificate, which teaches aspects of aerospace.

For the past two years, Boeing has been prime supporter of the British Military Tournament, which showcases military tradition, talent and pageantry. The 2011 tournament drew 70,000 guests, including Her Majesty Queen Elizabeth II. The event raises funds for three military charities.

"The tournament has been a tremendous success and we're very pleased," said Mike Kurth, managing director, Boeing Defence UK.

Boeing also supports educational activities at the National Memorial Arboretum, which honors all who gave their lives in the service of their country and all who have served and suffered because of conflict. It recognizes the armed forces and emergency services. On 150 acres (61 hectares) are 200 memorials placed among 50,000 trees.

Boeing has also supported the Imperial War Museum's year-long "War Story" exhibition, honoring British military personnel serving in Afghanistan.

Other areas of community engagement include:

- The Prince's Trust, supported by His Royal Highness Prince Charles, the Prince of Wales, helps students at risk of underachievement stay engaged in their educational development. Since 1976, the program has helped more than 650,000 students.
- The Earth Restoration Service sends native tree saplings to schools throughout and outside of the U.K. On Earth Day 2012, about 60 Boeing volunteers worked with more than 100 children to plant 280 trees at four local schools.
- Boeing UK, beginning in 2013, will support flying scholarships in collaboration with the Air League. The program will help young people, the disabled and veterans learn to fly solo, encouraging their personal development and introducing them to career possibilities in aerospace. ■

**PHOTO:** Marling School, located in Stroud, Gloucestershire, makes progress on its Schools Build a Plane Challenge airplane. MARLING SCHOOL





## Higher learning

The University of Sheffield in South Yorkshire is one of several “red brick” universities established in English industrial cities more than a century ago. Today, it is a world leader in metallurgy and engineering research—and Boeing is a part of that.

In 2001, the university and Boeing created an advanced center for machining research: the Advanced Manufacturing Research Centre with Boeing, or AMRC. Soon, others joined in this collaborative effort, including Rolls-Royce and Messier-Bugatti-Dowty.

AMRC’s innovative methods of machining titanium, along with other advancements, led to Messier-Bugatti-Dowty’s winning bid to manufacture 787 Dreamliner landing gear.

Keith Ridgway, AMRC’s research director, was a driving force behind the center, which has expanded rapidly over the past decade.

“Having the Boeing brand behind us gave AMRC a big boost when we started,” Ridgway said. “It was a great vote of confidence.”

In 2011, AMRC was named a Boeing Supplier of the Year for its work in developing new technologies and processes for machining high-performance metal alloys for aerospace and other industries.

The United Kingdom’s aerospace heritage has produced strong engineering talent and research capabilities, and Boeing has developed partnerships with U.K. institutions that provide valuable support to meet company research goals.

“The United Kingdom has important areas of world-leading technological strength,” said Richard Mills, Boeing strategy director for the U.K. and Ireland. “We have identified centers of expertise and

found ways to leverage technology that is valuable to our programs.”

Cambridge University is a leader in Information Technology research, a field that interests Boeing as it moves to provide integrated solutions for customers. With Cranfield University, Boeing works on projects that reflect the university’s reputation and expertise in aviation, aeronautics and aircraft development. Cranfield’s wholly owned commercial subsidiary, Cranfield Aerospace, built the X-48B Blended Wing Body subscale demonstrator to Boeing’s specifications. Boeing also works in strategic partnerships with universities in Strathclyde, Southampton and Bristol and signed a deal in October 2011 with the University of Nottingham to research carbon fiber recycling.

Business alliances provide valuable resources, too. Boeing’s work with QinetiQ, based in Farnborough, includes use of that company’s airframe and jet noise testing facilities. Its wind tunnel has been used in the development of the 737 MAX jetliner. And TWI, with facilities across the U.K., has expertise in advanced areas such as friction stir welding and laser manufacturing. ■

*For more on the Boeing Research & Technology–Europe center, see story in the June issue of Frontiers.*

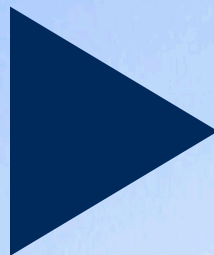
**PHOTOS: (Top)** A 3-D virtual reality system in operation at the AMRC in Sheffield. **(Insets, from left)** The AMRC with Boeing; its innovative machining work is a vital contribution to Boeing and many U.K.-based suppliers; the AMRC is a flexible facility that can accommodate many different types of machinery to test materials and processes. AMRC





**PHOTOS: (Above)** One of the most difficult maneuvers in the Blue Angels' flight demonstration, the line-abreast loop exemplifies precision and teamwork honed over months of practice. **U.S. NAVY PHOTO BY MC1 RACHEL McMARR (Insets)** Before the jets take to the sky, a complex choreography of maintenance and ground operations plays out with equal precision. **BOB FERGUSON/BOEING; U.S. NAVY PHOTO (SECOND FROM RIGHT) BY MC2 JEN BLAKE**





## Born to fly INVERTED

U.S. Navy's Blue Angels have thrilled crowds for more than a half-century

**E**ven if you don't love air shows, it's hard to imagine not getting excited by the sight of blue-and-gold Boeing F/A-18 Hornets roaring across the sky in a tight diamond or delta formation, or performing loops, barrel rolls and other breathtaking maneuvers, sometimes with only an arm's length separating the wingtip of one jet and the canopy of another.

Six jets performing a gravity-defying ballet in the sky at several hundred miles per hour, the pilots using special breathing techniques to keep from blacking out because of the high G-forces pushing against them during more extreme maneuvers.

Precision and teamwork. Power and noise. It's the Blue Angels, the U.S. Navy's premier flight demonstration team.

Each year, the Blue Angels perform at air shows and other events across the





country and sometimes overseas. They are scheduled to appear again the first week of August for Seattle's annual Seafair celebration, which Boeing has supported since the first Seafair in 1950.

In addition to sponsoring the Maritime Celebration during Seafair Fleet Week, Boeing provides financial support for Seafair and Boeing employees volunteer to help with related community activities. Seafair concludes with weekend hydroplane races on Lake Washington and performances over the racecourse by the Blue Angels. During their annual Seattle visit, the six Blue Angels jets are parked near the Museum of Flight at Boeing Field.

"The community feels a sense of ownership with the Blue Angels. It's such a tradition," said Beth Knox, president and chief executive of Seafair. "The reception the Blue Angels get is phenomenal. Seattleites understand the value of our military, and they love seeing the pilots showcase their spectacular flying abilities."

And Boeing's support of Seafair and the Blue Angels, she added, is "part of the fabric of the community that makes the Seattle area so special."

Boeing's connection with the Blue Angels is far more than just the builder of the high-





**PHOTOS: (Above)** The Blue Angels can tailor their demonstrations for various cloud conditions, a must when they perform over Seafair, with Seattle's rapidly changing weather. U.S. NAVY PHOTO BY MC2 ANDREW JOHNSON **(Insets)** The four-jet diamond and the six-jet delta formations demonstrate the flying skills of U.S. Navy and Marine Corps aviators; two "solo" jets show off the capabilities of the Boeing F/A-18 Hornet. U.S. NAVY PHOTOS BY MC SEAMEN CHARLES WHETSTINE; MC1 THOMAS J. BRENNAN; PM AIRMAN KRISTIN M. JOHNSON; PM2 ELI J. MEDELLIN





performance, supersonic jets the team flies.

Three civilian representatives from Boeing provide advice and assistance to the Blue Angels.

Senior Boeing technical advisers Edward “Robbie” Robinson and Marty Patterson are experts on the F/A-18 Hornet. Both are based with the Blue Angels at Naval Air Station Pensacola, Fla., and accompany the team to show sites and to winter training at Naval Air Facility El Centro, Calif. Also representing Boeing is supply and logistics expert Todd Lawson. The flow and availability of parts is a prime concern to a squadron on the move, and Lawson ensures that need is met. He is based at Naval Air Station Oceana, Va.

“No Blue Angels flight demonstration in the team’s 66-year history has been canceled due to maintenance problems, which demonstrates the commitment to excellence that exists among this group of men and women,” Robinson said. “It’s a privilege to help them uphold that commitment.”

Last month, Boeing photographer Bob Ferguson spent several days with the Blue Angels team in Pensacola, where it trains and prepares for upcoming shows. It was an opportunity to show a different and down-to-earth side of the Blue Angels from the thrills they provide in the air.

Those thrills began 66 years ago, in June 1946, when the newly formed team of naval aviators, flying Grumman F6F Hellcats, performed at what was then its home base in Jacksonville, Fla.

Less than a year earlier, at the end of World War II, Chester W. Nimitz, then the chief of Naval Operations, had ordered the formation of the flight demonstration team to keep the public interested in naval aviation.

It was not the first U.S. Navy aerobatic team. Those were the High Hatters and the



**PHOTOS: (Above)** The Blue Angels usually return to their base in Pensacola, Fla., after a weekend air show and perform maintenance and practice flights. **(Insets)** Robbie Robinson, top left, is one of three Boeing technical representatives who work with U.S. Navy crews to keep the Hornets in top shape. **BOB FERGUSON/BOEING**









Three Seahawks, according to Boeing historian Mike Lombardi, and they both flew Boeing F2Bs back in the 1920s.

The name Blue Angels was picked by the original team when it was planning a show in New York in 1946, according to the official Blue Angels website. One team member came across the name of the city's famous Blue Angel nightclub in *The New Yorker* magazine.

The Blue Angels flew various Grumman planes from their formation until the 1960s when they transitioned to F-4 Phantoms, and since then they have flown only jets built by McDonnell Douglas, one of the Boeing heritage companies.

In 1986, the Blue Angels celebrated their 40th anniversary by unveiling the F/A-18 Hornet, which has a top speed of nearly Mach 2, or twice the speed of sound.

During an air show, the top speed flown is about 700 mph (1,130 kilometers per hour) by one of the two solo pilots. The closest the jets come to one another is when four are in the diamond formation and the wingtip of one fighter is only 18 inches (45 centimeters) from the canopy of another, according to the Blue Angels website.

The jets bear the official colors for the U.S. Navy—blue and gold.

Every two years, either after or before they perform at Chicago's air show over Lake Michigan, the Blue Angels visit Boeing's St. Louis factory where employees now build the F/A-18 Super Hornet, a bigger and more capable version of the Hornet. No decision has been made yet for the Blue Angels to transition to the Super Hornet, according to the Navy. ■

**PHOTOS: (Above)** Boeing F/A-18 Hornets, shown here flying in a diamond formation, have served the Blue Angels for 26 years, more than a third of the team's history. **BOB FERGUSON/BOEING (Insets)** In glimmering blue and yellow paint, the jets demonstrate Navy precision and teamwork for hundreds of thousands each year at air shows around the United States and sometimes overseas. **BOB FERGUSON/BOEING; U.S. NAVY PHOTO (FAR RIGHT) BY PM2 RYAN J. COURTADE**







# Wing dynasty

China's flagship airline has a long and close relationship with Boeing

By Marcy Polhemus



**C**an you name the world's largest airline by market value? Here's a hint: It's not based in the United States or the Middle East. But it is in the biggest international market for Boeing airplanes.

The market, of course, is China. And the airline is Air China.

Since President Richard Nixon made his historic visit to China in 1972, marking an important step in normalizing relations between the United States and the People's Republic of China, Boeing has enjoyed a close working relationship with China's aviation industry and, in particular, the country's designated flag carrier, Air China.

"Air China has been on the leading edge of introducing almost every airplane Boeing has produced in the past 40 years," said Ihssane Mounir, Boeing Commercial Airplanes vice president of Sales and Marketing for Greater China and Korea.

In 2010, Boeing and Air China marked the 800th Boeing airplane delivery to China, a Boeing Next-Generation 737-800.

"Air China is a pioneering company and, together, Boeing and Air China have brought many aircraft to market," Mounir said.

Air China was the first Chinese airline to operate the 777-300ER (Extended Range) and is the first to operate the 737-800 with the Boeing Sky Interior. Air China was a partner with Boeing on

the launch of the 787 in 2004 and has 15 787s on order.

With its purchase of five 747-8 Intercontinental jetliners in 2011 to expand its international routes, Air China became the first Chinese carrier to purchase the passenger version of the fuel-efficient 747-8. Air China has been operating 747s since the 1980s.

Air China Chairman Wang Changshun said the airline's consistent growth and success are due to many factors, including its key partnership with Boeing.

"We have achieved steady and increasing operation revenues, carrying nearly 70 million passengers and continuously improving operation performances," he said, adding: "Our relationship with Boeing is vitally important to our ability to actively compete in both domestic and international markets."

Air China advocates a customer-service orientation, Wang said. It has been listed as a four-star airline in the Skytrax airline ranking system, and is the first airline to introduce a service management system certified by international authorities.

Boeing and Air China have partnered on important environmental improvements, too, such as finding alternatives to fossil fuels. In October 2011, Boeing, along with Chinese and U.S. aviation and energy partners, teamed with Air China to conduct China's first sustainable biofuel flight using a 747-400. ■

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**PHOTO ILLUSTRATION:** An artist's concept of a 747-8 Intercontinental in the Air China livery. The airline will be the first in China to operate the 747-8 Intercontinental. BRANDON LUONG/BOEING; AIRPLANE GRAPHIC: BOEING; GREAT WALL PHOTO: SHUTTERSTOCK







## WHERE EAGLES DARE

Four U.S. Air Force Boeing F-15C's maneuver during an air-to-air training sortie in May. They are part of the Oregon Air National Guard's 142nd Fighter Wing based in Portland, Ore. To download this image as a wallpaper for your computer screen, visit [www.boeing.com/frontiers/downloads](http://www.boeing.com/frontiers/downloads). PHOTO: JIM HASELTINE/HIGH-G PRODUCTIONS









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