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Frontiers

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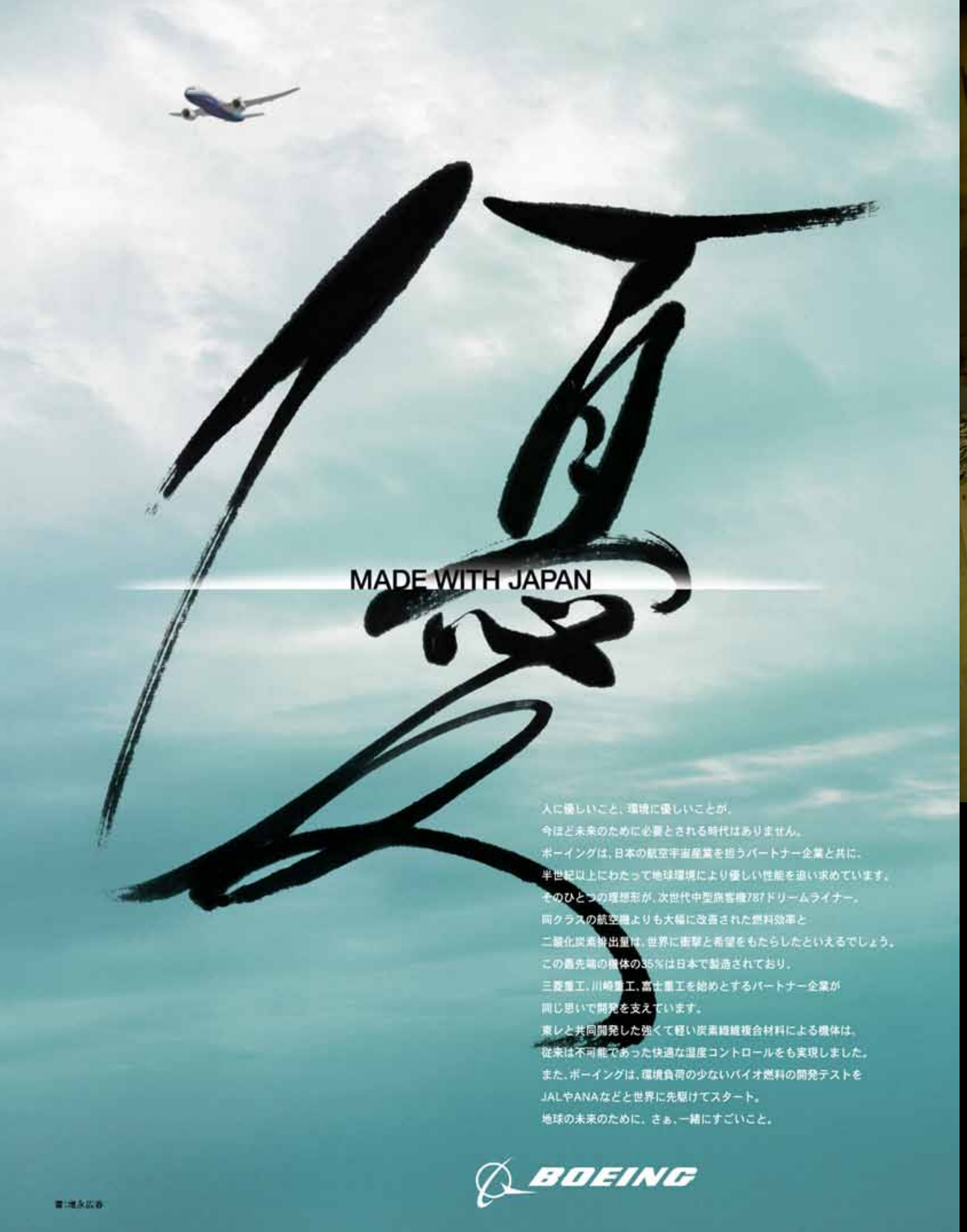
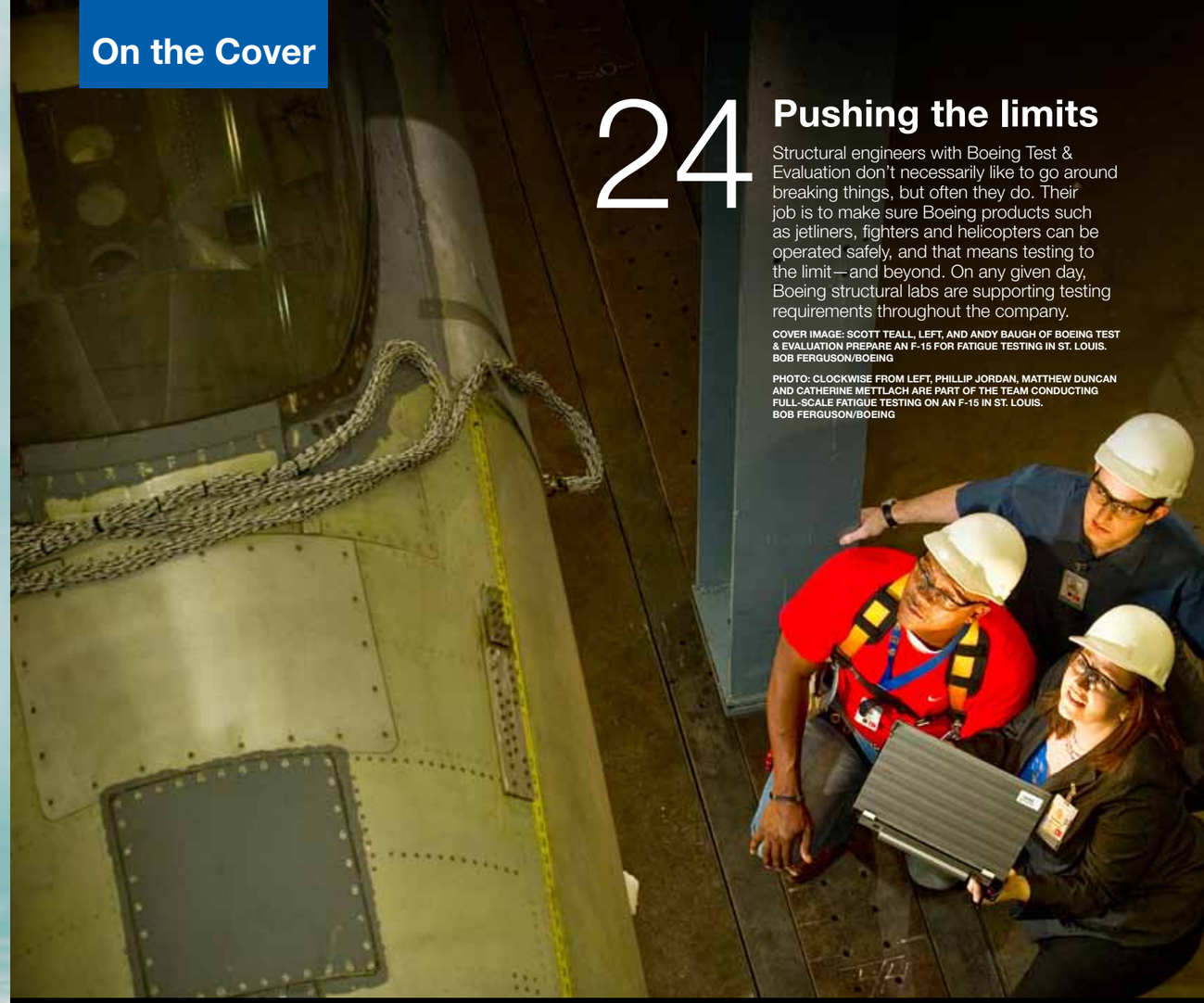
Xtreme measures

Testing structures to the breaking point helps ensure Boeing products are safe





On the Cover

24 Pushing the limits

Structural engineers with Boeing Test & Evaluation don't necessarily like to go around breaking things, but often they do. Their job is to make sure Boeing products such as jetliners, fighters and helicopters can be operated safely, and that means testing to the limit—and beyond. On any given day, Boeing structural labs are supporting testing requirements throughout the company.

COVER IMAGE: SCOTT TEALL, LEFT, AND ANDY BAUGH OF BOEING TEST & EVALUATION PREPARE AN F-15 FOR FATIGUE TESTING IN ST. LOUIS. BOB FERGUSON/BOEING

PHOTO: CLOCKWISE FROM LEFT, PHILLIP JORDAN, MATTHEW DUNCAN AND CATHERINE METTLACH ARE PART OF THE TEAM CONDUCTING FULL-SCALE FATIGUE TESTING ON AN F-15 IN ST. LOUIS. BOB FERGUSON/BOEING

Ad watch

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

Inside cover:

"787" is part of a series of ads that reinforces Boeing's partnership with Japan, a relationship that began more than 50 years ago. The campaign features the art of calligraphy, a symbolic tradition of Japanese culture that communicates not only words but a deeper and richer meaning.

Page 6:

This ad recognizes the efforts of Dreamflight, a U.K. charity that takes seriously ill and disabled children, without their parents but under the care of a team of doctors and health care professionals, on a memorable vacation to Orlando, Fla.

Back cover:

Corporate citizenship refers to the work Boeing does, both as a company and through its employees, to improve the world. This ad illustrates Boeing's commitment to initiatives that nurture the visionaries and leaders of tomorrow.

Frontiers

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No way but up

The prototype for what would become the CH-47 Chinook flew for the first time 50 years ago this month. The tandem-rotor design was based on the pioneering helicopter work of Frank Piasecki, founder of the company that would later develop into the Boeing rotorcraft operations near Philadelphia. PHOTO: BOEING ARCHIVES

At your service

Boeing employees from 27 sites around the world participated in the company's second annual Global Day of Service. More than 2,500 volunteers, their families and friends improved low-income homes, repaired nature trails, cleaned up areas damaged by floods, and performed other acts of community service. PHOTO: BOEING

INSIDE

Parts 'R' us

Nearly 13,000 Boeing commercial airplanes are in service around the world. Getting customers the spare parts and service they need is a massive undertaking that involves some 25,000 shipments a week from the Spares Distribution Center in Seattle and seven other worldwide Boeing facilities. This photo essay captures the scale of the work done by employees each day at the Seattle center.
PHOTO: BOB FERGUSON/BOEING

Earning its wings

The 747-8 is about to enter service and among the many improvements from the 747-400 is an advanced wing with control surfaces that are moved using fly-by-wire (electronically controlled) technology instead of cables. More than 200 Flight Controls employees and others worked many hours to make these improvements—and they overcame significant engineering and software challenges. PHOTO: ED TURNER/BOEING

CORRECTION

The facility near Philadelphia, Pa., where the CH-47 Chinook is built is the former General Steel Castings Corp., not Baldwin Locomotive Works as noted in the July issue of *Frontiers*, Page 20.

Vigilant and watchful—every day

In the 10 years since the 9/11 attacks, Boeing has aggressively enhanced its security

This month marks 10 years since terrorists took to the skies over New York, Pennsylvania and Washington, D.C. We watched in disbelief as our Boeing airplanes were flown into the World Trade Center, the Pentagon and a field in Pennsylvania. Three members of our Boeing team were among those who died.

These attacks spawned the need for heightened awareness and enhanced security around the world. Today, this reality remains the new norm as ongoing threats and other global events reinforce the paramount importance of security to our company and our industry.

Over the past 10 years, Boeing has taken a broader and deeper look at our own security. In our mission to protect people, property and information, we've aggressively assessed our vulnerabilities and implemented protective programs. We've accomplished this by working closely with the appropriate government agencies—both inside the United States and internationally—in areas of common interest and concern for ensuring the security and safety of our people and operations.

Internally, we use more robust and innovative technologies to better secure our facilities and tighten access to our property, products and systems. Our company badges—once used mainly as visual identifiers—now authenticate an individual's authorized entrance to company property and our internal systems. We've greatly enhanced our background screening requirements for all new hires and other non-Boeing personnel, and we've used our own Boeing-developed technologies to expand the monitoring capabilities around our facilities. And in areas where much more stringent access measures are required, we're exploring advanced security technologies such as biometrics, the method for uniquely recognizing people based on physical attributes such as fingerprints or retinal identification.

And the Security & Fire Protection people you see every day—and many you don't—are all supporting our endeavors to keep every facet of our great company safe.

But the most evident change has been among our own employees. We as individuals better understand the need to be personal stakeholders in our own security and to practice ongoing situational awareness. The Boeing people who design and build our products, develop our systems, interface with our customers and suppliers, and manage our workforce have become one of our most reliable sources for spotting unusual circumstances.

In recent years, several potential terrorist attacks around the world were thwarted because citizens saw something suspicious and notified local authorities. These individuals trusted and acted on their instincts—and it saved lives. It's imperative that we all share in this responsibility. *If you see something suspicious, say something!*

The events of 9/11 affected each of us. As you read this issue of *Frontiers*, reflect on those we lost and honor their memory. And remember, it's you—the employees—who help make our company a safe and secure place to work by remaining vigilant and watchful every day. ■

See pages 12–13 to read comments from employees about how 9/11 affected them and what it means to them today.

Leadership Message

"We need to be personal stakeholders in our own security and to practice ongoing situational awareness."

– Dave Komendat

Vice president and chief security officer

PHOTO: MARIAN LOCKHART/BOEING

Snapshot

SMILING ON A DREAM

A happy face left by a skywriting aircraft at the Oshkosh air show in Wisconsin appears to be directly above the tail of the 787 Dreamliner in this photo taken in late July. Lines of aviation enthusiasts waiting to tour the 787 stretched for more than a half-mile. In a note to the show's organizers, Mike Carriker, chief pilot for the 787, who flew the airplane to Oshkosh, wrote: "It was a dream of mine to see the jet on display! I remember walking through there in 2004 when the 787 was still a real dream and thinking just how good the new Boeing airplane would look sitting right where it sat yesterday." PHOTO: MIKE MILEY

Quotables

"My lawnmower is louder than the 787."

– Tweet from an aviation enthusiast who had arrived at the Oshkosh, Wis., air show to watch the landing of the Dreamliner. Patd64 was one of the thousands who lined the runway waving and cheering.

"There's nothing you can express to feel that kind of power."

– Shannon Faulk, Flight Operations mechanic, talking about what it's like to be in the St. Louis "hush house" when the jet engines of a just-finished F-15 or F/A-18 are fired up for the first time. See story on Page 32.

"It's ready to be sent in harm's way."

– Mark Kosko, program director for Boeing Unmanned Underwater Systems, talking about the company's 18-foot-long (5.5-meter) submarine drone Echo Ranger, which could soon be ready for U.S. Navy missions. It is undergoing tests off the California coast, as reported in the Los Angeles Times, *Aug. 20.*

Why We're Here

Eye for discovery

In search of global research that can help make Boeing more competitive

By Marna Kagele

More than $1 trillion of research and development work is taking place globally. In this *Frontiers* series that profiles employees talking about their jobs, Marna Kagele of the Global Technology Visibility and Integration team at Boeing Research & Technology explains how she keeps an eye out for discoveries that can improve Boeing's products, services and processes. PHOTO: MARIAN LOCKHART/BOEING

I don't work on any specific business programs or technology projects. But I feel like I have a role in Boeing's success by making sure we are at the forefront of technology.

Most of the people in Boeing Research & Technology work on specific research and development projects that support the business units. To complement their work, the organization's Global Technology group, which includes our team, keeps an eye on research and development that happens outside the company. We look at what universities, consortia or other companies are doing in research that might fit the needs of Boeing. In particular, I look for trends in technology, as well as potentially game-changing technologies, that could enhance Boeing's competitiveness. I recently developed a Strategy Room to help decision-makers visualize the important information they need.

The discoveries we make help Boeing get the most out of our R&D investments. If someone outside the company is performing good work in an important area, then we can leverage those findings, instead of spending the time and money duplicating them. And when Boeing has access to key technologies, whether they're developed in Boeing or elsewhere, we can make our products more capable and our processes more efficient. And that makes us more competitive.

We have a technology visibility system on the Boeing intranet at http://tsvc.web.boeing.com so people across the company can use our research. And to make sure our information is as complete as possible, we look for other external research findings made by teams across the company and include what they have learned.

I joined Boeing as a design engineer working on the space shuttle main engines. This role suits me because I still get to stay active in technology, even though I'm not performing engineering work on a daily basis. I'm passionate about technology development, and this job lets me keep a hand in it while also having input on the business side. ■

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Helicopter heroes

It was 50 years ago that a prototype helicopter first flew and a legend was born—the CH-47

By Mike Lombardi

Currently serving on the front lines of the global fight against terrorism, the CH-47 Chinook is the epitome of the innovative tandem-rotor helicopter designs produced through the genius of helicopter pioneer Frank Piasecki, founder of the company that would later develop into the Boeing operations near Philadelphia.

The CH-47, having been continuously modernized, has provided unmatched capability for U.S. and allied troops since its introduction 50 years ago this month.

First flown on Sept. 21, 1961, the YCH-1B prototype for what would later be known as the CH-47 was originally a design of the Vertol Helicopter Co. of Philadelphia, a company that traced its history to 1943 when Piasecki established the P-V Engineering Forum after flying the United States' second successful helicopter—the PV-2. In 1946, the company became Piasecki Helicopter Corp.

The Chinook's roots actually go back to 1945 when the U.S. Navy ordered a large rescue and transport helicopter and Piasecki and his team developed a tandem-rotor helicopter capable of carrying 10 passengers.

Known as the HRP, it was the largest helicopter in the world at the time and represented the first successful use of the tandem-rotor design. Nicknamed the "Flying Banana," the HRP originated the distinct banana shape of tandem-rotor helicopters that served as a foundation for the design of the CH-47.

The advantage of this unique design allows for low load-per-rotor area, eliminates the need for a tail rotor, increases lift and stability, and provides a large range for center of gravity.

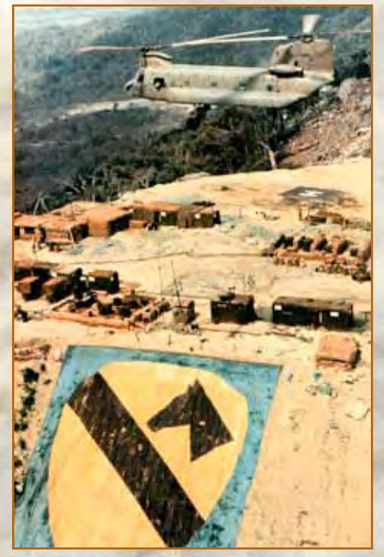
The HRP was followed by the U.S. Navy HUP/UH-25, the first helicopter to incorporate overlapping tandem rotors, and the U.S. Air Force CH-21, a long-range helicopter transport designed for use in the Arctic.

Piasecki stepped down in 1955 as chairman of his company, which then became Vertol Aircraft Corp. The engineering team established by Piasecki continued to the next generation of tandem-rotor helicopters and achieved success with the introduction of prototypes that would lead to the CH-46 Sea Knight and CH-47 Chinook.

In 1960, The Boeing Company, looking to expand into vertical flight, purchased Vertol and provided financial resources and expertise to support production of the Sea Knight and Chinook.

The U.S. Army took delivery of its first Chinook in August 1962, and within three years CH-47s flew into combat accompanying the U.S. 1st Cavalry Division when it deployed to Vietnam in 1965.

In 1978, Boeing introduced the CH-47D, a modernization program that converted 472 earlier model Chinooks into an essentially new CH-47 fleet with upgraded power plants and transmission systems that could handle nearly twice the original lift capacity of the CH-47A.



Just as earlier Chinooks proved themselves in wartime, the D model has played a key role for U.S. and allied troops in the deserts of Iraq and the mountains of Afghanistan. The highly modified MH-47 series is operated by the U.S. Army Special Operations Forces.

When the Chinook first flew in 1961 *Boeing Magazine* wrote: "There is a saying in the aviation industry that you can tell a winner by its appearance. If it looks good, chances are it will be good. If this is true, then the Boeing Vertol HC-1B, now in production for the U.S. Army, has a great future."

Indeed. It's a future that will extend well into the 21st century, with Boeing employees near Philadelphia now building the latest model of the Chinook, the CH-47F (See July 2011 *Frontiers*).

The world's premier large helicopter is the longest production program in Boeing history and one of the longest in aviation history. Its longevity and success are a tribute to the men and women of Boeing Philadelphia and the pioneering spirit of Frank Piasecki. ■

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The hard work and dedication of the Boeing Philadelphia team have created an aircraft that is truly a joy to fly.

– Jeffrey Bender, chief pilot for H-47 Programs, and Mark Schwerke, chief pilot for H-47 Production Flight Test

PHOTOS: (Above) A CH-47 Chinook is shown conducting exercises in Afghanistan. U.S. ARMY **(Insets, from top)** The forerunner of the Chinook, the XHRP-X, the world's first successful tandem-rotor helicopter; the Model 234 Commercial Chinook carries 44 passengers in an interior similar to a Boeing commercial jet; one job that only a Chinook can do is providing transport and resupply to otherwise inaccessible mountaintop firebases. BOEING ARCHIVES

From adversity, strength

When terrorists attacked the United States on the morning of Sept. 11, 2001, the worldwide Boeing team felt an acute sense of pain. Not only were its airplanes—vehicles designed and built to bring people together—used to target the World Trade Center and sites in Washington, D.C., but the company lost three of its own in the attacks: Chad Keller, D.C. Lee and Ruben Ornedo.

"The events of 9/11 remain fresh in our memories, and the impact of that tragic day will be felt for generations," said Jim McNerney, Boeing chairman, president and CEO. "We remember and honor those who died and what their sacrifices meant. While we cannot change the past, we can help shape a better future through products and services that protect the freedoms we hold dear and ensure the safety and security of worldwide air travel."

Frontiers recently asked employees to reflect on what Sept. 11 means to them today, a decade later—what they've learned, how their lives have changed, how they've moved forward. Following are some of their responses.

PHOTO: Searchlights placed next to the site of the World Trade Center create two vertical columns of light in remembrance of the Sept. 11, 2001, attacks. SHUTTERSTOCK

"I remember feeling a profound sense of disbelief and loss. I am more cautious and less trusting and pay more attention to my surroundings and the people who surround me as I go through my days. I find that my pride in this country is stronger. … I believe we need to be better citizens, we need to speak up when we have something to say and present a possible solution instead of just complaining. Then we need to get involved and help implement the steps to make things right."

– Denise Maurer, Manufacturing engineer, Boeing Defense, Space & Security, Huntsville, Ala.

"I had recently relinquished command of the Chief of Naval Operations Intelligence Plot in the Pentagon. That morning seven at the Intelligence Plot—including the commander who relieved me—were killed. Retired Adm. Bud Flanagan, founder of [Boeing subsidiary] Kestrel, lost 658 colleagues at Cantor Fitzgerald in the World Trade Center. Kestrel was formed to assist in the effort to prevent our nation from experiencing another such day."

– David Radi, president, Kestrel–Boeing Defense, Space & Security, Annapolis Junction, Md.

"I was stranded far from home and family on 9/11. When I moved to the Renton, Wash., site, I became an evacuation focal. I also trained new employees to safely get out of the final assembly building in the event an emergency like 9/11 happens. It scares me when the evacuation alarm goes off, but I help sweep and clear the area. I want to ensure I do my part to help my co-workers get to safety."

– Audrea Worthington, process analyst, Instrumentation and Data Systems, Boeing Test & Evaluation, Seattle

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"When the first airplane struck, I was on my way to an engineering class at the University of Puerto Rico. I knew that it would be my duty as a future engineer to help rebuild. In 2004, Boeing gave me the opportunity to join its team and continue the tradition of making safe, reliable aircraft that would connect the people and resources necessary to overcome this tragedy. I am proud of being a part of Commercial Airplanes, and of having witnessed the resilience and creativity of the Boeing family."

– Aimee Rodriguez Colon, Product Development–Structures, Boeing Commercial Airplanes, Everett, Wash.

"What we learn from adverse situations like this: Healing comes in baby steps. We have the strength, the knowledge and the ability to pick ourselves up and move on. We have allies around the world. We go on with our families and friends, with love and hope. Motto: We overcome."

– Lee Brooks, office administrator, Systems Integration Processes and Tools, Boeing Commercial Airplanes, Everett, Wash.













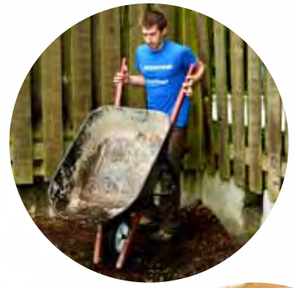



World-class service

More than 2,500 volunteers from Boeing sites around the world participated in the second annual Global Day of Service, working with communities on various projects and activities.

In China, Korea, India, Japan, Australia and the United States, Boeing volunteers, family members and friends turned out to help on July 16. In Australia, they cleaned up from damaging floods earlier this year; in China, they showed children and teachers a 747 freighter and hangar; in Southern California, they repaired nature trails; and in St. Louis, they improved homes for low-income families.

"This day of service grew from a grass-roots effort that was fueled by employees who not only wanted to do the right thing to help others in their communities, but who also wanted to join their colleagues around the world to be part of this larger Boeing experience," said Patrice Mingo, Boeing director of employee volunteer programs for Global Corporate Citizenship. ■

PHOTOS: Boeing sites that participated in the 2011 Global Day of Service included Brisbane and Melbourne, Australia; Chicago; Dallas (Jeppesen and Aviall); Fort Walton Beach, Fla.; Houston; Philadelphia; Portland; Puget Sound (multiple sites); Seoul, South Korea; Shanghai; St. Louis; Southern California (multiple sites); Tokyo; Washington, D.C.; and Wichita. BOEING

Speed to spare

When customers need parts for Boeing airplanes, the Spares Distribution Center delivers

By Stephanie A. Miller and photos by Bob Ferguson

It's a support network that spans the globe—for Boeing airplanes.

Nearly 13,000 Boeing commercial jetliners are in service around the world, and those airplanes need support and spare parts. Making sure they get what they need quickly involves hundreds of Boeing employees and a material management distribution system that serves more than 600 airlines and about 1,400 customers.

In a typical week, some 25,000 shipments go out from eight worldwide Boeing facilities, the largest of which is the Spares Distribution Center, or SDC, near Seattle.

"The SDC is where the rubber hits the road," said Bill Brill, a Global Logistics specialist at the center. "We get to execute the plan and deliver parts to our customers and help keep their aircraft making revenue."

Under the center's sprawling 15-acre (6-hectare) roof, not far from the south end of the runways at Seattle–Tacoma International Airport, are millions of spare parts. Some are as big as a 777 thrust reverser, which is deployed on the engine to slow the airplane after landing. Others are so tiny, "you almost need a magnifying glass to see them," said Jeannene Willging, team lead for Inventory Operations, Carousel. The 54 computer-activated carousels at the center store and pick some 100,000 part numbers.

"It always amazes me that a teeny part is holding up a plane somewhere, whether it be in the factory or in flight," Willging said.

Opened in 1993, the Seattle center covers just over 700,000 square feet (65,000 square meters). An automated conveyor system more than two miles (three kilometers) long carries parts to and from their proper storage bins. Many of those parts are kept in 24 high-bay bins, each 60 feet (18 meters) high and 320 feet (100 meters) long. Employees

PHOTO: Dan Spears, a team lead in Heavy Crating, operates a stacker while moving parts to another section of the Spares Distribution Center.

“Any customer, anywhere in the world, can order a part from us anytime, day or night, any day of the week or weekend, and our teams spring into action.”

– Brett Nichols, operations manager for the Spares Distribution Center

PHOTOS: (Below) Shipping and distribution facilitators John Murray, from left, Paul Seaman and Greg Young use hybrid machines to enter high-bay rows to pick parts. **(Insets, from left)** John Murray; Carl Ward, left, IT global infrastructure engagement, and Paul Seaman; shipping and distribution facilitator Martin Hamilton; and Greg Young.

operate hydraulic-powered lifts to fetch or store parts in those bins.

The Seattle center shipped 800,000 customer orders in 2010. Depending on the size and weight of the part, a wooden crate or cardboard box is constructed inside the center for shipment. Recently, employees shipped a 767 wing skin to a customer in a box they made measuring 76 feet (23 meters) long.

The most urgent request the center handles involves an airplane on ground, or AOG. A plane can’t fly—or make money for the customer—until it is repaired. An AOG order can be processed and out the door within four hours. Routine orders can be shipped the next business day.

Boeing teams are on call and ready to travel to any location to assess the damage to an aircraft on the ground, make a repair estimate, and stay and do the repairs if the customer asks. Sometimes, it might mean sleeping in tents for weeks or longer if the site is remote.

“The incident repair orders are interesting because they can include anything—tents, portable toilets, generators and other items for the crews that are repairing aircraft out in the field,” Brill said. “It is not just parts going out.”

Boeing’s other distribution locations are in Los Angeles, Atlanta, Dallas, London, Singapore and Beijing, as well as Dubai in the United Arab Emirates. In Long Beach, Calif., the Emergent Build Center supports the majority of customer requests for spare parts for out-of-production Boeing planes.

Along with the Spares Distribution Center in Seattle, they all play important roles in helping Commercial Aviation Services support Boeing customers.

Brett Nichols, operations manager for the Spares Distribution Center, noted that the facility never shuts down.

“Any customer, anywhere in the world,” he said, “can order a part from us anytime, day or night, any day of the week or weekend, and our teams spring into action striving to get that customer their order as quickly as we possibly can so they can continue running their business of flying.” ■

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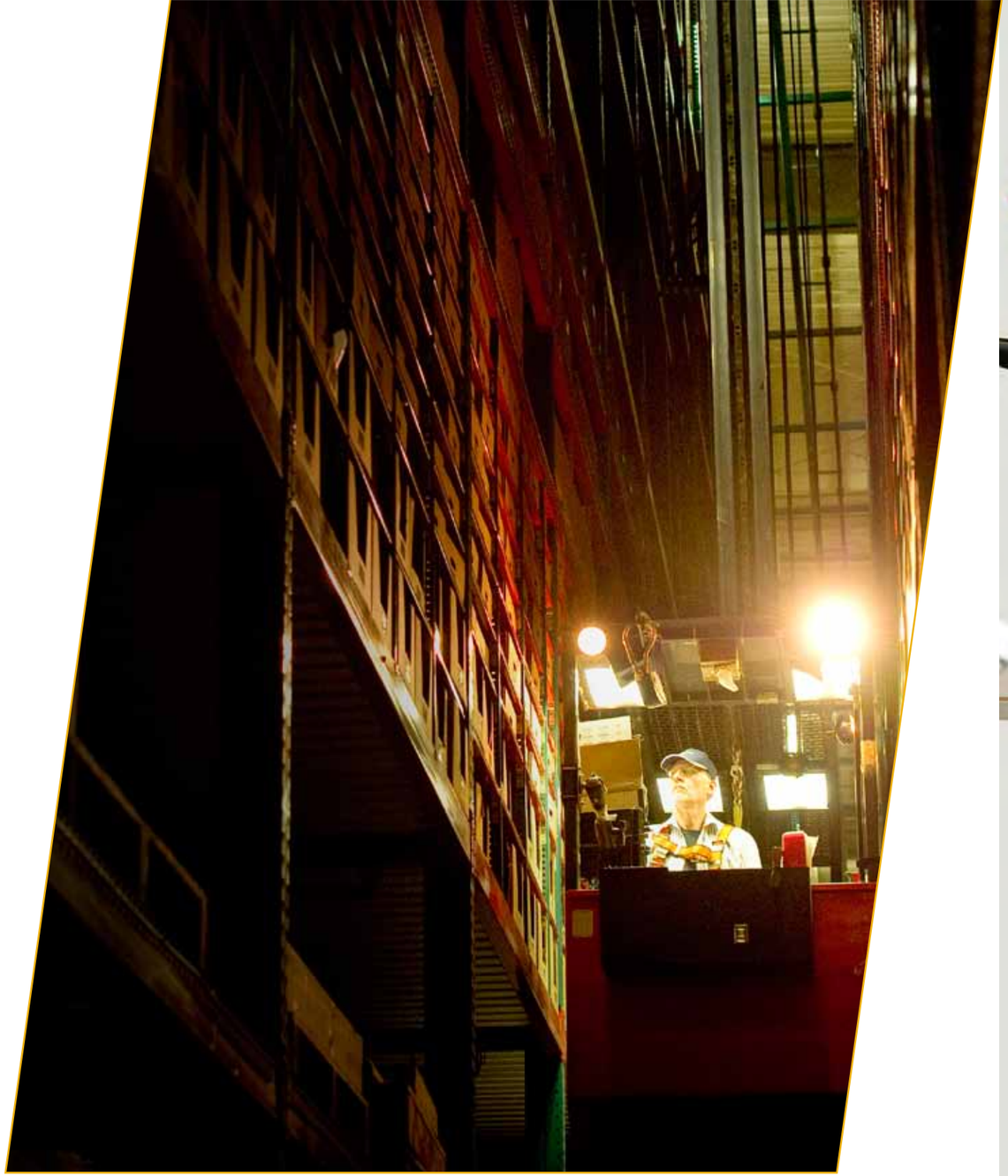
"The purpose of the SDC is simple: To get the right part to the right place at the right time.

– Dale Wilkinson, vice president of Material Service

PHOTOS: (Above) Dave Smith, shipping and distribution facilitator, and Brett Nichols, Spares Distribution Center operations manager, meet in the bulk storage area to locate a part for a customer. **(Insets, from left)** Shipping and distribution facilitators Yu Tse, Patty Triplett, Keith Haynes and Brian Morley.



PHOTOS: (Above) Paul Seaman, shipping and distribution facilitator, in a high-bay hybrid machine. The high-bay area can get dark between rows, so machines have their own lighting to help staff pick parts. **(Insets, from left)** Amado Hardi, repair station mechanic, and Dennis Malloy, shipping and distribution facilitator.

Goal!

Brazil's GOL Airlines has grown into one of the world's largest 737 operators

By Adam Morgan

When GOL Airlines took delivery of its 61st Next-Generation 737 from Boeing in early August, it added yet another milestone in its fast track to becoming—in just 10 years—the world's third-largest 737 low-cost carrier.

The delivery also made GOL the first airline in Latin America to receive the Next-Generation 737 with an improved-performance engine, furthering the airline's position as a global aviation leader.

"GOL's success is built on a foundation of innovation and efficiency," said Constantino de Oliveira Jr., GOL's chief executive officer. "Every decision we make is part of our deliberate plan to provide the most affordable and efficient service in the industry."

GOL launched commercial service on Jan. 15, 2001, from Brasilia to Sao Paulo using one of four Next-Generation 737-700s leased from Boeing Capital Corporation. Today, GOL operates more than 130 737-700s and 737-800s—including the 61 airplanes it has acquired directly from Boeing. It offers the most extensive route network in South America, with approximately 900 daily flights to 63 destinations in 10 countries. Combined with more than 30 operational partnerships with foreign companies, GOL's route network is among the best serving customers traveling to, from and within Brazil.

Since its launch, the airline, whose name means "goal," has been upgrading its all-737 fleet with Boeing's latest technology improvements and was a launch customer for the Boeing Sky Interior. With operations out of Santos Dumont Airport in Rio de Janeiro, the Brazilian airport known for its short runway, GOL helped drive the requirements for the 737 Short Field Performance Package. It also supported its certification and entry into service.

In 2010, GOL partnered with Boeing to launch a pilot project within its maintenance and repair organization to lower lead time and costs for spare parts, as well as improve dispatch reliability. The project is expanding this year to house hundreds of expandable parts, including dispatch essential parts, which helps GOL reduce its stocking levels and cuts inventory holding costs.

GOL is one of Boeing's largest users of Toolbox, which helps manage technical documentation and records associated with aircraft maintenance and repair activities. The airline also acquired the Airplane Health Management Performance Monitoring module to track and manage fleet fuel consumption.

"Boeing is proud to be a part of GOL's first 10 years as they've grown from a modest upstart to one of the largest 737 operators in the world and a driving force in commercial aviation," said Van Rex Gallard, vice president of Sales for Latin America, Africa and the Caribbean. "Their commitment to continuous improvement has been validated time and again with the airline's investment, not only in hardware and software that make their airplanes and operations run more efficiently but also in technology like the Boeing Sky Interior that benefits their passengers' comfort as well." ■

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PHOTOS: (Above left) Constantino de Oliveira Jr., chief executive officer of GOL Airlines. GOL AIRLINES **(Above)** A Next-Generation 737 in the GOL livery. The airline was the first in Latin America to receive an airplane with the improved-performance engine. JIM ANDERSON/BOEING

PHOTOS: (Top) As part of the F-15C full-scale fatigue test in St. Louis, the aircraft's wing is covered with tension pads bonded to the surface. BOB FERGUSON/BOEING **(Insets, from left)** In Everett, Wash., Dale Best prepares for the 747-8 Freighter rudder proof test, which simulates loads on the rudder surfaces; a Boeing Test & Evaluation team in Everett oversees the 747-8 Intercontinental rudder proof test. JEREMIAH SCOTT/BOEING

Outer *limits*

By testing to the extreme, and often beyond, structural engineers help ensure Boeing products are safe

By Jennifer Hawton

Boeing is known for having safe, durable products. So what does Liam Brett-Eiger do for the company?

"I'm a professional destroyer," quipped Brett-Eiger, a structural materials test engineer.

Brett-Eiger and 160-some Boeing Test & Evaluation structural test engineers may have a good sense of humor, but their work is serious business: They have a hand in making sure that all Boeing products can be operated safely.

The team pushes structures to their physical limits, finding out where the breaking point is—often with an audible pop, snap or crack. Their efforts help ensure the safety of Boeing jets by verifying that the breaking point lies exceptionally far away from what a pilot may experience, even in extreme circumstances.

"Our job is to make sure that passengers and crew can trust the airplane they're in," said Marshall Short, Lab Test Operations vice president. "We test—and sometimes break—things so people know they can trust our products."

"It's too bad the average traveler has no idea about all

“We push every piece of every product to its limits—and beyond—to ensure the products can easily handle any situation…”

– Michelle Fitzgerald, deputy capability leader for structural testing

PHOTO: A time-lapse photo of the 787 full-scale static test demonstrates how the jetliner’s wings withstand 150 percent of expected forces. The wings are bent to 20 feet (6 meters) at the maximum test load. JENNIFER REITZ/BOEING

the work these teams do to keep them safe,” he added.

Structural tests fall into two main categories: static and fatigue.

Static testing determines an airframe’s ability to carry loads. Loads applied during the final phase of static testing are 50 percent greater than loads that may be encountered in service. Photos and videos of static testing, with airplanes encased in large scaffold-like structures, show dramatic images of airplanes surviving seemingly impossible stresses, such as having their wings bent almost vertical.

Fatigue testing subjects airframes to the equivalent of up to three lifetimes of in-service wear and tear to help determine durability. This work also helps set operator maintenance and repair schedules.

Boeing was one of the early pioneers of full-scale static and fatigue testing, beginning in the 1920s. The basics behind these tests haven’t changed over the years, but the execution has—dramatically. For instance, data-collection techniques have advanced significantly since the company started structural testing.

Originally, there were several “deflection men” responsible for manually recording data points.

Today, Boeing static tests use a system that’s precise, sophisticated and the largest of its kind. Devices that capture any change in position to within .0025 of an inch allow more than 50 design engineers and stress analysts to remotely monitor airframe health, comparing their predictions to test data in real time.

The way loads are applied to the airframe has also evolved. Each structural test once required 29 employees, including 11 “pump men” who manually operated hydraulic controls to apply flight loads to a test article. Today, two engineers operate one computer that controls in excess of 150 servo-hydraulic load systems.

Recent Lean+ improvements to the 787 test program significantly shortened the test setup, according to Lee McNeil, 787 test setup lead engineer.

The upgrades included new ways to build full-scale static test structures, and using large-scale laser tools that can easily measure an entire structure at one time.

“Although the tools and instruments have advanced, our job still is as exciting as it ever was,” said Michelle Fitzgerald, deputy capability leader for structural testing. “We push every piece of every product to its limits—and beyond—to ensure the products can easily handle any situation they are likely to encounter.”

From verifying the usable life of a stowage bin to identifying ways to improve the safety of helicopters, the test teams have done it all in making sure Boeing products are safe—in and out of the sky.

“I don’t stress when I fly,” Fitzgerald added. “I’ve seen those wings bend 26 feet [8 meters]—I have supreme confidence in our products and I know that they will withstand anything they come across in flight.” ■

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For this structural engineer, the fun and excitement of work is in the variety of testing programs

After 32 years as a structural test engineer, Edward (Sam) Baker still gets excited when he talks about the different Boeing programs he's had a hand in testing.

These include International Space Station hardware, space shuttles, Delta rockets and the X-51 WaveRider.

His favorite?

Baker is hard-pressed to say, explaining that it's the variety of programs that makes the job exciting. But he finally signals out his support of the structural testing on the massive Delta IV rocket.

"Ever since watching Apollo launches as a kid, I've been interested in rockets," Baker said. "I've followed rocket programs ever since, so it was a thrill to be a part of that legacy."

Today, Baker, who's based in Huntington Beach, Calif., is involved in fatigue testing on a critical part of the B-1B bomber. But he also supports fatigue testing on the F-15C in St. Louis.

The B-1B testing provides the U.S. Air Force with critical data used to define aircraft maintenance and budget needs for the existing B-1B fleet. The fatigue testing Baker oversees is part of what is known as a "life extension program."

Baker's work takes place specifically on the dorsal longeron—a 40-foot-long (12-meter-long) component that essentially is the spine of the aircraft. The longeron starts at the cockpit and runs down the centerline of the fuselage, ending at the wingbox. The testing is done on an actual piece of hardware cut from a deactivated aircraft.

Fatigue testing helps simulate the cyclical stress that occurs on an aircraft during a lifetime of flight. Aircraft are stressed in many ways, such as during takeoff and landing or while making maneuvers. During this type of fatigue testing, data are gathered that provide a better understanding of how an aircraft and specific parts will age over time.

The work that Baker performs in St. Louis in support of the F-15C program is similar to what he's doing on the B-1B. But the entire F-15C is being subjected to fatigue testing, not just a part of it. As with the B-1B, the primary goal is to provide critical data to the customer on how an existing aircraft will react to various stress patterns.

Regardless of the program, Baker said, "it's really a team effort. You need a skilled team of the right size and with different skill sets in order to put together a successful test."

He also said the integration and consolidation of the company's widespread testing operations into one organization, Boeing Test & Evaluation, has created a "test community" that didn't exist before.

"There are cultural differences and it will take time to sort through those," he said, "but in the long run, integration will help us develop common systems and provide employees more opportunities."

– Suzi Hammond

PHOTO: Sam Baker examines F-15 structure load pads. BRUCE BECKER/BOEING

Structural testing around Boeing

On any given day, Boeing structural test labs are supporting testing requirements throughout the enterprise. Here is a snapshot of just some of the current structural testing being conducted around the company.

PUGET SOUND REGION

787-8 full-scale fatigue test
30-month test to simulate two lifetimes of airline service

B-1B full-scale wing test
Five-year test to simulate two extended lifetimes of service

P-8A Poseidon full-scale fatigue test
Currently preparing for the program to test two in-service lifetimes

CALIFORNIA

Commercial Crew Transportation System
Development and risk-reduction testing of selected structures and subsystems; supports future qualification testing of a commercial transport space vehicle for rendezvous with the International Space Station and the Bigelow Aerospace space station

United Launch Alliance
Structural qualification test for Delta IV common booster core metallic liquid oxygen skirt

747-8 Rudder Rig
Test bed for simulation of flight conditions in support of flight testing

MESA

Apache Block III
Currently working main-rotor driveshaft fatigue test, transmission tests and composite main rotor blades for this significant AH-64 Apache upgrade

F-18 hail impact
Ice ball impact testing simulates in-flight hail damage to help create more durable radome for F-18 Growler

ST. LOUIS

F-15E full-scale fatigue tests
Five-year program to extend the life of the product

P-8A component fatigue tests
Certifying service life for horizontal stabilizer and landing gear

PHOTO: An F-15C airframe is hoisted into the full-scale fatigue test fixture. On the ground are, from left, Jeff Crow, Dan Kretschmer, Phillip Jordan, Matthew Duncan and Catherine Mettlach. At the top are Andy Baugh, left, and Scott Teall. BOB FERGUSON/BOEING

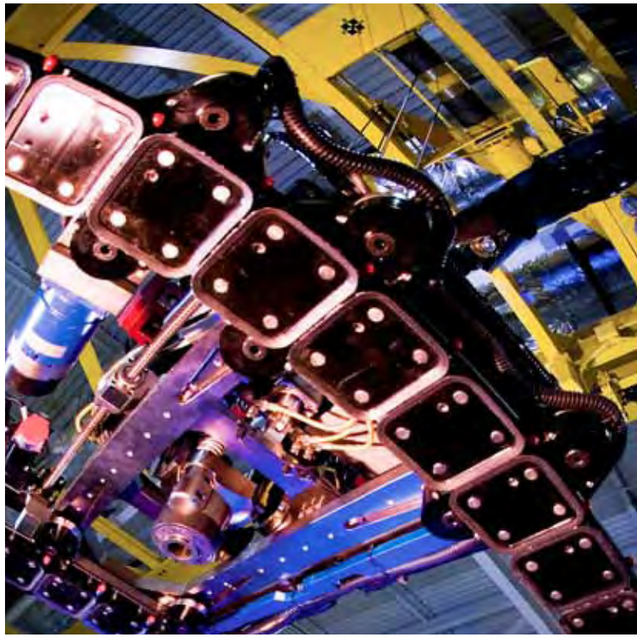
Valuable thoughts

What Boeing is doing to get the most from a key asset—intellectual property

By Candace Heckman

"Boeing spends billions of dollars on research and development, and the company must be able to both recover and maximize the value of these investments."

– Luis Valdes, director of Business Development and Licensing



Perhaps even more than its physical products and services, Boeing's inventions, collective know-how, information, images, ideas and brand—that is, its intellectual property—are among the company's most valuable assets. Using Boeing's intellectual property wisely in developing and improving new products and services, as well as leveraging how it is used by others, is critical for the company.

Frontiers spoke with Martha Ries, vice president of Boeing Intellectual Property Management, and Luis Valdes, director of Business Development and Licensing, to better understand how the company extracts the most value from its innovation.

How does the company determine the value of its intellectual property?

Ries: We are really talking about three types of value. The first is the intrinsic value of whatever product we're manufacturing or service we're offering—the innovative materials and the way we make them for the 787 Dreamliner, for example.

Then, there is the value of the IP to the company—can the idea, information, invention be used or repurposed in another area of the company? We've got a strategy to guide this effort, and it's how we can get a bigger bang from our buck.

Third, Boeing's IP more often than not will have value to others—our customers, suppliers, competitors. This is where our ability to license the IP comes in. The business models we create around third-party licenses have huge revenue potential.

Valdes: Boeing has a lot of IP to offer for licensing, and we are already adding millions of dollars to annual earnings. But the company has only scratched the surface.

There is big demand by others to use our IP—primarily because it's cheaper for another company to pay Boeing to use our IP than it is creating the IP themselves or investing in an alternative.

How can Boeing control entities that don't ask to license its technology, but just take it?

Valdes: Unfortunately, we often find these situations—for instance, when others manufacture parts or perform modifications to Boeing products without our permission. When it comes to asserting Boeing's IP rights, there are really two ways to go: one, legal action; or two, we can knock on their door with a licensing contract. Sometimes legal action is the best recourse. But the opportunity to recover the value of our intellectual property through licensing is often better for Boeing's relationship with the alleged infringer, who could be an existing or future customer or supplier.

If we are creating the intellectual property to build our own products, why would we allow others to use it?

Valdes: There will always be some intellectual property that Boeing will choose not to share. And that knowledge and information we will guard zealously, because if we didn't, we could lose our competitive advantage.

That said, there is a fair bit of our IP that is both protected and already out in the open, like published patents. Look at technology like Flex Track [a portable, automated machine for precisely drilling contoured and flat surfaces], which has value outside the aerospace industry. Or consider the 787 simulator, which we now license. Competition in technology innovation is fierce, and if we come up with some revolutionary way of building an airplane, that doesn't mean someone else won't have the same or better ideas. Licensing also enables global alliances that create partnerships not only for business but also for new discoveries.

What's the connection between licensing and new discoveries?

Ries: The point of patents is to encourage inventors to share their ideas without fear that someone will steal them.

But when Boeing licenses its inventions, it also lets others build upon our technology. When that happens, we can get the benefit of what others create. This is another way Boeing can control who uses an invention, and for what purpose. And, in most cases, this allows the company to collect royalties, which, at a basic level, is how we can recover the enormous investments made toward research and development.

Valdes: Boeing spends billions of dollars on research and development, and the company must be able to both recover and maximize the value of these investments. The return we make on this investment helps determine how much money we can continue to put back into research and development. ■

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PHOTOS: (Far left and above left) Martha Ries, left, and Luis Valdes oversee Boeing's efforts to get the most value from its innovation—including licensing developments such as the 787's simulator. GAIL HANUSA/BOEING **(Above)** Another example of licensed technology is Flex Track, a Boeing-developed machine for precise drilling. BOB FERGUSON/BOEING

Prizefighters

Quality and pride motivate employees who build Boeing's jet fighters

By Eric Fetters-Walp and Chamila Jayaweera

The Boeing employees who build the company's highly capable jet fighters keep close to mind why they work hard to make each aircraft perfect.

"There are a lot of employees here who have kids out flying the Super Hornets and the F-15s," said Kevin Jung, a sheet metal assembler and riveter on the F-15 production line.

Hundreds of employees work on the F-15, F/A-18E/F Super Hornet and EA-18G Growler lines at the Boeing St. Louis site, knowing that the lives of fighter pilots from the United States and its allies depend on their workmanship.

It's easy to understand why they're proud of their products. The F-15 Eagle is the fastest U.S.-built jet fighter currently in production, with a perfect air-combat record. During the past

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PHOTOS: (Left) An F/A-18 Super Hornet, assembled at Boeing's St. Louis site, cuts through the sky. U.S. NAVY **(Insets, clockwise from top)** Shawn Wright reams holes into an F/A-18 wing skin; Kenneth Johnson with an F-15; Ken Niezwaag of F/A-18 Installations works on the aircraft's electric routing; Scott Marlett, working on the F/A-18 Flight Ramp, performs a toolbox inventory check; and Gregory Ory of F/A-18 Quality Check inspects aircraft components. BOB FERGUSON/BOEING

30 years, Boeing has built more than 1,600 of the aircraft, and the U.S. Air Force plans to keep flying its F-15E models through 2035. In addition to the U.S., F-15 customers include the Republic of Korea, Singapore, Japan, Saudi Arabia and Israel. International orders have extended the production line into at least 2013.

The Growler is based on the F/A-18E/F Super Hornet, which is the U.S. Navy's front-line strike fighter. So far, the Super Hornet and Growler teams have delivered more than 500 aircraft to U.S. and international customers on time and on budget. Known for its versatility in diverse missions, the F/A-18 also is designed with superior survivability. Last September, the Navy awarded a new multiyear contract to Boeing for 124 Super Hornets and EA-18G Growlers, ensuring aircraft continue to roll off of that line through 2015. With strong international opportunities, program leaders say the Super Hornet line should still be producing aircraft through the end of the decade—and beyond.

Earlier this year, the EA-18G Growler flew its first combat missions as part of Operation Odyssey Dawn over Libya, and

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PHOTOS: (Left) The F-15 Eagle is the fastest fighter jet in production in the United States. U.S. AIR FORCE **(Insets, clockwise from top left)** The F-15, with joined body and wings, in final assembly; Daniel Wagoner, left, and Douglas Lawhorn work on the F/A-18's cockpit; Jeffery Johnston performs part of the F-15's final assembly inspection; the F-15's vertical stabilizers and powerful jet engines; and the F-15's sophisticated radome nose in final assembly.
BOB FERGUSON/BOEING

according to the Navy it performed well.

James Morales, a sheet metal assembler and riveter, said the day when the first Super Hornet came out of the St. Louis factory was one he won't forget. "When those hangar doors opened up, I felt like a new dad. Even today, 500 aircraft later, I get that same feeling," said Morales, who has worked at the site for 27 years.

Once the jet fighters roll off the production line, they are tested before delivery. Shannon Faulk, a Flight Operations mechanic, said he enjoys trips into the "hush house," where the engines on just-finished Super Hornets and Growlers are fired up for the first time. The special building is designed to absorb the resulting roar.

"There's nothing you can express to feel that kind of power," Faulk said.

John Mueller, flight-ramp foreman, said the crew then runs each of the four Super Hornet and Growlers delivered to the Navy each month through a series of tests to make sure all components work together. It's a system the ramp team has perfected over the years.

Boeing test pilot Steve Schmidt relies on the crew's expertise.

"It's our job to take the plane up and make sure it's put together right and it is safe for flight for other people," Schmidt said. "I know a lot of people out there on the factory floor. I know the last thing they would want to do is put me in an unsafe airplane. So they take a lot of pride in their work to give me the best possible product that they can."

Ada Turner, Center Panstock and Door Drillout specialist for the F-15, said that while the manufacturing processes have been streamlined and improved throughout the years, the team is proud its aircraft requires more complex hands-on assembly work than other models. And when an F-15, Growler or Super Hornet takes off from the runway next to the St. Louis site, she said, it's a sight and sound to behold.

"I never get tired of seeing them go up and fly," Turner said, adding: "I wouldn't want to fly in one, though … too fast for me." ■

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PHOTOS: (Below) Michael Haupt, left, and Terry Mills inspect an F/A-18's cockpit canopy. **(Insets, clockwise from top left)** Julie Klubek, left, and John Bunk inspect an F/A-18's electrical wiring; Kevin James works on cockpit wire bundle routing for the F/A-18; Dennis Drier, left, and Scott Marlett of F/A-18 Pre-flight Operations conduct an inspection; Thomas Naeger drills into the nose barrel of an F/A-18; and Richard Hatcher installs cockpit wire bundles on the F/A-18. **BOB FERGUSON/BOEING**

“There’s nothing you can express to feel that kind of power.”

– Shannon Faulk, Flight Operations mechanic, on initial engine run-ups

PHOTOS: (Below) Keith Ternes, left, and Steven Stoverink work on the aft end of an F-15 fighter. **(Insets, clockwise from top)** An F-15 in final assembly; while Jimmy Morales works on top of an F/A-18, Lee Browning (bottom left) and Will Daugherty inspect the nose landing gear; an F-15 undergoing a wire integrity test; from left, Mike Carr, Mike Speciale and Steve Norman are responsible for the F-15 crew station buildup; and Brian Bert works with electrical cable routing on an F-15. BOB FERGUSON/BOEING

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“I know a lot of people out there on the factory floor. The last thing they would do is put me in an unsafe airplane.”

– Steve Schmidt, Boeing test pilot

PHOTOS: (Below) Staff Sgt. Michael Keller, aerial combat photographer, takes a self-portrait while in the back seat of an F-15E. U.S. AIR FORCE **(Insets, clockwise from top left)** Daniel Wagoner of the F/A-18 team; Robert Jacobs works on the F/A-18; Velus Matheney checks the F/A-18’s nose barrel; Bob Tarrant works inside the F/A-18 gun bay and nose barrel; and Steven Mintle inspects an F/A-18 fuselage for foreign object debris, or FOD.
BOB FERGUSON/BOEING

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Wings of innovation

The best of Boeing—and the best ideas—went into engineering the 747-8's advanced wing

By Bret Jensen

PHOTO: The redesigned wing on the 747-8 features fly-by-wire (electronically controlled) technology. GAIL HANUSA/BOEING

While there is no mistaking its evolution from the 747-400, the 747-8 is in many ways a fundamentally new and different airplane from its predecessor.

Improvements in the 747-8 include an advanced flight deck that incorporates some of the technologies developed for the 787, new engines developed for the 787, and one of the most advanced wings ever designed by Boeing engineers.

"People have really been giving their all for this airplane," said Elizabeth Pasztor, Commercial Airplanes chief engineer for Flight Controls. "The level of innovation and dedication … has been amazing."

The advanced wing on which the Flight Controls Engineering team worked features fly-by-wire (electronically controlled) spoilers and outboard ailerons, which are flight control surfaces that provide aircraft roll and speed-brake control. There also are double-slotted inboard and single-slotted outboard flaps—high-lift devices located on the trailing edge of the wing—that are extended to generate additional lift at low speeds. The 224-foot (68.3-meter) wing also features distinctive raked tips. All this combines to create less noise and improve fuel efficiency.

Since the 747-8 left the drawing board, as many as 225 Flight Controls employees and additional supplier representatives have toiled long hours to make improvements so the newest member of the 747 family flies better and more efficiently.

A demanding, highly compressed schedule was required to incorporate, perfect, test and certify not only the wing but all the new designs on the 747-8.

"The Boeing team has been fantastic," said Scott Pelton, Commercial Airplanes director of Airplane Systems Engineering. "Many employees have made significant personal sacrifices working long and late hours. Through these difficult conditions, they've maintained their personal integrity toward technical excellence and safety."

The wing design meant the 747-8 would need new software programming for the flight control computer to keep the same handling and landing characteristics as the 747-400. This allows pilots who fly the 747-400 to easily make the switch to the 747-8 with minimal training. Programming also was required to add enhancements such as turbulence mitigation for a smoother ride.

"Because the new wing is fly-by-wire, we in Flight Controls have greater flexibility to make changes to the airplane electronically," said Pio Fitzgerald, lead engineer for the 747-8 Flight Control Laws engineering group. "We can command the ailerons and elevators to behave a certain way, thus making the airplane perform and feel the way we want it to."

Enhancing and improving the airplane with software programming speeds development and production. It also allows flight controls engineers to more easily and quickly correct problems.

Once flight testing began on the 747-8, for example, a small vibration was detected in the outboard portion of the wing. Although the vibration was subtle—caused by

approximately an inch of wing-tip deflection—and didn't impact airplane performance or structural life, the flight controls engineers were challenged to find a solution.

Vibration is not unusual. The very first 747 had vibration in its wing. The solution back in the late 1960s was to add structure, which also added weight. Today, these types of problems can be fixed with flight controls software adjustments, avoiding a weight gain that would affect performance of the airplane.

The effort was dubbed OAMS, or Outboard Aileron Modal Suppression. The core team that went to work on a fix consisted of Fitzgerald, John Forster, Brad Xanthopoulos and Chuong Tran.

"We thought we should be able to utilize the fly-by-wire on the ailerons on the ends of the wings to control the vibration," said autopilot engineer Forster. "We've got a more modern actuator out there attached to a new flight computer. There must be a solution using the ailerons to control it."

Added Xanthopoulos, Flight Controls engineer: "It was a unique solution. But the data showed that it was the better solution."

Tran, also a Flight Controls engineer, worked on the control law design team while on loan from the 787 program. "We saw that using the aileron was better. It became the only choice."

All involved were putting in long hours when the first upgrades to address the vibration issue went into flight computer software in the summer of 2010.

"I was amazed how many people came together in a short period of time and worked together selflessly to come up with a solution that worked," said Fitzgerald, who was recently named Commercial Airplanes Engineer of the Year for 2010. He credits his team and sees them sharing in the award.

Meanwhile, the 747-8 Freighter is nearing delivery to the first customer. Delivery of the passenger version, the Intercontinental, will follow once flight testing is completed.

Innovative engineering and programming make the 747-8 the most advanced 747 ever built. Challenges had to be overcome, but after much work it is the high-performance airplane its designers envisioned years ago. ■

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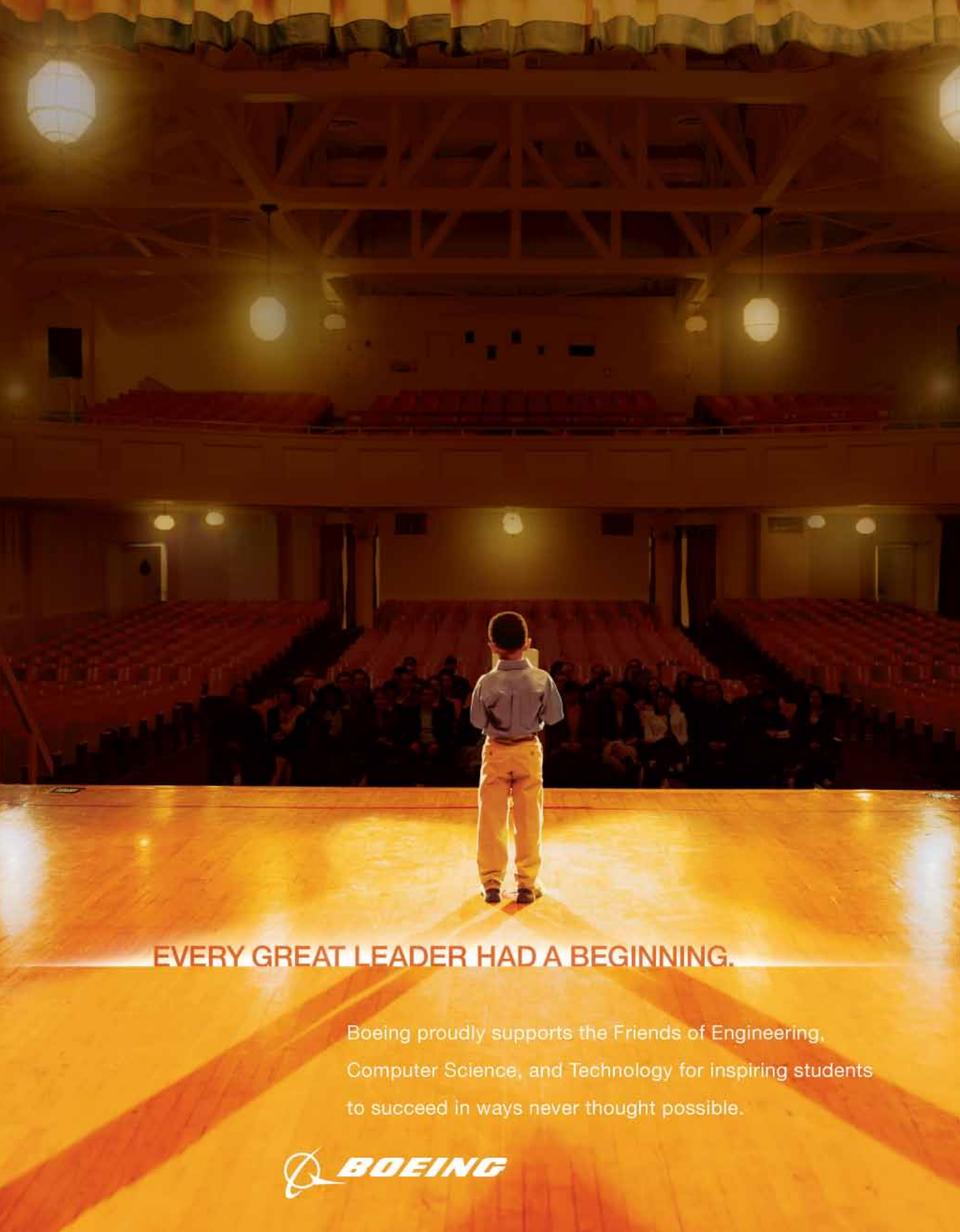
PHOTOS: (Above) The advanced flight deck of the 747-8 contains new technology, but it is similar enough to the 747-400 that pilots rated for that airplane can be rated for the 747-8 with minimal training. **BOEING**

(Below) Flight Controls engineers John Forster (from left), Pio Fitzgerald and Chuong Tran review flight-test data next to a flight control computer similar to that used on the 747-8. **ED TURNER/BOEING**

In Focus

HIGH PLAINS DREAMER

A 787 Dreamliner prepares to take off in late July from El Alto in western Bolivia, with Illimani Mountain in the background. The airplane was there performing high-altitude takeoffs. El Alto, near Bolivia's capital of La Paz, is one of the highest major cities in the world at an elevation of 13,325 feet (4,061 meters). The 787 program last month completed all flight tests required for type certification of the 787-8 Dreamliner with Rolls-Royce engines. PHOTO: LEO DEJILLAS/BOEING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Computer Science, and Technology for inspiring students
to succeed in ways never thought possible.
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