

Frontiers

Breaking barriers

Boeing, which turns 100 next July, has blazed trails in aerospace by proving it can be done





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BOEING 100 2016
A百年征程
A century of
achievement and
innovation

'IT CAN BE DONE' POSTER

This special issue features a poster highlighting just a few of the many Boeing and heritage company products that have marked pivotal moments in aviation and aerospace.

Visit boeing.com/frontiers/downloads for download options. Employees may visit 100.boeing.com for more information.

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Cover: A Boeing F/A-18 Super Hornet generates a "vapor cone" during a flyby near Ocean City, Md., in 2012. The phenomenon is caused by compression of moisture in the air during high-speed flight or tight turns in certain atmospheric conditions, such as when the air is humid, and the low pressure of airflow around the jet. **SHUTTERSTOCK** Photo (Far right): Jeff Lau, left, and Jeff Roach check clearances on a dynamic load fixture used to test next-generation electric flight control actuators. **BOB FERGUSON | BOEING**



The next 12 months will be exciting ones at Boeing as the company prepares to celebrate 100 years of aerospace leadership through innovation and daring that changed the world. It's also a time to look ahead to Boeing's second century and a global workforce and vision that will drive continued success. Inside this special issue is a pullout poster featuring a few of the trailblazing products from Boeing and its heritage companies that have transformed aerospace. One can only imagine what the next 100 years will bring.

100



Jim McNerney

Chairman

New leader, new century, enduring competitiveness

From a strong foundation, Boeing enters its centennial year poised to sustain a steady upward trajectory

Boeing enters its centennial year this month with new energy at the helm, exciting innovation in the pipeline and a renewed commitment to fuel the company's growth through ongoing productivity gains.

It's a great place to be. As you'll see in this issue, we have reached this point because the people of Boeing, past and present, have made a habit of breaking through—building a strong, integrated company to win in our highly competitive global markets.

Our new president and CEO, Dennis Muilenburg, possesses both an appreciation of our past accomplishments and the energy and skill to drive those yet to come. With his immense passion for our company, its employees and our customers, he is well-suited to lead Boeing into its second century.

Throughout the centennial observations, we will seek to draw inspiration from Bill Boeing, our other heritage founders and what our

predecessors collectively represent—a passion not only to build better airplanes but also to develop, improve and lead an entire aerospace industry that has innovation at its core.

As our own history reflects, for Boeing to thrive for another century:

- We must continue to operate with integrity, to live the Boeing values and develop and promote leaders who exemplify them.
- We must keep investing in innovation, new technologies and our people, while relentlessly pursuing first-time quality, productivity and workplace safety—not only to fuel and fund those investments but also to keep our people injury-free.
- We must sustain and nurture the breadth of our business—maintaining scale across defense, space and commercial airplanes (and the services to support them). This is a major advantage our competitors wish they had.

- Working as “One Boeing” must be the only way we work—collaborating across businesses and functions, sharing knowledge and expertise, and scaling up our innovation along with all the elements that support it. Nobody can beat us when we play as a team.
- And we must continue expanding internationally—building our global partnerships and footprint, and engaging with the best and brightest around the world.

Aerospace is not a business for the faint of heart; it's a business for people who believe in their mission, who persevere through ups and downs of large-scale innovation, market disruptions, and more—simply because they want to make the world better.

It has been my privilege to serve as CEO of Boeing for the past decade. It is a humbling and rewarding stewardship—built upon our founders' legacy and values, and the wonder and imagination inspired by the science of flight.

I am confident that Dennis—with the best employees in the world—will move Boeing across the 100-year threshold to a bright, prosperous and more competitive future. ■

Dennis Muilenburg

President and chief executive officer



What drives Dennis?

Dennis Muilenburg, president and newly named chief executive officer of Boeing, answers *Frontiers'* questions about what makes him tick

What motivates you?

My family, the customers and employees of this company, and the missions we support. I've spent my entire career at Boeing, and I want all of its stakeholders to be successful for the long haul.

You're known for very high energy. Do you expect everyone around you to match that?

I expect my team to out-perform the competition in all dimensions. Energy is part of the equation, but we also need people who can think very deeply, who can help us slow down or pause when need be. So I prefer my team consist of individuals who are different from me—with a diversity of personalities and styles and backgrounds.

With the stresses of running a big business, do you have any work-life balance?

It's all about striving for a well-balanced life—more a blending than a competition between the personal and the professional. I work a lot. Spending time with my wife and kids, staying fit, and participating in

community activities helps me manage stress. I invest my energy in ways that support my values and are mutually reinforcing. I set boundaries, prioritize my time and surround myself with a strong support network. Despite my best efforts, though, like many people, I occasionally struggle to find the right rhythm. That's when falling back on foundational values becomes even more important.

You have held leadership positions with a number of high-profile endeavors, some of which—like the Air Traffic Management business and the Future Combat Systems program—ended prematurely because of changes in the market or in the customer's strategy. What did you learn from them?

I've typically sought out tough assignments involving big technological or consensus-building challenges. Those don't always play out as planned, but you've got to go into it with the perspective that if you get it all right the first time, great; if it's not completely successful, you learn a lot that you can apply to the next

one. Taking on hard tasks builds your ability as a leader. Difficult challenges grow less intimidating the more you do them. You boost your capacity for handling and even leveraging complexity, for doing the kinds of big, global things that we do.

The company also benefits from what your team learns—often through the application of new technologies, capabilities or business models across other programs—even if your particular project or business doesn't pan out.

Do you plan to make any big changes at Boeing?

Thanks to the hard work of talented employees around the world—and as a result of Jim McNerney's leadership—our company today is financially strong and well-positioned in our markets. So we already have a solid foundation. Rather than make a radical shift, I'd like to see us deepen and broaden the approach we're already on, and accelerate where necessary—get everybody on board, engage and inspire our people, and focus even more on developing up-and-coming leaders. We must have the best team and talent, deliver world-class results, and position Boeing to lead in its second century. ■

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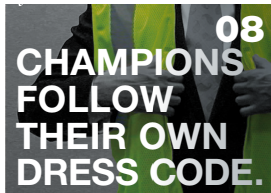
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ADVERTISEMENTS

The stories behind the ads in this issue.



This ad is part of a new campaign featuring Chinook, the world standard in heavy-lift rotorcraft. It is currently running in domestic and global trade publications.



Go for Zero—One Day at a Time is Boeing's effort to create a zero-injury workplace. This ad was derived from a video released as part of an employee safety event to help encourage conversations about taking action to reduce injuries.



"Shared Vision" is the first ad in a new Boeing Commercial Airplanes leadership advertising campaign designed to communicate the many ways Boeing airplanes and services enable opportunity and success for customers. The ads are running in trade publications and online.



This ad is the second of four that will launch in India as part of Boeing's new "Together. Building the Future" advertising campaign. It speaks to the industrial partnership with Boeing supplier TAL in building the spine for the 787-9 Dreamliner.

IAM PROMOTIONS

No promotions listed for periods ending May 29 and June 5, 12 and 19.

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FSC LOGO

THIS CONNECTED. ONLY CHINOOK.

MISSION:
INFILTRATION

The CH-47F Chinook is the world standard in heavy-lift rotorcraft, delivering unmatched multi-mission capability. More powerful than ever and featuring advanced flight controls and a fully integrated digital cockpit, the CH-47F performs under the most challenging conditions: high altitude, adverse weather, night or day. So whether the mission is transport of troops and equipment, special ops, search and rescue, or delivering disaster relief, there's only one that does it all. Only Chinook.

 **BOEING**



**CHAMPIONS
FOLLOW
THEIR OWN
DRESS CODE.**

**WE'RE ALL
CHAMPIONS
FOR SAFETY.**



GO4ZERO
One Day at a Time.

LEADERSHIP MESSAGE

Greg Hyslop

Vice president and general manager
Boeing Research & Technology



Journey of innovation

Boeing's second century, like its first, will be driven by the ingenuity, imagination and dedication of employees

The men and women of Boeing have created an inspiring legacy of innovation—one that has defended freedom for millions and propelled people across previously untraversed skies and beyond into space. Their innovation is what has driven Boeing to prosper for the past 100 years, and is the key to success in our second century.

As stewards of this history, it is our responsibility to build an even more inspiring future, and continue Bill Boeing's legacy of applying innovation to solve problems and change the world. One hundred years later, technology advances at ever-accelerating speeds, but the lesson of our founders still holds true: Our company's future depends on our ability to focus creativity and invention into practical and measurable value for our customers.

We face many challenges in our second century—increased competition, lower defense spending and customer demands for more capability at lower prices. These challenges compel us to find not

only technology that provides the capabilities our customers want but technology that will allow us to design, build and test these products and services in ways that are more innovative and effective.

Companies that thrive for the long term are those that can make a real difference for their customers through disciplined innovation that is focused on business impact. There is no tension between invention and business discipline when both are done right.

We expect that balance of innovation and disciplined execution in every Boeing program. We place that same priority on innovation and execution at Boeing Research & Technology (BR&T). As the company's core research and development organization, we strive to make every research dollar count. Our teams work alongside engineers in Commercial Airplanes and Defense, Space & Security as well as researchers around the world to scan and assess emerging technologies, ensuring we invest in and develop the right technologies to win in the market today and in the future. (See story, Page 16.)

We call our strategy for achieving this creative yet disciplined approach the "BR&T Way." It's a set of principles that guide how we think about our jobs and how we strive to be a trusted business partner. They include:

- **Be curious** – Ask the "why" questions and search out the hard problems.
- **Be creative** – Solving hard problems requires innovation. Innovative solutions may not be the most complex, and may be an intelligent use of existing technologies. Finding the most effective answer to a hard problem is always our goal.
- **Be courageous** – Courage can take the form of challenging old ways of thinking, being willing to stop work on a project that isn't working, or remaining committed to a project that has great potential for success and significant business impact.
- **Share what we know** – Imagine what can be accomplished if the collective knowledge and experiences of more than 160,000 Boeing employees were shared across the enterprise. "One Boeing" works and we are always better, together.

These principles can be applied by every Boeing employee. They outline the mindset of a team that is focused on our customers and winning in the marketplace. In fact, they reflect Mr. Boeing's belief that we can build something better.

We can only imagine the technology advances in Boeing's next 100 years. But we do know that achieving them will require every team member's ingenuity, imagination, drive, dedication and hard work to solve our customers' toughest problems. It is an exciting way to set the stage for our next century of business. ■

PHOTO: MARIAN LOCKHART | BOEING

SNAPSHOT

Victory role

A Boeing B-29 Superfortress performs a flyby of the Washington Monument in Washington, D.C., May 8, one of dozens of period airplanes passing in review to mark the 70th anniversary of the end of hostilities in Europe during World War II. Boeing started production of the B-29 in 1943, and nearly 4,000 were built. The world's heaviest production airplane at the time, the B-29 had innovative features including pressurized crew compartments for high-altitude flying and guns fired by remote control. Boeing and its heritage companies were well-represented in the Arsenal of Democracy flyover, with aircraft including the North American P-51 Mustang and B-25 Mitchell, the Boeing B-17 and Stearman Kaydet, and the Douglas C-47 Skytrain and SBD Dauntless. PHOTO: GETTY IMAGES





QUOTABLES

“When you get out the other end, you just do not feel ‘crumpled.’”

—Andrew Harrison, managing director at Stansted Airport in the United Kingdom, on how passengers say they feel more refreshed after trips on the 787 Dreamliner compared with other long-haul jetliners. Thompson Airways operates 787s out of the airport. *Cambridge News*, May 29

“Half-airplane, half-helicopter, totally badass.”

—Headline on how the Bell Boeing V-22 Osprey has become an indispensable vehicle for the U.S. military, playing critical roles in combat, support and humanitarian relief operations. *New York Post*, May 24

WHAT WE DO

Making a connection

For this IT employee, the real work isn't just performed on a computer

BY RYAN KIGGINS, AS TOLD TO LAUREN MCFARLAND

Ryan Kiggins is a systems and data analyst with Information Technology in Auburn, Wash. In this *Frontiers* series that profiles employees talking about their jobs, Kiggins explains why he enjoys leaving the office to go out on the factory floor with employees and help them find solutions to problems.

My goal is to spend as little time behind my desk as possible.

By walking the factory floor with employees who rely on our IT solutions, I find that we are able to help them identify waste, see ways to improve what they are doing, and create positive relationships that make coming to work fun and exciting. I also want my customers to feel like IT is doing things with and for them, instead of doing things to them.

Most people know what the experience of getting on a commercial airplane is like, but getting out on the floor and seeing airplanes being assembled is truly jaw-dropping; it never gets old. The sheer size and complexity of what we do as a company is energizing. What I try to focus on every day is helping the people who are creating and delivering our amazing products.

I work with people from all parts of Boeing—such as Boeing Fabrication and the company's product and services programs—to translate what they need into solutions that make their work lives better. People come to me with a problem of some type, and I will go out and meet with them, and find and deliver an IT process or solution.

Earlier this year, for example, I received a call from a senior manager on the 767 tanker program. He'd previously used a software tool from my group that helped manage and track kits on the 787, and he was looking for a similar solution for the new 767 line, which builds both the 767-300 Freighter and the 767-2C, the platform for the new KC-46A tanker.

I met his team in Everett, walked the floor and identified a solution for helping them manage their inventory. With slight modifications to an existing tool, we implemented a solution to the program in just 35 calendar days. It already has saved the 767 program more than 2,300 labor hours.

In my opinion, this is the single most important aspect of software development—understanding the actual problem that needs to be solved. In many cases, the real problem ends up being different from what the person needing help described or understood. Then it's my job to define the customer's requirements in a way that they can understand.

IT solutions are critical to automating our factories so we can support new airplane programs and achieve our goals to increase production rates by helping the folks building the airplanes do so faster and safer, and with better quality. ■

LAUREN.E.MCFARLAND@BOEING.COM





Ryan Kiggins

HAS WORKED FOR BOEING:
16 years

TEAM:
IT Product Systems

LOCATION:
Auburn, Wash.

PHOTO: GAIL HANUSA | BOEING

A night view from an airplane window. The window frame is visible in the foreground, framing a view of an airport runway at night. The runway is illuminated with a series of lights, including a prominent yellow light streak that curves across the scene. The background shows a dark sky and distant mountains.

**FROM SHARED VISION TO SHARED
A BETTER WAY TO FLY.**

VALUE

Built into every Boeing airplane is a relationship that transcends route maps and data points. It's a personal commitment to share your vision and understand your business like no one else can. A commitment that continually delivers products, technologies and services that create bigger opportunities for you today and tomorrow. It's a nonstop commitment to superior value. That's a better way to fly.





MISSOURI:

Here BR&T specializes in systems technology; digital aviation and support technology; rate-independent production; metallics and fabrication development; next-generation materials.

SOUTH CAROLINA:

BR&T's work here includes advanced manufacturing technology; composite fuselage/propulsion production.

EUROPE:

Areas of focus for BR&T here include environmental; safety; air traffic management; unmanned aircraft systems.

WASHINGTON:

Here BR&T works on manufacturing technology integration; composite wing manufacturing.

BRAZIL:

BR&T's focus here is on biofuels; air traffic management; metals and biomaterials; support and services.

CALIFORNIA:

BR&T's work here includes flight sciences; electronics and networked systems; structures; automated assembly; extreme environments.

ALABAMA:

Here BR&T focuses on simulation and decision analytics; metals and chemical technology.

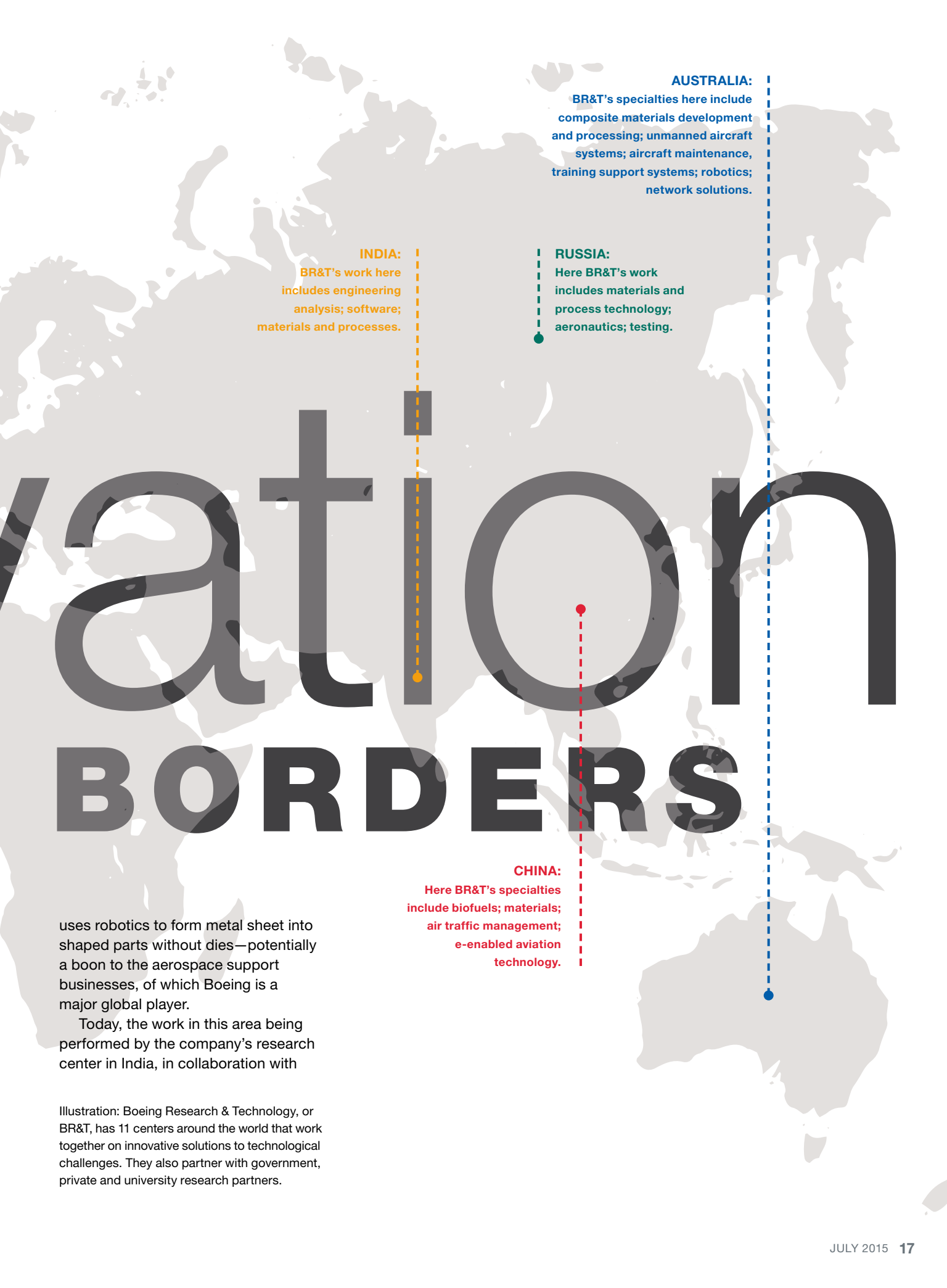
Innovate Across

Boeing's 11 global research centers work together to drive innovative solutions

BY KATHERINE ZEMTSEFF

When Om Prakash began working at Boeing Research & Technology-India in 2009, part of his job was to connect promising new technologies and the rest of Boeing.

One thing that immediately drew his interest was a technology called incremental sheet forming, which



AUSTRALIA:

BR&T's specialties here include composite materials development and processing; unmanned aircraft systems; aircraft maintenance, training support systems; robotics; network solutions.

INDIA:

BR&T's work here includes engineering analysis; software; materials and processes.

RUSSIA:

Here BR&T's work includes materials and process technology; aeronautics; testing.

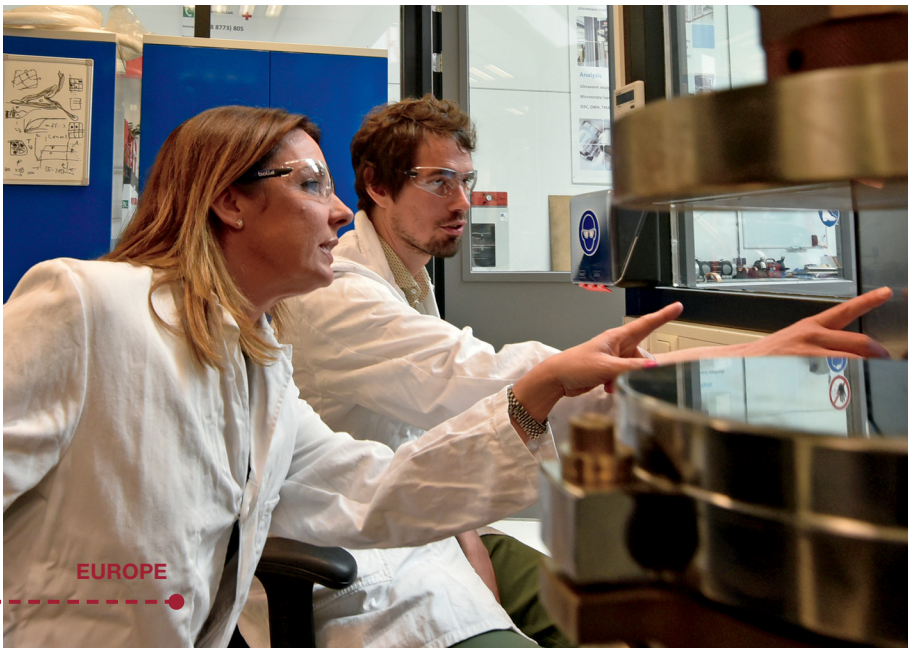
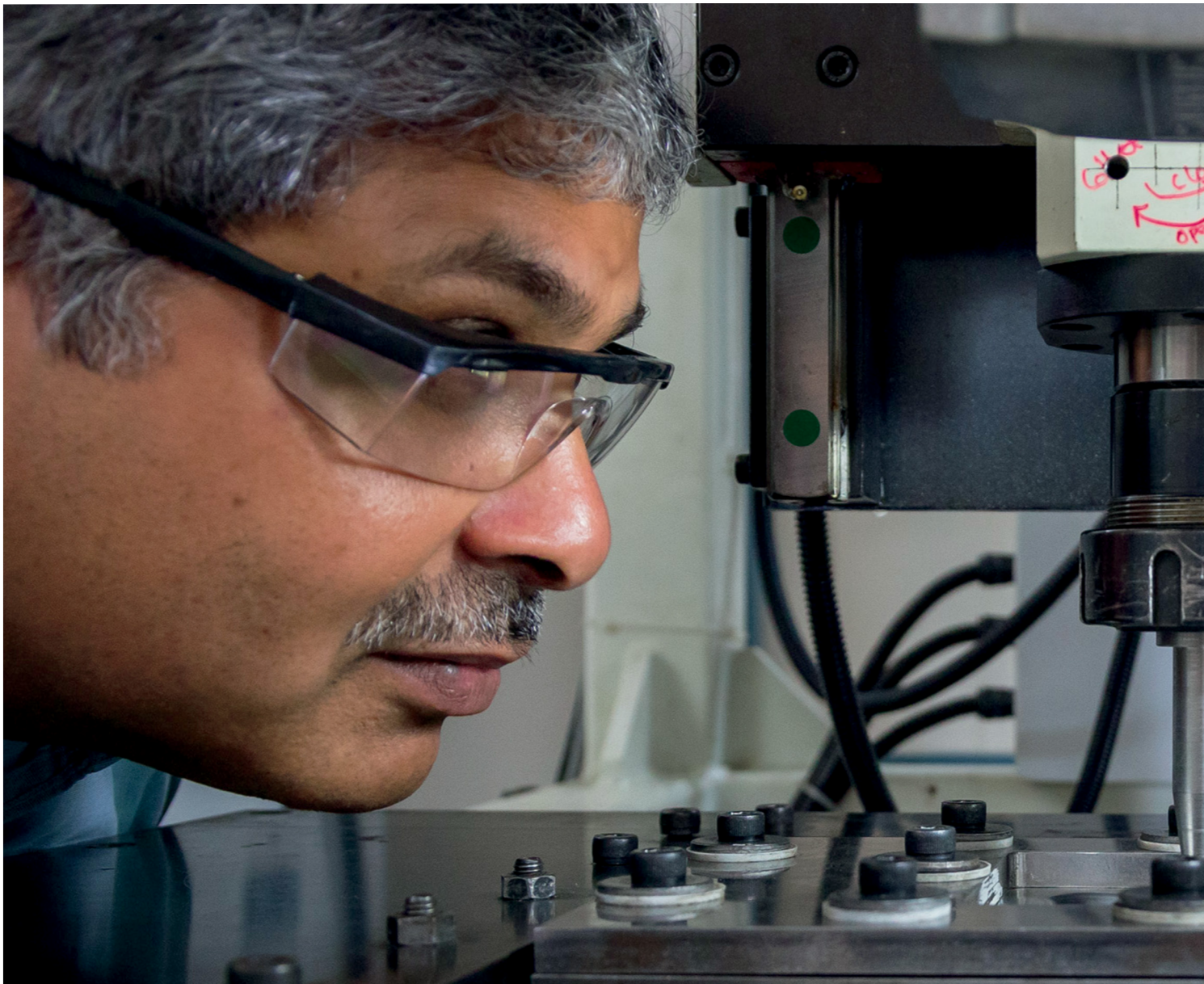
CHINA:

Here BR&T's specialties include biofuels; materials; air traffic management; e-enabled aviation technology.

uses robotics to form metal sheet into shaped parts without dies—potentially a boon to the aerospace support businesses, of which Boeing is a major global player.

Today, the work in this area being performed by the company's research center in India, in collaboration with

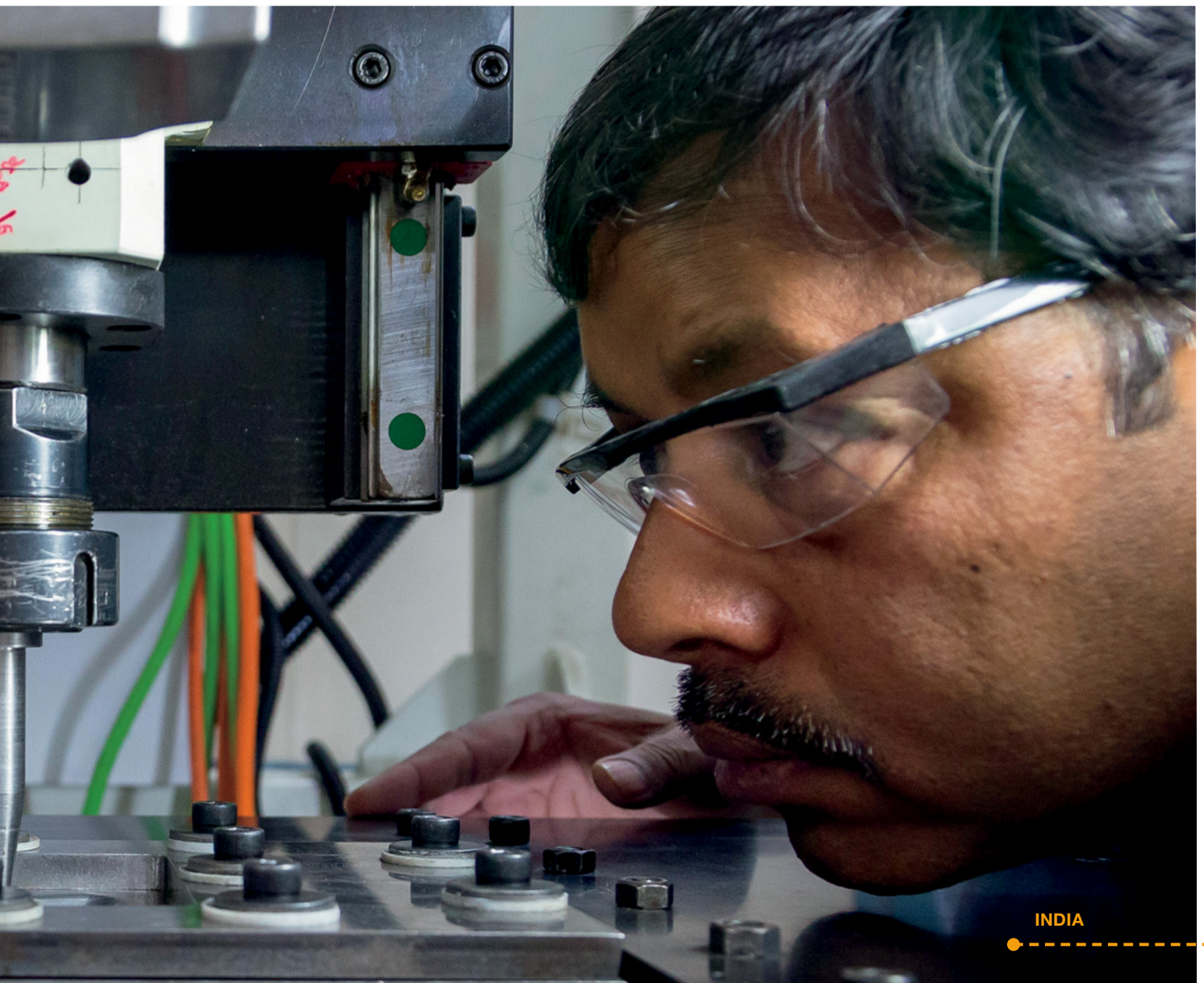
Illustration: Boeing Research & Technology, or BR&T, has 11 centers around the world that work together on innovative solutions to technological challenges. They also partner with government, private and university research partners.



the Indian Institute of Technology, is part of a worldwide approach that is coordinated with partners in the United States and with Boeing's research and technology center in Australia.

"I love this technology, and its potential," Prakash said. "What I saw was a promising academic exercise, but it wasn't really exactly what we needed. Once we started a formal effort, we were able to shape the research to create something that could be tremendously beneficial."

Boeing Research & Technology-India is one of 11 global company research centers that work together to drive innovative solutions. These facilities support Boeing's international



INDIA

approach to research and global talent development, bringing together technical expertise from around the world to solve technological challenges—and ultimately to make Boeing more competitive, said Bill Lyons, director of Global Research and Development Strategy for Boeing Research & Technology.

“If you want products and services to excel, you have to involve others, and you have to embrace diversity of thought and culture,” Lyons said. “For us to be successful in the next century we need to explore the talent, development and ideas that come from across the globe.”

The research centers are in five U.S.

states and six international sites. Each has different specialties and develops relationships with partners, such as universities. Researchers at each center are responsible for identifying what the technologies of the future could be—as far as 30 years out.

One of these technologies is incremental sheet forming.

Generally, to create a metal part for a product, a die is formed in the shape of the part. Metal is molded around the die. This works well for an aircraft in production, but not necessarily for parts that are rare or old. Stored parts take up valuable space in warehouses and may be located in another part of the world from where they are needed.

If a part cannot be located, the die must be found to make a new one. And making a new die is an expensive task. Ultimately, these issues delay an aircraft's return to service.

With incremental sheet forming, instead of using a die a sheet of metal is carefully held along the edges, as two pointed styli apply pressure from either

Photos: (Above) Professor N. Venkata Reddy, left, of the Indian Institute of Technology–Hyderabad and Om Prakash of Boeing examine a thermoplastic system. (Far left) Nieves Lapeña-Rey, left, and Wouter Groeve, deputy chief technology officer of the Thermoplastics Composite Research Center, perform mechanical tests. **ASSOCIATED PRESS**



MISSOURI

side of the sheet to create a shape.

The technology is promising because it could save time, allow parts to be created wherever a machine exists and remove the need to store parts. That's why it has piqued the interest of Boeing teams that work to support customer aircraft.

"The international research centers are very good for finding technologies that aren't being used in the United States and they're good at potentially

transitioning technologies to local organizations," said Kevin Slattery, chief scientist for metals, ceramics and mechanical parts with Boeing Research & Technology.

Until recently, Slattery was chief engineer of the Integrated Logistics team in Global Services & Support, part of Defense, Space & Security. Because the company's services and support business needs spare parts to help maintain older aircraft, incremental

sheet forming technology could be of significant value, Slattery noted.

For Bala Bharadvaj, leader of Boeing Research & Technology-India, the collaborative work being done there in developing this technology underscores the importance of the company's global research centers. The one in India, he said, is good for Boeing and good for India.

"There is an opportunity here to be stronger and to truly be a global citizen, leveraging strengths in different parts of the world," Bharadvaj said.



MISSOURI

Boeing has had a global presence for decades. But it had not fully tapped into technological research capabilities outside the U.S. before establishing a technology and research center in Europe in 2002, Lyons said. The center, he added, became the pathfinder for the five subsequent international research centers, and helped Boeing learn how to integrate a global team.

The strength of Boeing Research & Technology–Europe is the way it provides support to the rest of Boeing while bringing the unique experience

and strength in Europe to the table, said José Enrique Roman, leader of the European center. Those at the center are working on technologies at locations across Europe, from Spain to Germany to Poland. The 54 people at the center represent 12 nationalities and collectively speak 12 languages, Roman said.

One of those employees is Nieves Lapeña-Rey, senior technical manager of the materials and fuel cells team. She joined the European center the year it was founded and has led more than 14 projects, including a recent

one that involves partnering with the Thermoplastics Composite Research Center in the Netherlands.

Thermoplastic composites

Photos: (From far left) Jeff Roach, foreground, and Jeff Lau verify assembly of a dynamic load fixture used to test next-generation electric flight control actuators; Rich Belcke, foreground, and Jeff Lau verify the conditions and settings of electrical load and power distribution equipment used to test high-voltage direct current power systems. **BOB FERGUSON | BOEING**



are a lightweight material that's environmentally progressive, Lapeña-Rey said, explaining that thermoplastics create far less scrap during production, have virtually an infinite shelf life, and can be welded, which eliminates fasteners and allows for automating the manufacturing process. They also offer damage tolerance, reducing the total weight of the assembly.

The collaboration and partnership between Boeing's research center in Europe and the composite center in the Netherlands is supported by the Composites team at Boeing's research and technology center in St. Louis. The team is working on defining the optimal conditions such as temperature and curing time for producing high-quality thermoplastic aircraft components.

Boeing's center in Australia also is doing research on other areas of lightweight aerospace composites. The Boeing Research & Technology teams in the United States, Australia and Europe all are working together to make the most out of the synergies across their various research portfolios.

"Working globally and having different teams work on a project is an advantage because there is never only one solution to a problem," Lapeña-Rey said.

At the same time, Lapeña-Rey also is leading a project with nonprofit research institute IMDEA Materials in Spain, focusing on developing new

quick-cure thermoset resin chemistries for the production of composite aircraft parts made quickly and affordably without an autoclave. It's the type of innovation that will help drive Boeing's success and industry leadership in its second century, she said.

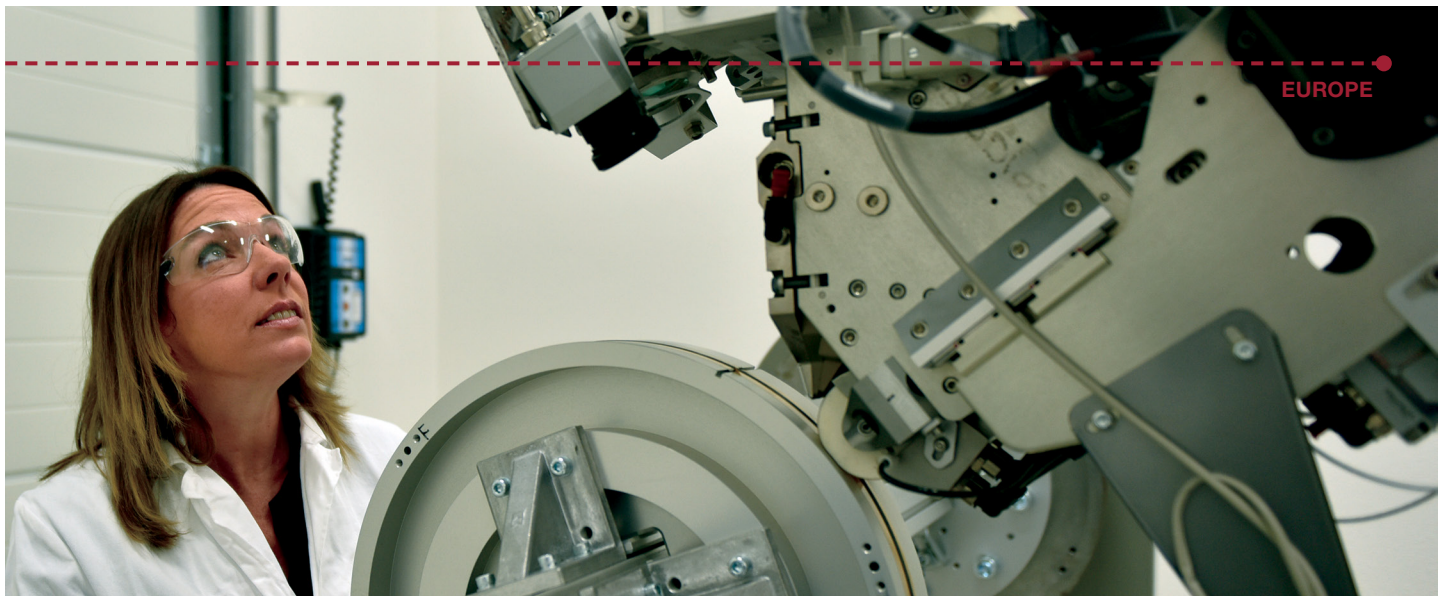
"If we are successful, this could go straight into a program," Lapeña-Rey said. "Whoever gets there quickest, it's a competitive advantage."

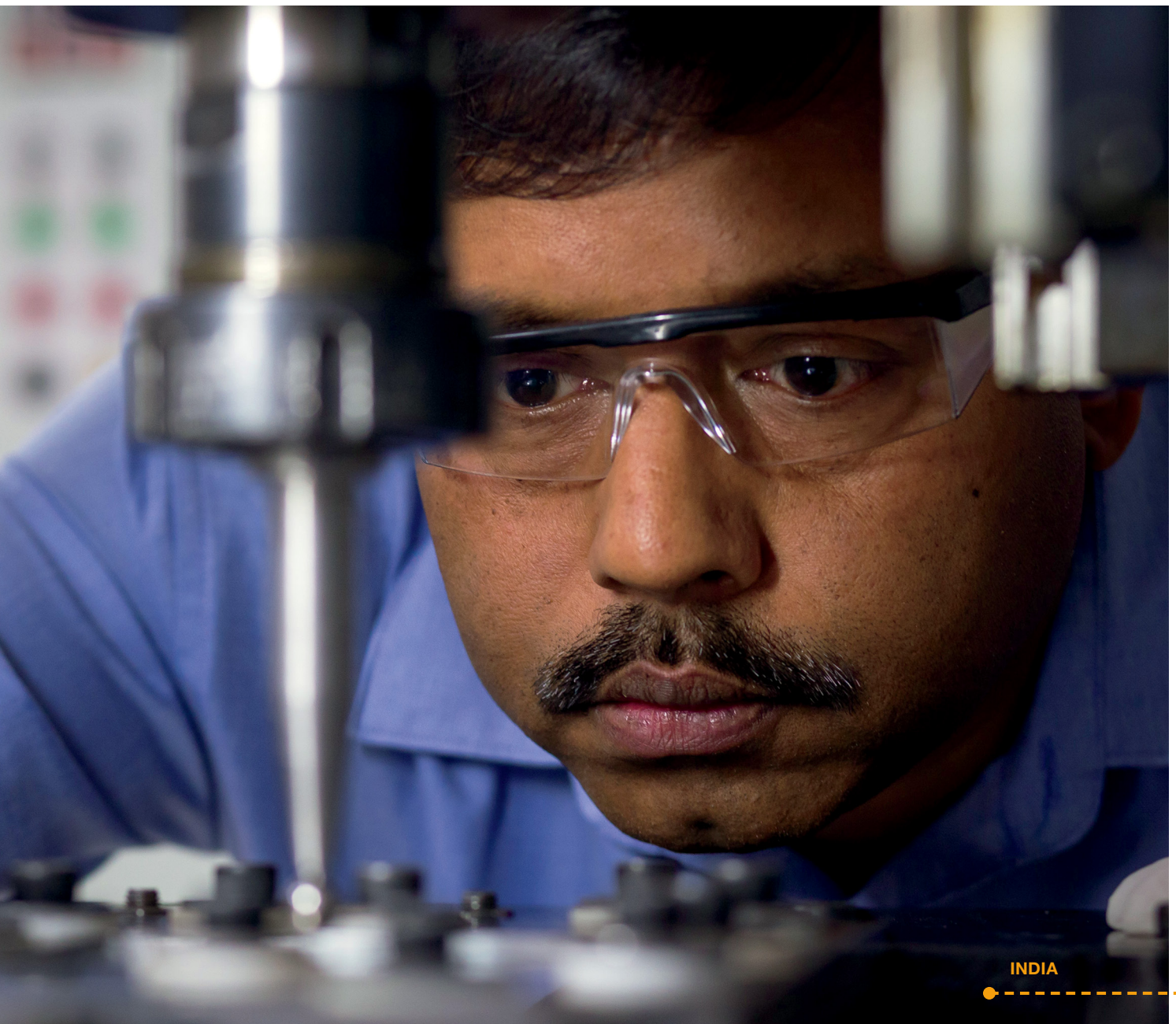
But "quick" for Lapeña-Rey is glacial speed for Jeff Roach and his quest to give Boeing another competitive advantage. He's measuring time in thousandths of a second.

Roach works at Boeing's research and technology center in St. Louis, where he's chief engineer of the Integrated Vehicle Energy Technology program at the Facility for Integration and Research of Subsystems Technologies.

As part of the Integrated Vehicle Energy Technology team, Roach improves the energy optimization for next-generation aircraft. The lab examines electrical power and actuation system testing. It collaborates with partners such as the Air Force Research Laboratory and shares results with the rest of Boeing Research & Technology, as well as throughout Boeing.

Today's aircraft have three to five times the heat load of older aircraft,





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increased secondary power demands for flight controls and more electric-powered systems than ever, Roach explained. As a result, loads can change dramatically in thousandths of a second. Energy systems must be able to handle the fluctuations quickly and effectively. Roach and his team figure out how to balance all these competing systems.

“Every time we make things smaller, we make them hotter. Everything is a trade-off between thermal and energy,” Roach said. “If we can prove this out, it will have a huge effect on the next-generation electric airplane.”

It’s but one example of the research

and innovation by Boeing that is taking place each day around the world, at the company’s research and technology centers, and with various partners. In all, the centers are involved in more than 340 ongoing projects, with more than 380 global partners.

These worldwide relationships and partnerships, and the ability to collaborate across borders, will help make Boeing stronger and more nimble, and ensure future success, Lyons said.

“Aerospace is one of those things that everybody wants to be a part of,” Lyons said. “We don’t have the answer to every problem. This century of aerospace

will open just as many frontiers as the last one did, but we now have even stronger imperatives of productivity and environmental sustainability. And diversity in thought, culture and ways of doing things is incredibly important in solving future challenges and realizing opportunities.” ■

KATHERINE.A.ZEMTSEFF@BOEING.COM

Photos: (Above) Om Prakash examines a thermoplastic system. (Far left) Nieves Lapeña-Rey performs mechanical tests using a fiber-placement machine. **ASSOCIATED PRESS**



THE VALUE of HISTORY

The Boeing Store's innovative offerings tap a huge market for company-branded items and aerospace nostalgia

BY DAN RALEY | PHOTOS BY BOB FERGUSON

Gerardo Mores, buyer and product developer for The Boeing Store, was on a business trip like no other in late 2013. He stood in a darkened, run-down warehouse in Tampa, Fla., huddled with others around a shipping crate held together by rusted screws, ready to inspect the contents.

"We opened up that crate," Mores recalled, "and it was like something out of *Raiders of the Lost Ark*."

Inside were six B-17 propeller blades produced for World War II, somehow undisturbed for more than seven decades. Paperwork, tucked in a leather packing slip, was dated 1941. Indiana Jones would have been in awe—this was the ultimate time capsule.


As Boeing readies for its 2016 centennial celebration, and employees and airplane enthusiasts express a

strong desire to acquire something unforgettable to commemorate the major milestone, the company is using innovative and investigative means to meet demand.

Mores and others have followed leads around the country to see what kind of iconic airplane parts can be retrieved, refurbished and resold. They've searched desert airfields, aircraft demolition and recycling companies, private collections, and even eBay for historical treasures. They've come back with passenger windows, wing flaps, rudder pedals, instrument panels, yokes, seats and more.

Testing this admittedly high-end market, The Boeing Store offered up 50 windows plied from a retired 747-100 jumbo jet, each bordered by a couple inches of buffed fuselage, signed by legendary design engineer Joe Sutter and priced at \$695. The vintage window supply was expected

Photo: Gerardo Mores of The Boeing Store inspects a 747 engine part, a Pratt & Whitney turbine ring, which will be refurbished and sold as a centennial gift.



to last three to six months. It was gone in three days.

Some employees have found they can't resist these repurposed artifacts, available through the company's Custom Hangar online storefront or Boeing Store's many factory outlets. Paul Hazzard, a 737 MAX project engineer, was given a 737 window by his wife. Hazzard discovered he had worked on the actual airplane, making the keepsake even more personal.

"To see it come back at the other end of my career, it meant a lot," Hazzard said of the window. "I could reunite with my past a little bit and acknowledge we did some good work."

The Boeing Store also will have more affordable centennial commemorative items for purchase, such as coins, coffee mugs, USB drives, tumblers and T-shirts, all of which cost \$26 or less.

Finding and selling classic airplane parts is only part of the store's centennial merchandising effort. Creating new keepsakes has turned into a steady business practice, with Boeing forming partnerships with leading companies worldwide to license and produce heirloom items that salute its 100 years of aerospace history.

"All of this stuff comes down to meaning," said Jim Newcomb, director of Brand & Digital Strategy. "Our hope for people who love Boeing is this will have a deep authenticity, and they'll find it inspirational."

Among the newly minted centennial collectibles are watches manufactured in England by boutique watchmaker Bremont, using aviation metals; classic flight jackets crafted by New Jersey apparel company Schott NYC, which created the first leather motorcycle jacket in 1928; aviator sunglasses issued by French company Groupe Logo, worn and critiqued by Boeing test pilots; and teddy bears inspired by company founder Bill Boeing and made by German company Steiff, which

Photo: Evan Rydinski, a fabricator for Decorative Metal Arts in Seattle, refinishes a North American F-86 Sabre jet nose cowling into a Boeing centennial keepsake.



invented the toy bear in 1902.

Bremont drew industry attention when it produced 251 aviation watches from actual parts from the P-51 Mustang, a renowned World War II fighter designed and built by North American Aviation, a Boeing heritage company. The watches were considered so different that savvy collectors quickly bought out the store. The London watchmaker followed that model with the launch of its 1903 Wright's Flyer watch, which is constructed incorporating pieces of fabric from Orville and Wilbur Wright's first airplane.

Boeing asked Bremont for something similar in a timepiece commemorating the company's legacy. To help this idea along, Boeing introduced the watchmaker to the Advanced Manufacturing Research Centre, a metallurgical research organization Boeing co-founded with Sheffield University in the United Kingdom. Bremont used metal developed at the center—material stronger than stainless steel, scratch-resistant and found in the landing gear of Boeing's F/A-18 jet fighter—to create a pair of limited-edition watches: the B&W, named for original company partners Boeing and George Conrad Westervelt; and the 247, honoring the model number of the world's first

modern airliner, the Boeing 247.

The watches are high-end and priced accordingly: One costs \$5,450, the other \$6,750. Boeing employees will receive a 20 percent discount.

Bremont co-founder Nick English recalled: "That's what's nice about working with Boeing; they get what we try to do. These are not cheap watches. They are beautifully engineered and will be passed down from generation to generation."

Schott has produced flight jackets honoring three military aircraft: the Boeing B-17 bomber, the P-51 Mustang and the F-4 Phantom from McDonnell Douglas, another Boeing heritage company. Each carries a commemorative patch. Handmade out of sheepskin, goatskin or cowhide, the jackets will retail from \$749 to \$1,149. Schott was one of the original wartime producers of the flight jacket, guaranteeing an authentic look.

Steiff, a 135-year-old company, has produced three different styles of teddy bear with a likeness to Bill Boeing. A limited edition of 100 22-inch (56-centimeter) bears, made with mohair and showing the company founder wearing glasses and a flight suit and carrying a mailbag, will retail for \$1,895. A smaller, less-detailed version will cost \$365, and an even smaller bear yet will go for \$59.50.

"It's a very customized and unique

item," said Jim Pitocco, Steiff president.

As for sunglasses, 18 Boeing test pilots agreed to have eye exams and wear several different pairs of test sunglasses for six months in 2011 and provide feedback. Four years later, Groupe Logo has released a signature Boeing pair that reduces overall glare yet doesn't obscure the view of flight-deck instrumentation, especially electronic display screens. The sunglasses retail from \$250 to \$490.

"The younger guys seemed to enjoy them and thought they were comfortable and still wear them," Boeing chief test pilot Chuck Killberg said. "They're competitively stylish."

There is no end to the potential for Boeing-branded high-end nostalgia. Across from Boeing Field in Seattle, unique items fill a third-floor conference room, each polished or repainted in an elegant manner, as the company decides what to pursue next. At the center of this impressive collection is a 747 wing-flap table, a refurbished wing section covered

Photos: (Below) English watchmaker Bremont has produced the limited-edition B&W for Boeing, named for original company partners Bill Boeing and George Conrad Westervelt. **BREMONT** (Right) This keepsake lamp was created from the combustion chamber of a Pratt & Whitney JT8 engine on the 727 jetliner.










by a glass surface that would seat perhaps a dozen people. It's for display only, but similar tables will cost \$35,000.

However, a nearby coffee table created from a 727 fuselage section with American flag livery is available for \$15,000. A blade-like stator from a jet engine, with a clock or mirror attached, is priced around \$1,900. Flight-deck instruments cost from \$1,500 to \$1,800. A 737 rudder pedal pushes the \$1,500 mark. A B-29 artificial horizon indicator is valued at \$950. Passenger windows removed from 727, 737, 747 and 767 airliners are Boeing's best-selling vintage items. They cost \$595 each. The Boeing Store keeps hundreds of windows stored in a warehouse in Tukwila, Wash.

Newer military aircraft parts are the most difficult to find. Since the terror attacks of 9/11, U.S. service branches have been under orders to destroy retired aviation equipment and components to keep them from making their way into the wrong hands, Mores said. Of the older stuff, Boeing still can provide a jet-fighter ejection seat, a P-51 control stick or even one of those B-17 prop blades uncovered in Florida.

All told, the store's vintage aircraft parts line has become so popular the company intends to keep mining them, and investigating new markets to tap, well after the centennial celebration has come and gone, according to Newcomb. Emotional connection is durable.

"This is Boeing, beginning to end," Mores said. "We produce the plane and even in its afterlife there's still value to its parts. It doesn't go away." 

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To see the collection of centennial-related merchandise available from The Boeing Store, visit boeingstore.com.

Photo: From left, Heather MacCoy, Kevin Debell, Jody Callan, Trent Henderson and Gerardo Mores of The Boeing Store are seated at a table made from a 747 wing, surrounded by other unique commemorative gifts.

Ever

As the 737 MAX begins to take shape, its production system advances, too

BY ERIC FETTERS-WALP | PHOTOS BY BOB FERGUSON

This is the second in a series on advanced manufacturing technology and the tools and processes designed to help employees make Commercial Airplanes products in a safer and more efficient and productive way, with more consistent quality.

Boeing has produced ever-advancing versions of its best-selling 737 for decades at its Renton, Wash., site, which has been transformed into the world's most productive commercial airplane factory.

And just as the 737 has advanced technologically, the production and assembly system has become smarter, safer and faster.

Now, as production of the 737 MAX begins, the Renton site is pushing again into the future, adding new technologies and practices to build its most advanced single-aisle airplane. While the automated Panel Assembly Line is the centerpiece of the transformation, other innovative changes and improvements are taking place in the day-to-day processes that

Photo: Kevin Petersen, a motive equipment operator, drives a specialized truck that delivers parts from the central Materials Marketplace to the final assembly line in Renton, Wash.



flow



drive life on the factory floor.

Among these is the new Materials Marketplace, which is streamlining how parts get to the final assembly line. Previously, parts would enter the factory from a number of warehousing and delivery areas and stack up next to the airplanes. Now parts are flowing to airplane mechanics as needed, from a central storehouse at the Renton site.

“It’s about being competitive on the 737 program and maximizing our supply-chain efficiency, as well as our space,” said Brigitte Woodard, director of Materials Management for the 737 program.

Without significantly adding to its space, the Renton site is now producing 42 737s a month on two final assembly lines. With the introduction of a third final assembly line this year, that rate will begin ramping up toward 52 a month. Only 10 years ago, the site was producing 21 airplanes a month.

The increased pace has made the final assembly area a busier place, where the presence of extra parts and people can create space and safety issues, said Carla Bowman, senior manager of Materials Management for the 737. At the same time, making parts available as they are needed is important to keeping the production lines running on schedule.

“We’re working a lot more collaboratively and communicating more with the supply base and employees to get them what they need when they need it,” Bowman said. “We know we need to deliver, the first time, what the airplane line needs.”

Doing that requires more standardized processes, more “kitting”—putting together all the pieces that a production mechanic needs to do his or her task—and more hands-on management of how and when parts come from Renton’s suppliers.

Technology also will play a role. For example, as parts enter the Materials Marketplace warehouse, radio-frequency identification (RFID) tags alert scanners at the doorway of the parts’ arrival. The RFID tags aren’t universally used at the facility, but “we’re starting very heavily down that path right now,” Bowman said. Similarly, QR codes—sometimes referred to as



“two-dimensional” bar codes or Quick Response Codes—are being considered to keep track of parts and production kits.

These advanced manufacturing technologies can help track the flow of parts as the Materials Marketplace employees try to perfect the system. It’s a big job. Right now, in an average 24-hour period, the warehouse receives about 2,300 items. If that sounds like a lot, it is, confirms Fred Frank, who leads the receiving team at the Materials Marketplace. “The volume of stuff is just huge,” Frank said.

The goal is to calibrate just-in-time delivery from suppliers so that no more than 1.5 days of inventory, in most cases, is moving through the warehouse. It’s a change in strategy from the past, Frank admitted, but he sees the purpose. “Once we start doing more kitting and getting our inventory down to what we need, I think it will be easier for everyone to understand why we’re doing this.”





After parts are received at the site's Materials Marketplace warehouse and marshaling yard, they are organized and prepared for delivery to the precise spots they are needed in the factory and on the production line. New, low-sided vehicles and trailers that are easier to load and unload then deliver the parts and kits to the factory at regular intervals. Once the process is more routine, Woodard said, automated vehicles could make the deliveries.

Deliveries are made as often as every two hours for a continuous flow of parts to the production lines, which reduces the need to stage supply carts and other pieces alongside the airplane for long periods of time.

The shift to the Materials Marketplace approach launched at the end of 2014, so it's still a work in progress, Woodard said. In the first few months, employees have identified and worked through challenges to implementing the new supply strategy.

Kerry Snell, a first-line manager in the Materials Marketplace, said there have been some bumps in the road, but that was expected.

So far, there are early indications that the new system is working, according to Snell, but more work is ahead.

The changes to streamline inventory management have enabled employees to transfer to other jobs at the Renton site, Snell added, but no employee reductions. The aim is to have people working safer and more productively through new processes and technology that support record production rates and improve quality, not to reduce jobs.

Shelley Phillips, a Lean+ practitioner for 737 Materials Management, said she and others in the program already have seen a "culture shift" as employees have started embracing the new system. She added that employees also have been willing to point out where improvements could be made or when things don't go as smoothly as hoped.

"It's not a culture where anyone will get beat up over it. It's about moving forward," Shelley said.

While Renton works to have the new processes and better flow of inventory and parts to the factory floor fully in place by the year's end, the Everett and South Carolina sites have begun planning to change their materials management processes in the same way Renton has, Woodard noted.

Meanwhile, even after decades of improving commercial airplane production in Renton, the site continues to evolve.

"Change is no longer an event around here," Woodard said. "It's what we do every day." ■

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To read more about advanced manufacturing, see the May 2015 issue of *Frontiers*.



Photos: (Clockwise from top) Lavis Hawkins, a material processor requirements facilitator with 737 Materials Management, works in Renton's new centralized parts warehouse; Lourdes "Liz" Hathaway of 737 Materials Management checks inventory in the Materials Marketplace facility in Renton; Frank Hoffman, left, and Marc Johnson, both of 737 Materials Management, help manage the flow of parts through the Materials Marketplace.



Changing the world

New book tells Boeing's history with compelling stories and photographs

BY DAN RALEY

*H*igher: 100 Years of Boeing is more than a book; it's a hardbound, coffee-table-size museum.

Through rarely seen photographs pulled from Boeing's archival treasure trove, readers come face to face with company founder Bill Boeing riding a turn-of-the-century steamer to Washington state; women factory workers in Seattle responding to the

urgent aviation needs of World War II; legendary test pilot Tex Johnston reclining in a chair, trademark cowboy boots planted firmly on a desk; and countless other iconic scenes presented on full pages.

Author Russ Banham guides readers through the unforgettable imagery with a compelling narrative, providing one of the most comprehensive accounts yet of how the world's largest aerospace company was founded and how it flourished. Banham's words and the company photos come together much like wings and a fuselage.




tucked in a slip cover and will sell for \$49 in The Boeing Store (commercial outlets will sell a 192-page version). In preparing the book, he worked in concert with filmmakers preparing a documentary on Boeing's centennial. The author said he was struck by the devotion to the job by the assembly-line workers, people who declared rather pointedly that the specific section of airplane they worked on, whether it was the flight deck or a wing, belonged to them.

"That told me about pride of ownership," Banham said. "To be engaged with thousands of others in the manufacturing of something so extraordinary, and not just mechanically and technologically, it serves a purpose. They're not just building a machine that's going to be cut from metal; this was important for humankind, for global economics."

In combing through Boeing's 10 decades, Banham said two industry-shaping events stood out

to him as a writer: Boeing's postwar discovery of German swept-wing research and the subsequent pioneering development of the revolutionary Boeing B-47 bomber; and the selling of the 747 jumbo jet to Pan American Airlines, even with the airline's founder and leader, Juan Trippe, dubious over the design.

Banham recounts how Boeing engineers brought rope to a large conference room and stretched it out to show the width of the 747, a ploy that won over Trippe and the others.

"I can see that period—it's like *Mad Men*," Banham said, referring to the fictional TV show. "It's got that promotional quality to it. I loved that story because I can see those guys in their '60s-era suits and '60s-era haircuts, with their marvelous idea of 'how we're going to sell them on this,' and they did." 

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Banham is an accomplished storyteller from Los Angeles who found ample inspiration in sizing up Boeing's worldwide impact and beyond, whether through the company's commercial travel inroads, collaboration in outer space exploration or other technological advances.

"The importance of Boeing on global culture is what appealed to me," he said. "Few companies can say, 'We changed the world in which we live.' Boeing can say that."

Banham's Boeing book is his 24th; many of his previous books are histories of major American companies, among them *The Ford Century* and *Coors: A Rocky Mountain Legend*. He's a respected former business journalist whose work has appeared in *The Journal of Commerce*, *The Wall Street Journal*, *The Economist* and *Forbes*, among other publications.

Banham needed eight months to research and write the 256-page custom edition of *Higher*, which comes



TRAILBLAZERS

Living the dream

Brien Wygle and other Boeing test pilots helped usher in the jet age—and lessons learned are still used today

BY DAN RALEY

As Boeing approaches the start of its second century in July 2016, *Frontiers* takes a look at some of the men and women who helped make Boeing a global leader in aerospace. This series highlights the innovation, skill and courage needed when daring to do the impossible.

Brien Wygle won't forget the first time he saw an airplane up close—it landed in his backyard.

Wygle grew up during the Great Depression on a Canadian wheat farm, north of Calgary, Alberta, and plane sightings in the remote setting were rare. Whenever one flew overhead, Wygle and his two brothers stopped whatever they were doing and watched until it disappeared from view.

They were more than a little astonished when a de Havilland Tiger Moth, an early-day biplane, touched down on the family acreage. The pilot explained he had an oil leak.

"It was an exciting experience," Wygle recalled in a recent interview in his Seattle-area home. "He landed right on our farm, which was startling. My father gave him some oil and electrical tape, and he took off again. ... I thought, That's what I want to do."

As Boeing prepares to celebrate its centennial, Wygle is among the many men and women who have made milestone contributions to the company. In his case, he used that childhood inspiration found on the Canadian prairie to become one of Boeing's pioneer test pilots.

Wygle helped usher in the jet era, then the jumbo-jet era. He was either the first or among the first to fly the 707, 727, 737, 747, 757 and 767. Coupled

with his extensive military and brief commercial airline service, he logged about 12,000 flight-hours.

He was at the forefront with others in determining flight limitations for each new jet model rolled out of the company's factories, establishing safety measures that guide Boeing test pilots to this day.

"The kinds of things that Brien did are still lessons our guys need to learn, and on rare occasion they may have to deploy some of those lessons," Boeing chief test pilot Chuck Killberg said. "By relating cautionary tales where things went wrong, we try to teach upcoming test pilots"—to detect and avoid potentially risky flight conditions.

Wygle launched his aviation career under demanding circumstances. Following high school graduation, he followed his older brother Hugh into the Royal Canadian Air Force and flew 202 missions during World War II, making cargo drops in a Douglas C-47 Skytrain over India and Burma (now Myanmar). He battled monsoons as well as adversaries. He landed on tiny airstrips built by British military forces, "dead-sticking" one approach—making a forced landing without any propulsion—after suffering a dual-engine failure.

Once the war ended, Wygle pursued an engineering degree from the University of British Columbia and kept flying. He joined the Royal Canadian Air Force Air Reserve and piloted everything from jet fighters to trainer aircraft, and worked for a small commercial airline.

Wygle, however, wanted to be a test pilot. In 1951, he joined Boeing and was sent to Wichita, Kan., to fly the B-47, aviation's first large swept-wing jet



and the engineering blueprint for the commercial jetliners that followed. Once Boeing unveiled the B-52 and Dash 80, the prototype for the company's first jetliner, the 707, Wygle was brought to Seattle. He and his colleagues trained airline pilots how to fly the 707. They were pivotal in establishing operational standards.

"It was pretty groundbreaking, a lot of things that we did," he said. "Everything had to be certified and the Federal Aviation Administration had not certified those planes before. These were jet airplanes, and we were first with them, the Boeing engineers and the test pilots. We helped set a lot of federal regulations



for certification for those jets. The FAA relied on Boeing to take them through it.”

Early on, Wygle often was partnered with test pilot Jack Waddell. They traded data with a ground crew. They measured control and stability. They were asked to push the jet to its highest allowable speeds at the most demanding altitude.

Wygle became fairly expert on

Photos: (Above) Brien Wygle flew 202 missions for the Royal Canadian Air Force during World War II before becoming a Boeing test pilot.

MARIAN LOCKHART | BOEING (Right) Wygle, shown on the flight line in Seattle, piloted the B-52 early in his Boeing career. **BOEING ARCHIVES**



airplane “flutter,” an in-flight uncontrolled oscillation that can lead to structural failure. It was his job to see how a jet would react under circumstances that were dangerous—and difficult to forecast.

“We had to take the airplane into those conditions and reach those limits and stop,” he said.

Wygle and Waddell were most closely associated with the 747—a jet that fascinated the public. It was more than twice the size of the 707—people thought it was too big to leave the ground. Wygle and his partner, who were the first to fly it, showed otherwise. They studied all aspects of the 747 for a couple of years before taking it on its first flight on Feb. 9, 1969, their names hand-painted on the fuselage along with that of flight engineer Jesse Wallick.

Besides breaking-in new airplanes, Wygle served five years as vice president of customer service. He retired from Boeing in 1990 but continued to fly, in a single-engine, two-seat airplane he and some friends built from a kit.

Wygle, who remains active as an executive committee member for the Museum of Flight in Seattle, flew without the aid of digital computers and simulators for much of his time as test pilot. He lived his dream that started on a Canadian farm.

“We didn’t know what was going to happen before flying the airplanes; they now know much more about how the airplane is going to fly,” he said. “I think the risk has gone down since the time I was a test pilot. But I came out OK and I very much enjoyed my career.” **100**

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Know of any Boeing or heritage company trailblazers you’d like to see interviewed in future issues of *Frontiers*? Send suggestions and a brief note about their contributions to boeingfrontiers@boeing.com.

Photos: (Top) Brien Wygle, center, shared the flight deck with fellow test pilot Jack Waddell, left, and flight engineer Jesse Wallick, right, for the 747 jumbo jet’s first flight in 1969. **BOEING ARCHIVES** (Bottom) Wygle, a military aviator, commercial pilot and test pilot, retired with 12,000 flight-hours. **MARIAN LOCKHART | BOEING**



CUSTOMER PROFILE



Blossoming future

787-9 opens new possibilities for Vietnam Airlines

BY JOANNA PICKUP | PHOTOS BY MARIAN LOCKHART

In Vietnam, the lotus is one of the most enduring symbols, representing enlightenment and perfection. It's a fitting icon for the national carrier, Vietnam Airlines, whose plans for fleet expansion and brand revitalization are in full bloom.

The newest Boeing jet to display the airline's iconic golden blossom is the 787-9 Dreamliner.

In June, as Vietnam Airlines prepared to welcome its first 787-9, Boeing showcased the jet in flying displays at the Paris Air Show, where it sported Vietnam Airlines' new blue

and gold livery. The flights highlighted the capabilities of an airplane the carrier considers central to its success in the fast-growing Southeast Asia market. Eighteen more are on order—seven through direct purchase.

"Our first 787 delivery is an important step toward our new future," said Pham Ngoc Minh, Vietnam Airlines president and CEO. "The 787 will be a

Photo: A Vietnam Airlines 787-9 Dreamliner displays its performance capabilities at last month's Paris Air Show in Le Bourget, France.



cornerstone of our growth, opening new routes and enhancing our capability in long-haul and transcontinental routes, helping Vietnam Airlines become a leading carrier in Southeast Asia.”

The airline operates about 360 domestic and international flights daily, with service to Europe, Asia and Oceania. Vietnam Airlines will be the first carrier to operate the 787-9 Dreamliner nonstop between Southeast Asia and Europe, with London’s Heathrow Airport slated as the first international destination and Frankfurt as the second.

“For our long flights to places such

as London, the 787 provides us with a significant advantage in terms of efficiency,” Minh said. “And as demand for flights within and to-and-from the region continues to grow, the flexibility of the Dreamliner will help us cater to these different markets, profitably.”

To enhance the passenger experience, Vietnam Airlines is upgrading its on-board features with in-flight texting; full-flat business-class seats; and extra leg room and large touch-screen TVs in economy class. In-flight Wi-Fi services also are set to be introduced.

Vietnam Airlines began operations in

1956 with flights to Saigon (now called Ho Chi Minh City) and Hanoi. It will be the first Asian airline to operate both the 787-9 Dreamliner and the Airbus A350-900.

Boeing’s relationship with the airline dates to 1995, when Vietnam Airlines leased three Boeing 767-300ER (Extended Range) airplanes.

The companies made history in 2001 when Vietnam Airlines purchased four Boeing 777-200ERs—the first business transaction finalized under the Bilateral Trade Agreement normalizing U.S.-Vietnam relations. The airline currently operates eight 777-200ERs.

In 2005, the airline was among the early customers to order the 787. Now, as it welcomes its first Dreamliner—golden lotus crowning the tail—Vietnam Airlines continues its journey toward enlightenment and perfection.

“We are proud of our long relationship with Boeing,” Minh said. “With our new 787s, we look forward to a prosperous future together.” ■

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Photo: A close-up of a Vietnam Airlines 787-9 Dreamliner at last month’s Paris Air Show.

To view a video of a Vietnam Airlines 787-9 Dreamliner rehearsal flight for the Paris Air Show, visit boeing.com/frontiers/video/july15.



MILESTONES

IN FOCUS

Snow bird

A CH-47F Chinook equipped with skis for snow operations is shown after setting down on the Kahiltna Glacier on Mount McKinley in Alaska. Soldiers and Chinooks from the U.S. Army 1st Battalion, 52nd Aviation Regiment, based at Fort Wainwright, Alaska, delivered supplies and equipment in April to base camps at 7,000 and 14,000 feet (2,100 and 4,300 meters)

prior to the 2015 climbing season. Nicknamed the “Sugar Bears,” the Army unit saves money and time moving cargo for the National Park Service while gaining valuable flight-crew experience operating Chinooks at high altitudes and in challenging terrain. Mount McKinley is North America’s highest peak, at 20,320 feet (6,194 meters). In the distance is 13,965-foot (4,257-meter) Mount Hunter.

PHOTO: JOHN PENNELL | U.S. ARMY







TOGETHER. BUILDING THE FUTURE.

The spine of the most advanced aircraft, 787-9 Dreamliner, made in India.