

# Frontiers

## Automation innovation

Robots, lasers and other advanced manufacturing tools help Fabrication employees safely meet rising production rates



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Cover: Mac "Duke" Maravel, a tool- and die-maker for Auburn (Wash.) Tooling Services, positions a superplastic forming die for cleaning by a robotic laser ablation tool (rear). BOB FERGUSON | BOEING

Photo: Jonathan Jorgenson, left, metal structures technician apprentice, and project manager Cesar Viray adjust automated drilling equipment on the 737 MAX Heat Shield robotic pulse line in Auburn, Wash. BOB FERGUSON | BOEING

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### Tom Downey

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### Brian Ames

Editorial director

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### Cecelia Goodnow

Commercial Airplanes editor

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Defense, Space & Security editor

### Junu Kim

Engineering, Operations & Technology editor

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Human Resources and Administration editor

### Beriah Osorio

Shared Services Group editor

### Eric Fetters-Walp

Staff writer

### Dan Raley

Staff writer

## PHOTOGRAPHY

### Bob Ferguson

Photo director

## ART

### Katie Sheahan

Designer

## ONLINE PRODUCTION

### Wendy Manning

Web manager

### Michael Craddock

Web designer

### Lynn Hesby

Web developer

### Tina Skelley

Information technology consultant

## CONTACT INFORMATION

**Email:** [boeingfrontiers@boeing.com](mailto:boeingfrontiers@boeing.com)

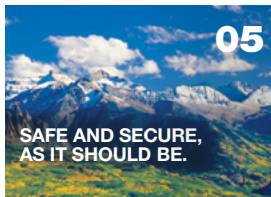
**Address:** Boeing Frontiers  
MC: 5003-0983  
100 North Riverside Plaza  
Chicago, IL 60606

**Phone:** 866-473-2016

**Website:** [boeing.com/frontiers](http://boeing.com/frontiers)

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The stories behind the ads in this issue.



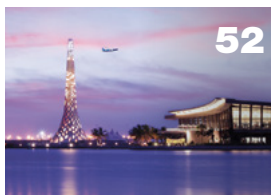
This new ad highlights the value of Boeing's experience and continuity on Ground-based Midcourse Defense, a highly complex and vital national security priority. It is running in trade publications.



Showcasing the F/A-18E/F Super Hornet, this recruitment ad emphasizes opportunities Boeing employees have to continually look for ways to build products bigger, smarter, faster, stronger and better. The ad primarily will run in career fair program guides at recruiting, diversity and college events.



Celebrating technical excellence and engineering achievement is the theme of this ad as Boeing congratulates winners of the 2015 Special Invention Awards and Technical Replication Awards, which will be presented at a ceremony this month.



Part of Boeing's Middle East "Together" campaign, this ad highlights Boeing's investment in education for the future in Saudi Arabia. Translated, the text reads: "Together we innovate. As a founding member of the KAUST Industrial Collaboration Program, Boeing is dedicated to educating and training the future generations of Saudi youth in the fields of technology, engineering and aerospace."

FSC LOGO

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# SAFE AND SECURE, AS IT SHOULD BE.

Ground-based Midcourse Defense (GMD) is on alert around the clock protecting the homeland. Since 1998, Boeing has provided continuous leadership in the development, execution and sustainment of this vital national security asset. The Boeing team's more than 30 years of experience and expertise in homeland defense ensures GMD readiness and reliability against any long-range ballistic missile threat.





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Vice president  
Intellectual Property Management



# Novel ideas matter

In a fiercely competitive global marketplace, innovative solutions from employees can be the difference

The competition is fierce. Our customers tell us we need to help them succeed in changing markets and environments full of competitive challenges. They want more value, capability and reliability, and they want it more quickly and more affordably, and with more certainty of delivery. And if we don't provide it, others will.

This requires innovation. And that's more than just a good idea, or even bringing a good idea to life.

Innovation means combining the diverse talent on the Boeing team with the broad-ranging requirements our customers have, and using our intellectual capital to create game-changing products and services that make the world better. According to independent evaluators, Boeing's intellectual property portfolio is one of the top, if not the best, in the business of aerospace and defense. We've worked hard over the past 99 years to get to this point, and we intend on strengthening this legacy.

Innovation is much more than creating something new or better. What we create must be "captured," or documented, and protected, so we own and control that innovation. Then,

what makes an idea truly valuable is how widespread it is adopted and can be replicated. Invention combined with replication not only drives innovation but also strengthens competitiveness.

It works something like this: If you run into a problem, chances are good that someone at the company already has figured out a solution. If not, and you come up with a novel approach or idea, that's great. It's called an invention. And chances are someone else around Boeing might run into the same problem and would benefit from your invention. When that teammate uses your idea to solve a problem, that's when replication happens.

The ability to reuse solutions is an important characteristic that helps set a large, diverse company like Boeing apart from others. We come up with ideas to grind away at difficult challenges and exciting opportunities alike, each step improving upon the last one. Through the process we make a difference in the world. Our breadth and depth of expertise is one of our competitive advantages.

This issue of *Frontiers* features an article about how people at production

worksites have created inventions that helped improve their processes—and that merited seeking patent protection. Boeing may be known across the world for its engineering marvels, but this story demonstrates that novel and valuable ideas can come from anyone and everyone. It also reflects the power of working as "One Boeing," where colleagues work across geographical and organizational barriers to develop better solutions that lead to higher-quality, safer, faster, more effective and more affordable products, services and processes.

Our customers have been speaking. We are listening. It's not going to be easy, but all of us at Boeing must continue to look hard for the answers.

And the more we learn from one another, the easier it becomes. Every day, each one of us is faced with at least a few big challenges. Technical or not, turn to your co-workers first for solutions. Search the Boeing Web or ask a question on inSite.

If you've figured out a novel solution, capture it by filing an invention disclosure. Or if you've already got a solution that you think might work for another program, reach out to that program. The value of your solution could make a world of difference for Boeing—and its ability to compete in its second century—in the fiercely competitive world marketplace. ■

PHOTO: BOB FERGUSON | BOEING

# Wing dynasty

A China Southern 787 Dreamliner, foreground, and another operated by Hainan Airlines, taxi at Beijing Capital International Airport. This year, 25 percent of all Commercial Airplanes deliveries, including about 30 percent of 737s, will go to Chinese airlines. PHOTO: BOEING





## QUOTABLES

“It’s a great name.”

—Former Gemini and Apollo astronaut Thomas Stafford on the name “Starliner” that Boeing gave its CST-100 spacecraft, which will carry astronauts to the International Space Station and other low-Earth orbit destinations. Associated Press, Sept. 4

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“We’re doing something new for the company and new for the industry, and it’s really exciting.”

—Perry Moore, 777X Wing director of Operations, talking about the huge autoclaves and other advanced manufacturing technology that will be used to make 777X wings in the new Composite Wing Center at the Everett, Wash., site. *Boeing News Now*, Sept. 7

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“Every day I would go out and tour the factory during my lunch. I would touch every 777 airplane because that was my plane.”

—Veronica O’Hara, a planning and schedule specialist on the 777 program in Everett, Wash. Read her story, and those of other employees, industry colleagues and enthusiasts, on Boeing’s centennial story sharing website at [boeing.com/our-stories](http://boeing.com/our-stories).



## WHAT WE DO

# Lifeline

Manufacturing technology expert puts his love of science to work by solving safety challenges

BY AL SALOUR, AS TOLD TO  
PATRICK SUMMERS

Al Salour, a Boeing Technical Fellow and an authority on manufacturing technology, explains how a recent project to improve the safety of Boeing painters became one of the most challenging—and rewarding—of his career.

My love of science started early. When I was 12 years old, I turned my bedroom into a chemistry lab. My parents didn't mind—they wanted me to be an engineer and encouraged me to learn as much as I could in science and math. It was the early inspiration that eventually led to my job at Boeing 30 years ago.

Today, I'm a technical leader in Boeing Research & Technology. My main focus is on sensor-based systems that manage and track the movement of parts, tools and other valuable assets in our factories.

Thanks to these inventions, we can attach a small transmitter or tag to a package, for example, and the signal is picked up by sensors throughout the factory to pinpoint the object's location. And keeping better track of tools or parts that employees need to complete their work helps us create a more efficient and effective workplace.

I recently was able to demonstrate that the same technology also can be put to use in a different but important situation.

The men and women who paint customer logos and liveries on our commercial and military aircraft often work on stackers, or platforms that can be moved up, down and from side to side, and can be dozens of feet up in the air. When working above ground level, painters wear a safety harness that is connected

by a hook to a retractable cable.

When connected correctly, the harness and cable, along with the stacker's guardrails, provide fall protection. After a paint hangar fatality in 2012, my team and I were asked to investigate the use of sensor technology in designing a different approach to improve the harness-and-cable system.

This was a challenging task; sensor and tag technology had never been used in this way. But knowing that we might be able to help keep a colleague safe was all the motivation we needed to keep working.

This is the part of my job I enjoy the most: The company has a need and we're able to find a solution where none existed. It's using science and technology to discover something new. In designing new ways to do our work, I can talk to universities and research centers all over the world. I get to learn something new every day—and I have the opportunity to find practical solutions to challenges faced by our Boeing teammates.

After almost a year of design and testing, we developed a system that automatically senses if a painter has failed to attach the cable to the harness. If the cable isn't correctly attached, the system will disable the mechanical lift that raises the stacker. The new sensor system is in use or being installed in several paint hangars throughout the company and is being evaluated for use in others.

This particular instance meant a lot to me because it's for the benefit of our employees. Applying this sensor-based technology required us to work through a variety of technical and practical issues. But it was a solution that helps create a safer working environment for colleagues in a very important job.

The result is we are improving safety, which makes this more rewarding than anything else I've done. When it's time for me to leave Boeing, I want to walk away knowing that I made a difference. ■

PATRICK.A.SUMMERS@BOEING.COM





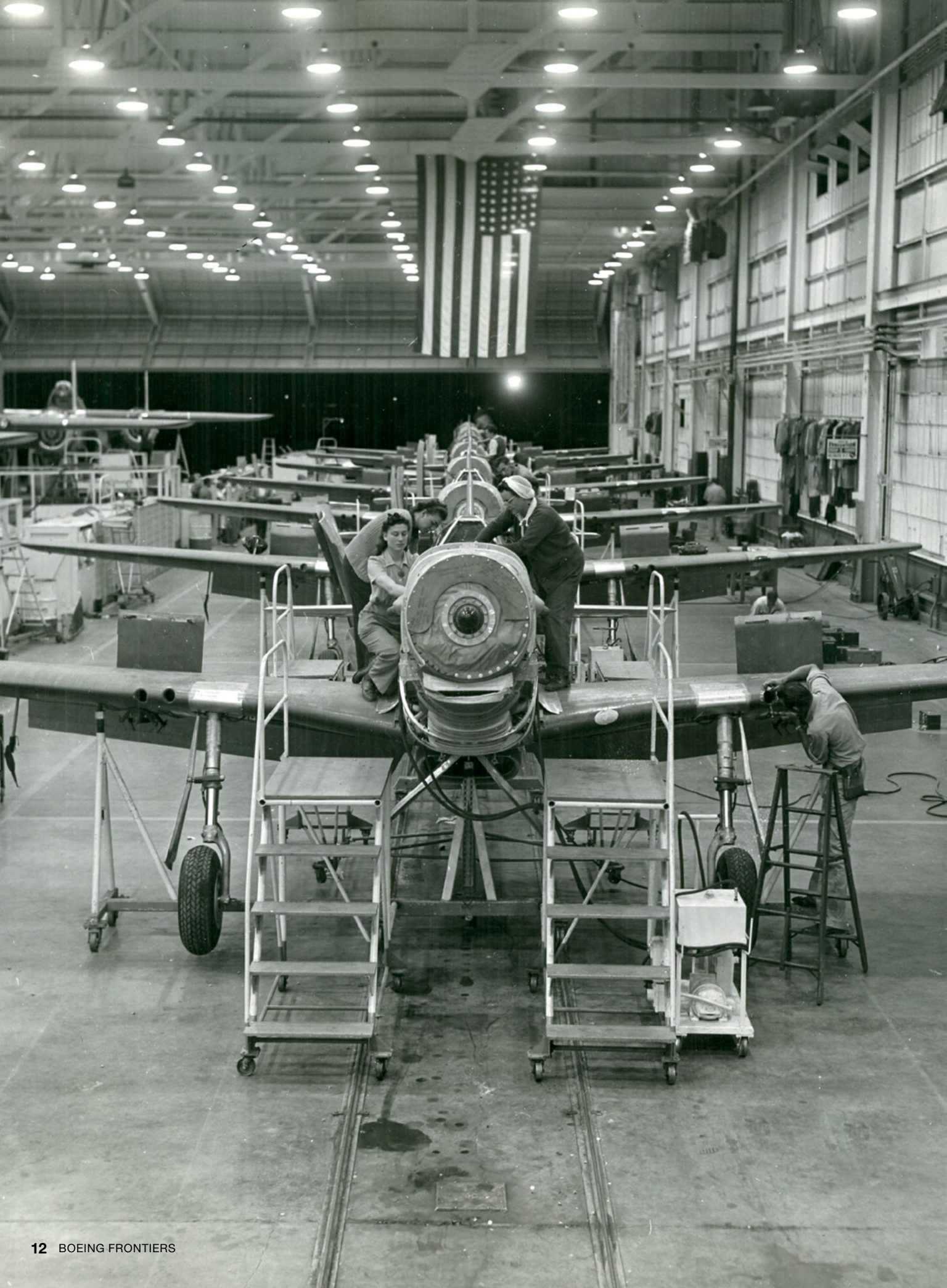
Al Salour

**HAS WORKED FOR BOEING:**  
30 years

**LOCATION:**  
St. Louis

**TEAM:**  
Boeing Research  
& Technology

PHOTO: RON BOOKOUT | BOEING



# Ace of aces

North America's P-51 Mustang was one of the best all-around fighters of WWII

BY MICHAEL LOMBARDI

Beloved and revered, it is a near-perfect blend of art and engineering—and one of the most lethal fighter planes of all time.

The P-51 Mustang, which flew for the first time 75 years ago this month, became the stuff of legend.

But the story of this iconic American fighter, from Boeing heritage company North American Aviation, began not in the U.S. but in Great Britain. In 1940, Great Britain was at war and desperately needed airplanes, in particular the U.S. front-line fighter Curtiss P-40. But Curtiss was committed to filling orders for the U.S. Army, so the British Air Ministry turned to North American, which had a proven track record delivering Harvard trainers to the Royal Air Force.

Rather than build P-40s, North American's chief designer, Edgar Schmued, counseled company president Dutch Kindelberger: "Let's not build an obsolete airplane, let's build a new one; we can design a better one and build a better one."

Kindelberger presented the British with a proposal for a new fighter that included two important innovations: the pioneering use of a laminar flow wing that greatly reduced drag from the airfoil, and an engine cooling system that gave the airplane a distinctive air scoop and created thrust from air heated by the radiator—known as the Meredith effect.

On May 29, North American received a contract from Great Britain for 320 of the fighters that the British named Mustang.

North American said it could produce a flying prototype within 100 days. As promised, on Sept. 9 it completed the prototype designated NA-73X after 102 days, but the aircraft had to wait for its Allison engine, sliding the first flight to Oct. 26, 1940.



One year later, production Mustangs arrived in Britain and the RAF put them into service. Pilots flying armed reconnaissance over occupied Europe praised the new planes and, in that role, became the first allied fighters to cross into Germany after the fall of France.

The U.S. Army Air Force first ordered the P-51 in July 1941 and initially called it the Apache. Later, Kindelberger recommended that the U.S. airplanes also be called Mustang.

The RAF and Rolls-Royce took steps to improve the Mustang's performance by replacing its Allison engine with the more powerful Rolls-Royce Merlin engine. North American also tested the Merlin and adopted it, creating a new Packard-built, Merlin-powered Mustang, designated the P-51B (the company also built it in Dallas as the P-51C).

Later, the P-51D model added a bubble canopy, giving the pilot all-around visibility. In addition to external drop tanks, these later versions had increased internal fuel capacity, allowing the Mustang to not only escort U.S. bombers to any target but also dominate the airspace over that target. That ability made the Mustang a critical component to the success of the U.S. airpower strategy against Germany, and contributed to its reputation as the finest all-around fighter of World War II.

In all, North American built nearly 16,000 Mustangs between 1940 and 1947 at plants in Dallas and in Inglewood, Calif. And Australia's Commonwealth Aircraft Corp. built 200 on the only Mustang production line outside the United States.

The Mustang continued to serve long after WWII in Air National Guard squadrons and with United Nations forces during the Korean War. It remains a mainstay at air races and air shows, where it is hugely popular with the public. The high degree of engineering, innovation and craftsmanship that gave birth to the Mustang was the hallmark of North American Aviation. A German scientist who evaluated the Mustang's design in 1943 said it "surpasses the quality customary in German aircraft construction."

Recalling Mustang's birth and critical role in this, Boeing's centennial year, is a reminder of just how important it can be to 'build something better.' ■

MICHAEL.J.LOMBARDI@BOEING.COM

Photos: (Far left) Rosie the Riveters work on final assembly of P-51B Mustangs at the North American plant in Inglewood, Calif. BOEING ARCHIVES (Above) A vintage P-51 Mustang. SHUTTERSTOCK



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Our Special Invention Award and Technical Replication Award 2015 winners.



## SPECIAL INVENTION AWARDS

selects finalists on the basis of technical innovation, degree of implementation, internal business value to Boeing, business value to customers, and licensing value to Boeing.

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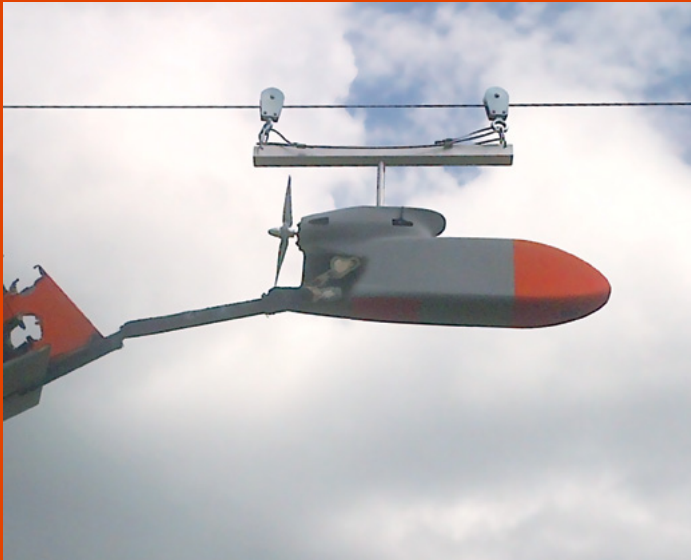
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# This is t

It may be small, but this compact laser weapon can zap unwanted unmanned aerial vehicles

BY QUEENA JONES

Isaac Neal had one chance—one shot. The mission? Find, track and shoot down an airborne unmanned aerial vehicle. And do so in front of an audience of about 60 people, including senior U.S. military officials.

“There were very important people looking directly over my shoulder, and other onlookers watching on screens nearby,” Neal recalled of the event this summer near the California coast. “I had to be careful. It felt like the whole world was watching.”

It was over in about 15 seconds. One shot. One toasted drone, which splashed down in the nearby Pacific.

“I took a deep breath of relief and put down the controller,” recalled Neal, an engineer with Boeing’s Laser & Electro-Optical Systems team in Albuquerque, N.M.

It was a standard gaming system controller. But this was no video game. It was a live-fire test, and for the first time Boeing’s Compact Laser Weapon System had just destroyed an unmanned aerial vehicle, or UAV, in flight. Unlike the U.S. Army’s High Energy Laser Mobile Demonstrator,



# S drone oast

or HEL MD, that Boeing built and demonstrated last year, the compact system is significantly smaller, lighter and more portable. The system weighs only about 650 pounds (300 kilograms) and can be carried in four suitcase-size containers. And it can be set up in a matter of minutes by a couple of soldiers or technicians.

“There aren’t a lot of ways to deal with UAV threats right now, but this is a very low-cost way,” said David DeYoung, director, Boeing Laser & Electro-Optical Systems. “To engage the UAV with a laser, the cost of the shot is basically the electricity to drive the laser. You’re not firing a missile with all the logistics trail and cost of the missile or firing bullets where you have to worry about where they fall.”

While the exercise in California marked the first time the Compact Laser Weapon System shot down a free-flying unmanned aerial vehicle, it was not Neal’s first time in the operator’s seat. He and others on the Laser & Electro-Optical Systems team had demonstrated the system to the U.S. Marine Corps earlier this year. And the team had damaged a tethered UAV in the rugged terrain of West Virginia during Boeing testing in July.

“We knew what the system was capable of, and we were confident in the system, but we had never taken a shot at an airborne drone,” Neal said. “We just had to trust the science, and

the beam size was exactly what it should have been.”

With the Marines, the team showed the system’s surveillance capabilities during a field exercise, tracking airborne objects such as helicopters and UAVs from miles away, and identifying and locating potential threats.

“Sometimes the need may be just identification of the threat, or to track the target and gauge its direction and location, not destroy the target,” explained Jeff Malanify, project engineer.

Boeing originally designed the compact system to identify objects on the ground at significant ranges. But a customer asked the company to further evolve it to track moving, airborne objects—and shoot them down once within firing range.

The Compact Laser Weapon System includes a battery, a water-cooled chiller, a commercially available fiber laser and an upgraded beam director that weighs about 40 percent less than Boeing’s first model. It can direct a beam with a power of up to 10 kilowatts.

That beam can precisely zero in on a target. It can be aimed, for example, to hit only the tail of a UAV and debilitate or destroy its directional control.

Once within range, the system can automatically track a target and take over for the human operator. While Boeing is not publicly disclosing the exact ranges for tracking and targeting, the system can track targets at tens

of miles (10 miles is 16 kilometers).

The laser mounts on a tripod, much like a camera, and the motor, or gimbal, aims the laser in any direction. The silent, invisible laser beam travels at the speed of light, hitting the target almost instantly. And the “ammunition” is virtually free—the only cost is the electricity, which can be supplied by a standard 220-volt outlet, a generator or even a battery pack.

Boeing has delivered its first prototype to an undisclosed military customer.

Neal and his colleagues on the Laser & Electro-Optical Systems team now are refining and testing the second-generation system, based on the customer’s recommendations. Neal said he had always hoped, as a young engineering student, that he could one day help develop technologies to solve problems.

“But to be a part of the team developing something that will protect our troops,” he said, “that’s something I never imagined a couple of years ago.” ■

QUEENA.L.JONES@BOEING.COM

Photos: (From top) An unmanned aerial vehicle, which flew along a guide wire for test control, exhibits tail damage after a few seconds of lasing; the Compact Laser Weapon System identifies and tracks targets at significant ranges over rugged terrain. JEREMY MANNING | BOEING



# UPPING THE GAME

## Employees are using advanced manufacturing tools to increase safety, quality—and competitiveness

BY ERIC FETTERS-WALP | PHOTOS BY BOB FERGUSON

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

Price Alley knows firsthand how taxing it is to drill holes in the composite materials used for the 787 and 777. It's a task that requires both precision and strength.

"When I first got here, I thought I was Superman and could do anything," said Alley, a New Assembly mechanic at the Composites Manufacturing Center in Frederickson, Wash. He works on the airplanes' empennage—the vertical fin and horizontal stabilizer that form the airplane's tail assembly. But even the most skilled mechanics, he said, realize that avoiding ergonomic and repetitive-motion injuries gets more difficult after years of performing the manual drilling work.

"The drilling, over time, can hurt your shoulders, your ligaments, your wrists—just all over your body. It creeps up on you, so you don't always know you're getting hurt until you're hurt," Alley said.

But soon, 80 percent of the 4,000 holes required on each empennage unit will be drilled by robots.

"What we're trying to do is take the processes with the most ergonomic issues and literally take those out of their hands," said Brittany Ballard, an equipment engineer who is leading the facility's switch to robotic drilling.

Boeing Fabrication, part of Boeing Commercial Airplanes, employs more than 16,000 people in the U.S., Canada and Australia for the in-house production of the thousands of parts used on the company's commercial jetliners. Much of the work involves fashioning raw materials into complex pieces that go to final assembly lines

for installation. These jobs often use repetitive motions and processes that can result in high injury rates. And that makes those jobs ideal candidates for advanced manufacturing technology.

"Our people come first, and we need to eliminate the repetitive tasks that can result in injuries," said Mark Rubadue, Advanced Manufacturing leader for Fabrication. Advanced manufacturing technology can accomplish that and improve quality without job losses, he said. "We're all trying to up our game, to be the best in the world at manufacturing."

Fabrication is fully embracing automation and other new tools to keep up with Boeing's fast-paced production rates. The \$5.5 billion business has nearly four dozen advanced manufacturing projects in various stages across its facilities. Those projects are focused on the

Photo: Cammy Hell, metal structures technician, configures a single-flush drill end-effector on the 737 MAX robotic pulse line at the Boeing Fabrication site in Auburn, Wash.

jobs that simply aren't efficient to do manually, or that cause the most injuries or quality issues.

"We're not trying to just solve the easy problems. We're deliberately going after the difficult ones," said Patrick Hopkins, Right Size Equipment manager at the Interiors Responsibility Center in Everett, Wash.

His work area has started using a robotically controlled router to cut bin face panels. Employees there also are testing an automated sander to smooth composite interior parts—a tedious, time-consuming job by hand—and an automated process to wrap parts with decorative coverings. That would reduce the manual labor for that task by about 90 percent and reduce a 20-minute job to about a quarter of that time, Hopkins said. Work still is ongoing to perfect this automation, but employees who perform the tasks are supportive of the effort.

"This is a start," said Ronald Tice, a toolmaker in the Interiors Responsibility Center. "There's excitement on the production floor about this."

At the nearby silk-screen shop, employees produce wallpaper for airplane interiors, using a manual process to combine layers of material into the finished product. The process, in addition to being a repetitive-motion injury risk, creates troublesome static electricity, resulting in wrinkled layers. To combat the problems, shop employees helped develop a prototype machine that automates most of the production steps. The machine has greatly reduced manufacturing time and injury risks and has cut defects by 82 percent. In the past two years, the machine has helped make and cut 10 million feet (3,050,000 meters) of wallpaper, according to Jesse Howard, a toolmaker in the Interiors Responsibility Center Right Size Equipment Lab.

"The machine uses the static to get the layers to stick together," Howard said. "It also lays down the layers without wrinkles, and the glue in the middle layer doesn't have time to get contaminated by dust and other small particles."

Robots already perform drilling and countersinking work on the single-piece heat shield (the heat shield protects the pylon and wing from the engines' exhaust heat) for the 777 and 787 models at Fabrication's site in Auburn, Wash., and automated tools are gearing up to make

the 737 MAX heat shield. The site's expert tool- and die-makers also have started using similar technology to dramatically speed up an everyday chore.

Superplastic forming dies are used to shape heat shields and other parts under high heat and pressure at the site. Employees coat the dies with spray-on lubricants to make sure the pieces they're shaping don't stick to the die. It's a necessary step, but it leaves a stubborn film on the dies, which need to be cleaned before employees can use them again.

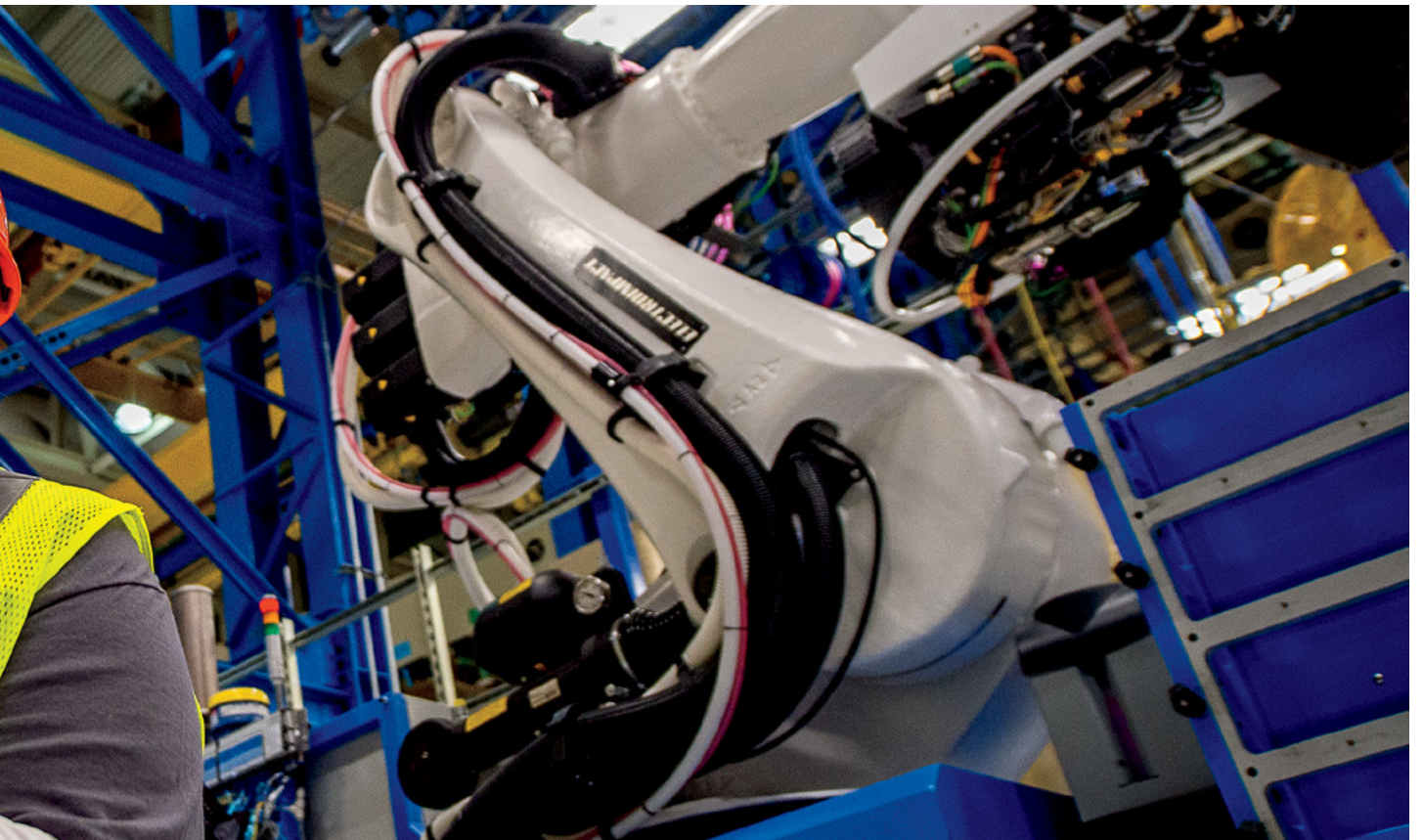
"That has been a purely manual process that involves scouring pads and sanding discs," said Marc Petersen, a

Boeing Research & Technology metals engineer. "It's been a problem for a long time. There really was a lot of motivation to find a safer and quicker solution."

The site's tool- and die-makers take turns performing the cleaning job, which can take up to an entire shift and isn't ergonomically friendly. "It's

Photos: (Right) Chris Barney, process engineer at the Interiors Responsibility Center in Everett, Wash., checks one of the center's newly installed automation tools. (Below) Brittany Ballard, equipment engineer, near the New Assembly Process robot cell in Frederickson, Wash., which will automate drilling work on 777 empennage parts.





a job that nobody likes and nobody wants to do,” Petersen said.

So a joint team from Fabrication Auburn Tooling Services and Boeing Research & Technology devised a solution that uses laser ablation. A laser at the end of a robotic arm strips the dried lubricant from the die in about seven minutes. It doesn’t do the entire job, but the additional manual work takes only 20 to 30 minutes.

“For the big dies, this is perfect. They’re so heavy and dangerous to move around while cleaning, as well as being so time-consuming,” said Ray Messer, a Fabrication tool- and die-maker.

Boeing Fabrication’s advanced manufacturing push extends to its international sites as well.

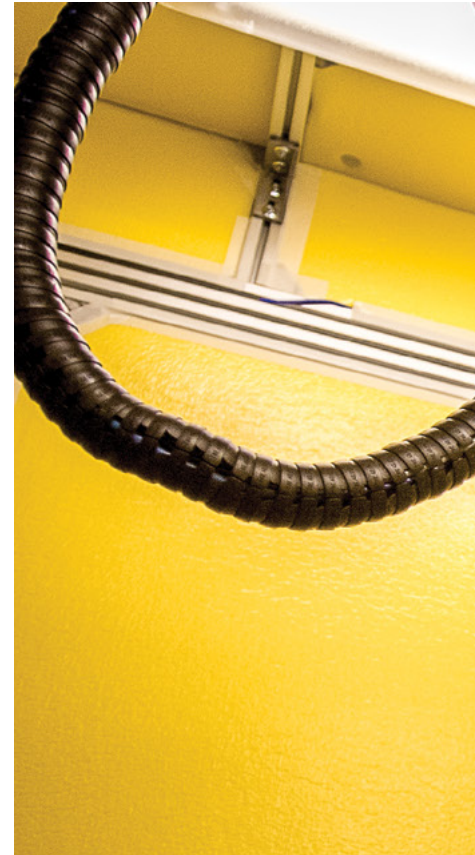
Boeing Aerostructures Australia pioneered robotic drilling and trimming of composite parts more than 15 years ago, and the 737 aileron and 787 movable trailing edge assembly lines today employ robots for hole-drilling and inspection. In all, the Melbourne, Australia, factory uses 14 automated assembly machines on its assembly lines, with four more

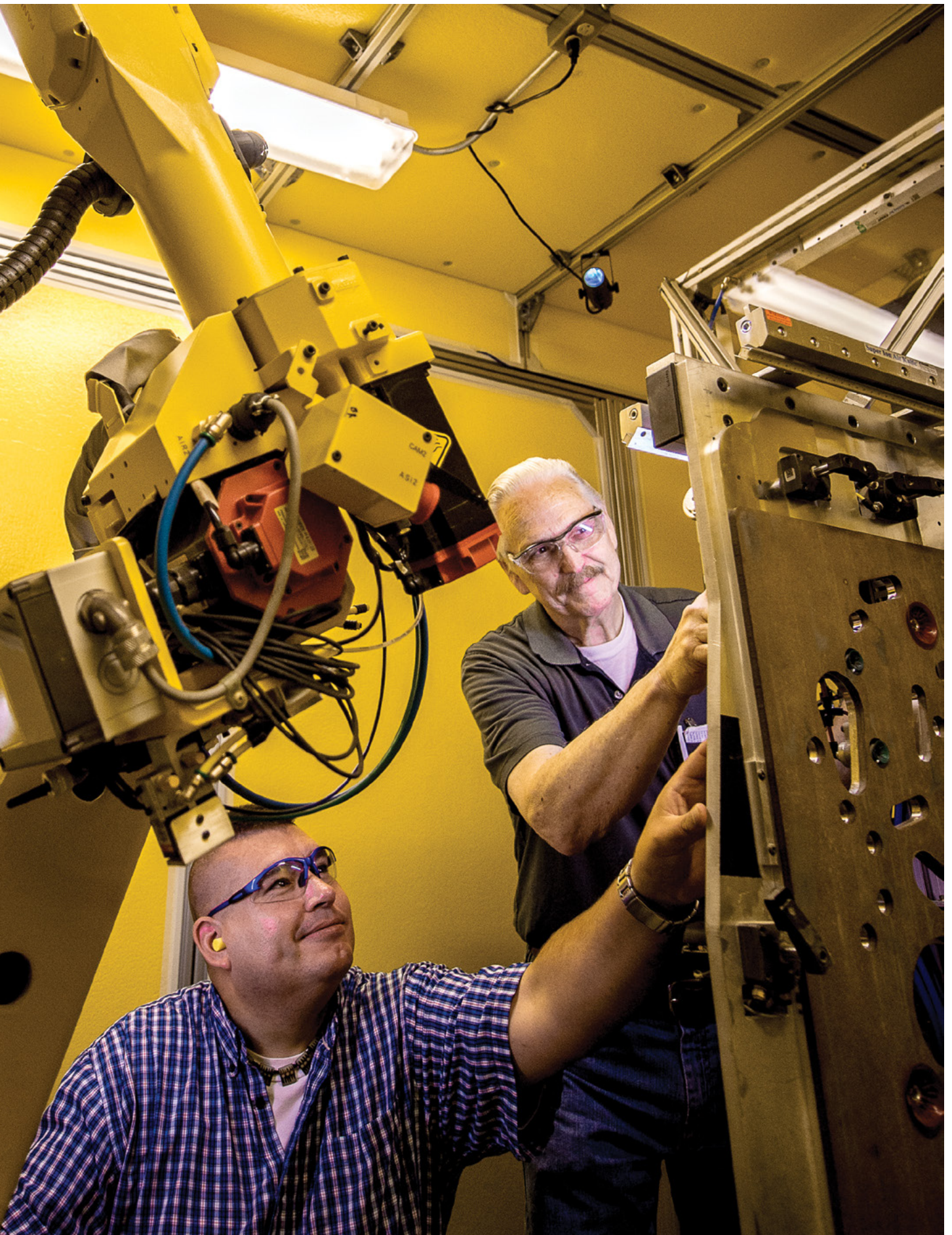
to be added in the coming months to support 787 rate increases and improve accuracy and ergonomics. Boeing Research & Technology–Australia also is working to introduce “light” robotic technologies that would allow the robot and operator to work side by side on tasks where safety is an issue.

“We’ve looked for opportunities to implement automated tooling with the aim of reducing the potential of manual lifting injuries in our operations,” said Peter Gleeson, Production Support Engineering manager for Boeing Aerostructures Australia. “The new robots remove the need for operators to manually lift heavy bars when changing out the components.”

In addition to changing the way

Photos: (Below) Price Alley, New Assembly mechanic in the Composites Manufacturing Center in Frederickson, Wash. (Right) Jason Murray, left, Fabrication mechanic, and Richard Kohn, Right Size Equipment mechanic, evaluate test results of a robot on the Interior Responsibility Center’s new 737 stow bin “model line.”





employees perform fabrication work, these new machines are changing the look of Boeing factories. Instead of huge, fixed-location “monument” tools, many of the automated machines are smaller and easier to move as production priorities change over time.

It will take some adjustment and new skills for those who work on Fabrication’s production programs, but many are looking forward to the change.

At the Composites Manufacturing Center in Frederickson, Michael Luce, a Fabrication mechanic for the past 19 years who is now working on the New Assembly Process, said the mechanics’ expertise in building the 777 and 787 empennage parts will help them as they program and run the automated machinery.

“There will be a learning curve, but I’m excited,” Luce said. Working with the automated tools should bring more variety in addition to being less physically demanding, he added.

The site’s mechanics gave advice on the design of the new machinery to make it as user-friendly as possible. Ballard, the equipment engineer who is leading the facility’s switch to robotic drilling, said the project has convinced her that advanced manufacturing technology could make other tasks in Fabrication and elsewhere easier and less hazardous.

“It’s been a great learning experience for me,” she said. “There’s definitely a lot of technology I’ve seen along the way that can be used in other areas of the building.”

Rubadue, the Advanced Manufacturing leader for Fabrication, said more tools will be introduced in the years ahead. As more Fabrication operations make that transition to advanced technology, others within Boeing can learn from their experiences in how to best use new technology and processes, he said.

“We’re lucky. We’re in an industry that’s progressing, and we can control our destiny ahead,” Rubadue said. “Automation is just one of the tools we can use.” ■

[ERIC.C.FETTERS-WALP@BOEING.COM](mailto:ERIC.C.FETTERS-WALP@BOEING.COM)

Photo: Mac “Duke” Marvel, background, a tool- and die-maker with Auburn (Wash.) Tooling Services, helps position a superplastic forming die for cleaning by a robotic laser ablation tool (rear). Bob Gleim, numerical control programmer, checks settings on the tool’s control panel.







# Protecting great



# ideas

## Some of Boeing's most valuable inventions come from employees on the factory floor

BY ELIZABETH S. DAVIS

Chris Black knows about mislaid tools. For more than 27 years, he has been involved in many challenging searches to find them.

"Sometimes during assembly, employees accidentally leave behind tools and flashlights," said Black, inspection team leader for the Boeing Field Nondestructive Test Lab in Seattle. "If we don't recover them, they can roll around, and that can chew away at paint, corrode or cause other damage."

Once, he was called to the Boeing factory in Renton, Wash., to help locate a half-inch-long (1 centimeter) Apex tip, which resembles a Phillips screwdriver tip, that fell behind a flight-deck instrument panel. The build team had stopped work to ensure the small piece of foreign object debris, or FOD, was found before the airplane moved on, and Black had to remove the newly installed insulation blankets before he could find the tip.

Confident that there was a better, faster and cheaper way to find misplaced tools, Black set out to detect tools from outside an airplane's skin. Last year, he figured out how to magnetize tools without interfering with an airplane's structure or instrumentation. Magnetizing tools

shortened searches from days to minutes.

Although the idea seemed simple, Boeing's intellectual property experts said Black's invention was novel. So he submitted it earlier this year for patent protection; the innovation is now a pending patent.

"While I didn't initially think of myself as an inventor, I knew from my training and certifications—and especially from my factory experience—that this idea could be a winner," he said. "I was confident it would be something we could use on the line."

Boeing employees have been inventing and improving on designs, ideas and tools since the company began building airplanes nearly a century ago. While the invention glory often goes to the engineers and rocket scientists in the lab, some of the most valuable inventions are developed by people producing the aircraft, said Wayne Howe, a Technical Fellow and planner and strategist for Intellectual Property Management.

Traditionally, filing for patents on ideas that emerge from the factory floor hasn't always been a priority. But Howe said this perspective is changing. "It's not only engineers but a wide variety of technical and manufacturing employees who are coming up with great ideas. Now we're doing a better job of capturing them."

Associate Technical Fellow Li Chang sees the spirit of innovation everywhere he looks. An electrical engineer in Boeing Commercial Airplanes, Chang

is also the leader of the newly formed Boeing South Carolina Intellectual Property Committee and technical liaison for the Intellectual Property Management team in South Carolina.

"In the past two years there's been an exponential increase in inventors," Chang said. "That's because of an increase in engagement and involvement in creating a culture of innovation throughout Boeing—especially in production."

Employees from across the company are submitting invention disclosures in record numbers. Boeing South Carolina has seen its rate jump from 28 individual inventors submitting disclosures in 2011, to as many as 129 inventors during the first six months of 2015. Across the enterprise, the number of individual employees submitting invention disclosures reflects a similar trajectory: from 1,883 in 2011 to more than 2,700 in 2014.

And, it's not only engineers but also employees from Employee Development, Quality, Human Resources, Final Assembly and Delivery who are tendering these submissions. Chang attributes the local uptick in engagement to committee outreach. He said similar efforts are occurring across Boeing with favorable results.

"People are learning more about

Photo: At Boeing South Carolina, Li Chang, left, and Debbie Errazo review composite panels with cutouts for doors and windows that are more precise, thanks to an invention of Errazo's. JOSHUA DRAKE

why they should care about and protect intellectual property. They are also asking how they can become a bona fide inventor and contribute to creating a climate of innovation,” Chang said.

But before a potentially great idea can be turned into a valuable patent, would-be inventors need to know how to access resources and complete an invention disclosure.

Chang helped Debbie Errazo, a Composites Fabrication numerical control programmer at Boeing South Carolina, do just that.

Errazo was installing machine-reference targets for use in the Trim and Drill cell to cut door and window outlines and drill nearly 1,000 holes in fuselage panels when Chang stopped

by to chat. Errazo shared that she envisioned an easier way to do her work.

Errazo and her team noted that installing these reference targets used a process that was not consistently precise as they would have liked. This led to extra work time during trimming and drilling setup. Her invention proposed methods to reduce this variation and improve quality.

“I was hesitant at first to think that I could patent my concept,” Errazo said. “I was a machine operator with no technical background. But with Li’s guidance and mentoring, we went from having a concept to forming a team.”

In the days that followed, Chang checked in and suggested ways to improve the process. He also helped Errazo move her idea forward by pulling

together production and manufacturing engineers to collaborate and further flesh out the invention.

The result? Boeing filed for patent protection in 2014.

“When it comes to inventing something at Boeing—and filing a patent—I can honestly and proudly say ‘it can be done.’ Anyone with a vision and the help of a good team can do it,” Errazo said. “And now I wear an inventor pin on my lanyard!” ■

[ELIZABETH.S.DAVIS@BOEING.COM](mailto:ELIZABETH.S.DAVIS@BOEING.COM)

Photo: Inside a 737 main landing gear wheel well, Chris Black, left, and Kathy Ferguson, a materials engineer, use an electromagnetic field detector to find a previously magnetized tool. MARIAN LOCKHART | BOEING





# Keeping with tradition

Korean Air has a long history with Boeing and its jetliners, especially the 747

BY KEVIN YOO

When Korean Air set out to modernize its global fleet, it turned to an airplane it knows well—Boeing’s 747.

The country’s flag carrier had operated every model in the 747 family, starting with a 747-100 Freighter that joined the fleet in 1972. In 2012 the airline received its first 747-8 Freighter, followed by five more over the next few years.

Now Korean Air has the distinction of being the first airline to operate both the freighter and passenger versions of the newest “Queen of the Skies.” The airline took delivery of its first 747-8 Intercontinental in August and quickly put it to work, serving routes from Seoul to Frankfurt and Singapore. By November, as its fleet of Intercontinentals grows, the airline expects to use the new airplanes to serve San Francisco and Hong Kong routes.

Walter Cho, the airline’s executive vice president and chief marketing officer, flew to Everett, Wash., for the delivery of its first 747-8 Intercontinental. He said the airplane is a key part of the airline’s fleet modernization strategy, which aims to enhance the airline’s environmental efficiency, premium image and passenger comfort.

“This new aircraft delivers better fuel economy,” Cho said. “That is important to a global airline such as ours. And it supports our goal to build and operate a first-class fleet of world-class aircraft.”

Based in Seoul, Korean Air serves 128 cities in 45 countries and operates a fleet of 164 airplanes, of which 117 are from Boeing. Throughout its 40-year partnership with Boeing, the airline has owned and operated nearly every Boeing commercial airplane model.

Many more new airplanes—both single- and twin-aisle—will join the fleet by the time Korea enters the spotlight as host of the 2018 Winter Olympic Games in Pyeongchang.

Through its Aerospace Division, Korean Air also has become an important supplier, noted Hssane Mounir, vice president of Northeast Asia Sales for Boeing Commercial Airplanes.

“Our partnership runs deeper than buying and selling airplanes,” Mounir said.

Korean Air is the sole supplier of the distinctive raked wingtip on the 787 Dreamliner and 747-8, he noted, and one of the suppliers for the 737 MAX’s new Advanced Technology Winglet.

As one of the founding partner airlines of the Skyteam Alliance, Korean Air operates one of the world’s largest air cargo operations; it’s the largest cargo carrier between North America and Asia. The airline employs an all-Boeing fleet of 28 freighters including 747-400Fs, 747-8Fs and 777Fs.

In June the airline announced a commitment for up to 50 737 MAX 8 airplanes, including options. The announcement at the Paris Air Show included an identical commitment for the Airbus A321neo, plus an order for two Boeing 777-300ER (Extended Range) airplanes.

The airline now has nearly 70 Boeing orders, commitments and options in the pipeline including firm orders for 10 787-9 Dreamliners. The Intercontinental that delivered in August was one of 10 on order.

“We look forward to playing an integral role in Korean Air’s long-term success,” Mounir said, “as we continue to introduce new Boeing airplanes into their world-class fleet.” ■

KEVIN.K.YOO@BOEING.COM

To learn more about Boeing in Korea, see Page 38.

Photo: The first 747-8 Intercontinental for Korean Air awaits delivery at the Everett Delivery Center in Washington. COLLEEN PFEILSCHIEFTER | BOEING

# Peak exce



# excellence

Boeing employees in Colorado support critical programs, including missile defense and GPS

BY ERIC FETTERS-WALP  
PHOTOS BY BOB FERGUSON

In a darkened room in the south suburbs of Denver, employees provide around-the-clock service to airlines and other users of Jeppesen's aeronautical navigation tools. An hour's drive south on Interstate 25, engineers help make sure the Global Positioning System's constellation of satellites work flawlessly. At nearby Fort Carson, CH-47F Chinook and AH-64E Apache helicopters fly training missions within sight of the Rocky Mountains.

More than 1,900 Boeing employees, most with Defense, Space & Security or

Photo: The Rocky Mountains overlook Colorado Springs, Colo., where Boeing employees support several programs including missile defense and GPS.



Commercial Aviation Services, part of Commercial Airplanes, work in the state of Colorado on a number of programs. United Launch Alliance, the joint venture between Boeing and Lockheed Martin that uses Atlas and Delta rockets to provide launch services for government customers, also is based in the state. Overall, Boeing spent more than \$198 million with 225 suppliers and vendors in Colorado last year.

A significant portion of the defense programs the company supports in Colorado are classified and purposely don't draw attention.

That's the case for many of the Boeing teams in Colorado Springs, a city that hosts two U.S. Air Force bases, the U.S. Army's Fort Carson and the Air Force's Cheyenne Mountain Complex, which monitors much of North America's airspace for potential threats. From their offices around the city and at various bases, hundreds of Boeing employees mainly support the Army's Ground-based Missile Defense (GMD) program for homeland defense

and the Air Force-controlled Global Positioning System, or GPS, which Boeing helped develop.

"Most of our day-to-day activity is monitoring the GPS constellation. We look at the telemetry and the data and then analyze that to keep the older satellites running and get the new ones going," said Boeing's Ray Galik, manager of the Navigation and Integrated Mission Operations Support Center for GPS in Colorado Springs. "Our overall task is knowledge transfer—learning all the details so we can support the customer."

Being "close to the customer" isn't a metaphorical phrase in Colorado Springs. Part of Galik's team works within the complex of buildings at Schriever Air Force Base, constantly checking for any problems with the system used by the U.S. military as well as an estimated 3 billion people every day.

The U.S. Air Force's 100th Missile Defense Brigade also is based at Schriever, where an estimated 2,000 military and Boeing personnel

perform Missile Defense Agency-related work. The agency's facilities include the Joint GMD Training and Exercise Center, which Boeing has run for more than 10 years, training more than 4,500 warfighters.

Robert Greger, the center's Warfighter Training manager, said the U.S. Army-accredited "institution of excellence" works hard to train members of the U.S. armed forces in everything from the missile defense system's basics up to realistic exercises.

"There's something special about bringing in a new soldier and saying 'here's your tools,' and six months later seeing them doing their job well," Greger said.

Besides providing day-to-day monitoring and training on important military programs, Boeing Defense, Space & Security runs engineering centers in Colorado Springs and Denver.

"We provide engineering support for many programs across a large number of Boeing sites," said Jim Barduniotis, program manager for the Colorado Design Center. Colorado Springs





in particular, he said, is a great place from which to draw employees. “With the five major military installations here in the region, there are many military veterans who prefer to stay in this area. These candidates provide us with excellent talent pools and job applicants.”

Despite the relatively small size of the design center in Colorado, its engineers work on a long list of both military and commercial airplane programs, including the new 777X, he said. The nature of the work across programs also encourages collaboration, which may be easier because of its size.

“I like the small site. You may not know everybody here, but you recognize everyone,” said Shawn Cole, a Ground-based Missile Defense Plans



Photos: (Above) Intern Ane Frauches, left, and Doug Taylor, a Research Solutions strategist with Jeppesen, confer in Jeppesen’s research lab in Englewood, Colo. (Right) Sampson “Gil” Gilbert, foreground, and Steve Sladaritz, both managers with Wideband Global SATCOM, work in the program’s Colorado Springs, Colo., lab.





and Integration engineer.

Colorado Springs is also home to the U.S. Air Force Academy.

The academy will soon open its Center for Character and Leadership Development, which features a 105-foot (32-meter) glass tower that leans 39 degrees toward Polaris, the North Star and a fixed point in the night sky—true north. The leaning tower, intended to rival the architectural design of the nearby iconic Cadet Chapel, represents the moral compass of cadets, and ties in with their honor code and the academy's long tradition of leadership and character development.

The center's construction has

been funded partially by the U.S. government and by donors such as Boeing and the McDonnell family. The academy plans to dedicate the center entrance to Bill Boeing, founder of The

Photos: (Clockwise from far left) At the U.S. Air Force Academy in Colorado Springs, Colo., the glass tower at the Center for Character and Leadership Development points toward the North Star; from left, systems engineer Rebecca Simmons, software engineer Bradley Van Cleve and systems engineer Alexandra "Allie" Banks collaborate in the Boeing Denver Engineering Center; a sculpture of a Boeing B-29 World War II bomber near the iconic Cadet Chapel at the academy.



Boeing Company. The forum will be named for Sanford “Sandy” McDonnell and his family. McDonnell Aircraft is one of Boeing’s heritage companies.

In addition to the Air Force Academy and several important military operations, Colorado also hosts a cluster of aviation-related companies. A statue of one of the world’s best-known aviators, Capt. Elrey Jeppesen, stands in the terminal, which bears his name, at Denver International Airport. And the company he founded 81 years ago, Jeppesen, directs its worldwide operations from Englewood.

This Boeing subsidiary, part of Commercial Aviation Services, provides navigational data, operational planning tools and flight-training services to airlines, private pilots, military forces and a range of other customers. Jeppesen started the company after other pilots began buying the flight maps he made while flying for Varney Air Lines. In

the following decades, “Jepp” charts became a common tool in flight decks and cockpits around the world.

At a building near Jeppesen’s headquarters, dozens of employees put together binders full of charts for specific routes flown by airline customers. A nearby printing press hums loudly as it produces thousands of pages for flight-training manuals and related publications.

But Jeppesen’s future involves more pixels and less paper. More than a decade ago, the company helped to create the first Electronic Flight Bag for an airline customer. Instead of carrying around heavy chart binders, pilots could store the same information on portable computers, and it could be updated faster and more easily. That idea took a leap forward with the introduction of digital tablet devices, said Kellie Isaac, Jeppesen’s senior product manager

for Data Distribution Solutions.

“When the iPad came out, it was a game changer,” she said. “Ten years ago, we had 100 customers using DDM (Data Distribution and Management) on 5,000 devices. Now we have 1,000 customers using it on 160,000 devices—and it’s continuing to grow.”

Because Jeppesen’s customers work at all hours, the company’s operations center in Colorado similarly is always going. The facility, full of computer stations and big display screens, answers technical support calls and supports the company’s airline customers. The company’s simulation lab, also loaded with computers, supports Commercial Aviation Services’ Digital Aviation division and tries to envision the future tools that airlines will need for navigation and air traffic control.

Eman Sadi, business manager for Jeppesen’s Flight Operations, said



the combination of working for Boeing while living near some of the continent's highest mountains, as well as the scenic high plains that stretch across the eastern half of the state, helps Jeppesen attract and keep employees. That's a sentiment expressed as well by her local colleagues in Boeing Defense, Space & Security.

"We have great weather and a good quality of life. It's a healthy, active lifestyle," Sadi said. "And I love what we do. It's nice to be passionate about the company and the industry." ■

[ERIC.C.FETTERS-WALP@BOEING.COM](mailto:ERIC.C.FETTERS-WALP@BOEING.COM)

Photos: (Right) The Fort Carson U.S. Army base flies a fleet of 48 AH-64E Apaches (top and bottom) and 12 CH-47F Chinooks. (Below) A statue of Capt. Elrey Jeppesen greets visitors at Jeppesen headquarters in Englewood, Colo.



# Shared



# vision



Korea's growing presence in a dynamic part of the world presents new opportunities for Boeing

BY DAN RALEY

The Republic of Korea has risen from a newly formed country after World War II to an influential global presence, and Boeing and its heritage companies have witnessed this transformation firsthand.

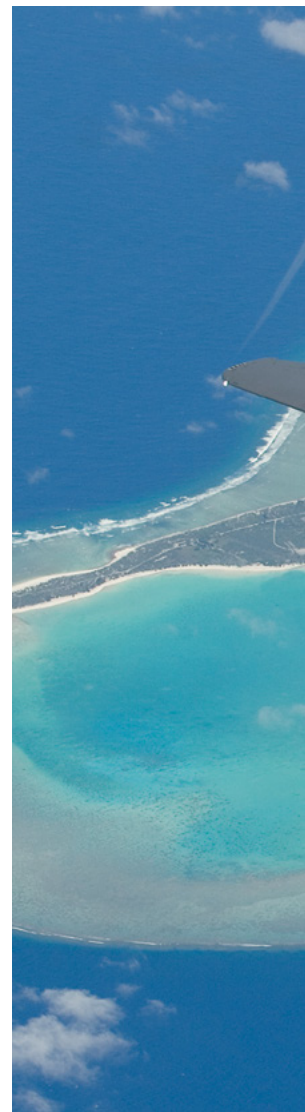
They've collectively shared in an

aerospace relationship with Korea since the enterprising country's earliest beginnings, a connection stretching nearly seven decades.

"We see Korea as one of our top 10 markets," said Marc Allen, president, Boeing International.

"Korea is part of the Asia story. It's obviously a rising economy in a rising region. It's a dynamic

Photo: Korea's new Incheon International Airport serves as a major hub in the region and a gateway to Asia. SHUTTERSTOCK



place. It plays a role as a real leader.”

Today, Korea operates nearly every current Boeing commercial airplane model and builds parts for each type. The country’s flagship carrier, Korean Air, recently took delivery of the first of 10 747-8 Intercontinental passenger planes it has on order. Meanwhile, the Korean military relies on a fleet of Boeing-made jet fighters, transport helicopters and Airborne Early Warning & Control, or AEW&C, aircraft for the country’s defense needs. It has also ordered Boeing’s Apache attack helicopter.

Few countries have undergone so much change in such a short time. Korea, which boasts a 50 million population, offers skylines interspersed with ancient palaces and temples offset by futuristic-looking skyscrapers.

It is an inviting yet ultra-competitive marketplace for aviation business,

according to Eric John, Boeing Korea president. At the recent Paris Air Show, Korean Air ordered 102 jets worth \$10 billion, 52 from Boeing and 50 from Airbus.

Boeing’s long history with Korea is used to good advantage in sales campaigns, John explained.

“What Boeing brings, in addition to what is a superior advantage in products and services, is a long-term and proven standard of commitment to Korea and to our customers and partners here. No other company in aerospace can provide that,” John said.

Korea, which counts global economic powers China, Japan and Russia as neighbors, utilizes one of the world’s more spectacular and modernistic airports—Incheon International Airport, located 30 miles (48 kilometers) outside of Seoul. All of this makes Korea a strategic aviation hub, said Ryan Weir,

Boeing Commercial Airplanes sales director for Korea’s Asiana Airlines and the country’s low-cost carriers.

“Incheon Airport is one of the biggest competitive advantages the country has,” Weir said. “It’s extremely new and efficient. It’s the gateway to Asia.”

Serving as a major hub in the region, Korea’s Incheon Airport links Boeing to key markets in Asia, including China and Southeast Asia, said Ihssane Mounir, vice president of Northeast Asia Sales, Boeing Commercial Airplanes.

“Korea is a very important market for Boeing in terms of long-term partnerships,” he said, “with opportunities for growth as airlines continue to modernize their fleets and services. In fact, the Korean commercial aviation market is fast approaching \$100 billion in market share, which is on par with Japan.”

Boeing and Korea have worked





together since the country separated from North Korea at the end of World War II. Korean National Airlines began ferrying passengers soon after in 1948 in four DC-3s and two DC-4s, built by heritage company Douglas.

During the 1950–53 Korean War, the Boeing-related presence was unmistakable. The U.S. Air Force supported United Nations forces flying missions using the F-86 Sabre, P-51 Mustang, Douglas Skyraider, Douglas A-26 Invader and McDonnell F-2H Banshee, each of which was a Boeing heritage aircraft.

In 1967, Korean Air Lines (now Korean Air) put its first jetliner into service, a Douglas DC-9, followed by a Boeing 707 two years later, effectively launching the country's modern commercial aviation business. KAL also was one of the first to operate the 747, helping usher in the

jumbo jet era, and the first to own both 747 passenger and freighter jets.

Korea is especially attractive as an aerospace customer because all major carriers do business there, the country ranks as China's No. 1 international travel destination, and its Gimpo-Jeju Island route is one of the most heavily traveled globally, according to Boeing employees who interact with the country.

Indeed, the Asia-Pacific region is projected to be the world's fastest-growing aviation market, according to the Boeing *Commercial Market Outlook*, ordering a possible 13,460 new airplanes and generating \$2 trillion in market value through 2033—nearly double the anticipated needs of the next-closest geographical region.

The majority of the commercial airplanes flown by the country's airlines are Boeing-made. Korean Air operates

89 Boeing passenger jets, plus it has 28 freighters, among them the new 747-8F. Asiana Airlines has 34 Boeing commercial jets and freighters, including 12 777-200ERs (Extended Range). Jeju Air operates 20 737-800s. Jin Air recently took delivery of its first new 737-800 and operates 14 737-800s. Air Busan, T'way Air and Eastar Jet operate 30 more 737s.

An expanding Korean cargo market could drive future airplane sales for Boeing; flight-training services is another area showing great promise, with Boeing and Korean Air working together to open a new training facility

Photos: (Far left) With afterburners red hot, a Korean F-15 prepares to take off. RON BOOKOUT | BOEING (Above) Two Republic of Korea F-15K fighters fly over Wake Island en route to Korea during their delivery flight. BOEING

next year, according to Boeing leaders.

“There are a lot of opportunities for Boeing in Korea,” said Roland Ramirez, Commercial Airplanes sales director for Korean Air. “It has unlimited growth potential.”

On the defense side, the country’s longtime uneasy relationship with North Korea has fueled repeated defense upgrades. Over the past decade, the military has taken delivery of 61 F-15K Slam Eagles and, over time, acquired 42 CH-47D Chinook transport helicopters. Beginning next month, it plans to receive the first of 36 AH-64E Apache attack helicopters.

Although facing military budget limitations, high utilization of current aircraft will require additional AEW&C aircraft, and an increasing submarine warfare threat will necessitate the addition of the P-8 Poseidon or other maritime surveillance aircraft in the future, according to Tim Nichols, director, Boeing Defense, Space & Security international business development.

“Sustainment and expansion of the strike aircraft fleet such as F-15K and Apache, and transport aircraft such as Chinook, also is critical,” Nichols said. “Special operations aircraft, such as the V-22 Osprey, will be of keen interest to Korea. The after-market services, support and modification upgrade business also will be a growth area.”

Acting on the need for the latter, the Boeing Avionics Maintenance, Repair and Overhaul (BAMRO) center—one of the first of its kind outside the U.S.—opened in the city of Yeongcheon in April to test and repair aircraft electronics beginning with the F-15K. Korean employees operate the center, which covers 10,800 square feet (1,000 square meters).

The equipment in place can be reconfigured to test most avionics on a variety of aircraft, and could be made available to others in Asia.

“The customer will benefit from reduced turnaround time and inventory savings as a result of the avionics repair services provided at the BAMRO,” said James O’Loughlin, vice president, Boeing Global Services & Support for Korea.

Boeing business relationships extend deep into the ever-expanding Korean aviation manufacturing industry. The Korean Air Aerospace Division currently supplies composite structures and

components for the 787 Dreamliner, 747-8 and 737 MAX, and previously has supported multiple Boeing military aircraft programs. Korea Aerospace Industries has provided parts for the 787, 777, 767, 747-8, 737 MAX and P-8, plus fuselage sections for the AH-64 Apache and F-15.

In August, the 300th AH-64E Apache fuselage, delivered to Boeing from Korea Aerospace Industries, held the distinction of being the first fuselage of an Apache

helicopter to return to its homeland. It is destined for the Korean army. Last year, Boeing spent more than \$460 million with Korean companies, including 25 different suppliers, and currently employs more than 200 people in seven Korean cities. In addition, Boeing invests and engages with local organizations focused on education and the environment, which are key areas of interest for the Korean people.

## Korea at a glance

Official name	<b>Republic of Korea</b>
Capital city	<b>Seoul</b>
Area	<b>38,500</b> square miles (99,700 square kilometers)
Population	<b>49,115,196</b> (estimated in July 2015)
Gross domestic product	<b>\$1.78 trillion USD</b> (estimated in 2014)

SOURCE: U.S. GOVERNMENT





Boeing also is a minority stakeholder in Incheon-based Huneed Technologies, which produces wireless communication equipment used on military aircraft. This unique relationship, according to Allen, epitomizes the broader aviation connection between Boeing and Korea, and it could be used as a benchmark for Boeing doing business in other countries.

“It’s all about finding the right

partners to work with and building collaborations,” Allen said of Huneed. “It’s a very good story to look at, not just for our success in Korea but for what we’ll do elsewhere with partners.” ■

[DANIEL.W.RALEY@BOEING.COM](mailto:DANIEL.W.RALEY@BOEING.COM)

To read more about Korean Air, see Page 29.

Photo: A Korean Air employee views the airline’s first 747-8 Intercontinental after its arrival at Incheon International Airport. GETTY

# Driving force

Carolyn Corvi helped implement changes to build Boeing jetliners more efficiently, including the 737 moving production line

BY DAN RALEY

As Boeing approaches the start of its second century in July 2016, *Frontiers* visits with some of the men and women who have helped make Boeing a global leader in aerospace.

When Boeing hired her in 1974, Carolyn Corvi was a recent college graduate simply bent on finding a good job. She had a history degree and an inquisitive approach. She had a lot to learn about aviation.

Over the next three and a half decades, Corvi rose through the ranks of the company by asking nonstop questions and providing groundbreaking solutions, according to Boeing colleagues. She wasn't hesitant in having an engineer or mechanic explain something at length to her until she had a firm grasp. The Seattle native used this opportunity to make history.

Corvi became a pioneering executive for Boeing—the first woman to head an airplane manufacturing program. She and her team introduced a moving assembly line to the 737 that cut production time more than half. She was the driving force behind the “Move to the Lake” project, which housed everyone inside the Renton, Wash., 737 factory responsible for designing, supporting and building the airplane.

All along, Corvi took the approach that she needed to be bold and decisive in order to be an effective leader.

“I grew up in a family where they said, ‘You can do anything you want, try new things, don't be afraid,’” she said.

Her Boeing colleagues early on spotted her ability to quickly move past details that bogged down others and see the big picture, Corvi recalled. They encouraged her to take responsibility, to make tough decisions and,

foremost, to ask those questions.

Co-workers nicknamed her “Ms. Why” on the factory floor, a label that amused her. But her management style was such that she got things done and her actions inspired other women in the company to follow her into similar high-ranking roles.

Elizabeth Lund, 777 vice president and general manager, worked closely with Corvi on three separate occasions. She watched the 737 leader work with the team to accept difficult change. She saw Corvi interact with people around her in a consistent and always respectful manner.

“She just taught us the importance of understanding the value stream and production system, and how it all relates,” Lund said. “She did it without ever being heavy-handed. She was a great teacher. She was a powerful leader.”

Corvi initially worked in Commercial Airplanes before serving multiple stints in Boeing Computer Services and the Shared Services Group, becoming a supervisor for the first time in 1979. In 1987, Boeing awarded Corvi a fellowship to attend the Massachusetts Institute of Technology and pursue a master's degree in management. She was the first woman to receive this Boeing honor, which at the time was three-plus decades old.

While in Boston, Corvi became familiar with the Toyota Lean Production System. She met people on the MIT campus who were researching the book *The Machine That Changed the World*, which detailed the Japanese car-maker's approach to manufacturing. A few years later, she and others from Boeing traveled to Japan to experience those same manufacturing principles by joining in and building



air conditioners alongside employees in a Hitachi factory.

To meet increased 737 delivery rates while putting the Toyota principles to work, Corvi, as vice president of Propulsion Systems, asked employees to apply these methods to the 737 engine build process. The goal was to build an engine in a shift rather than three.

“The team, to its credit, said, ‘We'll give it a try,’” she said. “We had workshops and we asked mechanics what to do. They completed the first engine in six and a half hours. It was an amazing experience.”

As leader of the 737 program in 2000, she introduced Lean measures



to production, creating a moving line that reduced flow time from 23 days to 10. The 737 team was able to make inroads by improving quality, creating flow and eliminating waste, which meant operating under a different mindset, according to Corvi.

“The Toyota Production System is

Photos: (Above) Carolyn Corvi, former Boeing executive, often spends time in retirement at Seattle’s Museum of Flight, where she is a board member. **MARIAN LOCKHART | BOEING** (Right) Corvi and her 737 team in Renton, Wash., implemented a moving production line, shown here in 2002, that cut flow time from 23 days to 10. **BOEING**





based on the continual elimination or removal of waste in every process, in everything you do,” she said. “That’s the approach we took on the 737 program. It’s a huge cultural change—to me, that’s the legacy.”

In 2001, an earthquake in the Seattle area damaged a Boeing facility that held 737 engineers. Rather than rebuild, Corvi received approval to create a new workspace inside the Renton factory. She brought engineering and manufacturing together in a more collaborative fashion, all under one roof.

“All of it was based on Carolyn having a very clear and inspired vision in seeing us working together in the future—it just made sense,” said Mark Garvin, Boeing Business Jets completion manager, who was heavily involved in planning the move. “She had strong beliefs. She’s about as courageous as they come.”

Plenty of companies have tried to implement the Toyota Production

System through the years, but few sustain it, unwilling to take the next step and make the cultural changes required, according to Corvi. Boeing has been a notable exception.

“She truly embedded Lean in the culture of The Boeing Company,” Lund said.

Corvi, who retired in 2008 as vice president and general manager of Airplane Programs, lives in Seattle and serves on three corporate boards and two nonprofit boards. One nonprofit is the Museum of Flight. Another is a medical center, one that asked her to help support the implementation of the Toyota principles and transformation of the center’s health care system.

Corvi and her husband have embraced retirement. They pursue adventure travel, hiking across the world in such places as Ethiopia, India, Japan, Mongolia, Myanmar, Vietnam and the United Kingdom. In the European destination, they walked more than 190 miles (310 kilometers) in 12 days.

At Boeing, Corvi covered lots of ground by asking a lot of questions. She said she pushed for change by engaging and empowering her teams, often using all of her powers of persuasion. She trusted her instincts and the people she worked with.

“It was making it OK to speak up and do things not conforming to standard,” Corvi said of her impact on Boeing. “You could be one of the guys but not be one of the guys. You could be yourself and come to work every day and not have to compromise yourself. I believe I was true to myself and true to everyone I worked with.” **700**

[DANIEL.W.RALEY@BOEING.COM](mailto:DANIEL.W.RALEY@BOEING.COM)

Photo: Carolyn Corvi, who served as 737 and 757 vice president and general manager among her many Boeing roles, in the factory in Renton, Wash., in December 2001. BOEING

## MILESTONES





IN FOCUS



# I'm so fly

A 777 operated by KLM Royal Dutch Airlines reflects sky and runway patterns as it taxis at Amsterdam's Schiphol Airport in the Netherlands before a recent flight. KLM is part of the Air France–KLM Group, one of the world's largest 777 operators. KLM has been flying Boeing airplanes since the early 1930s, beginning with the DC-2 built by Boeing heritage company Douglas Aircraft. PHOTO: MAURITS VINK



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