2023 Q1 | Volume 7 | Issue 23

IQ INNOVATION QUARTERLY

INNOVATION. INSIGHT. INSIDE AEROSPACE.

Flash Forward

Inside an aerospace lightning lab

PLUS: Wayne's World
A shining example of Australian-made autonomy, cobot 'Wayne' works alongside humans.

LIGHT TOUCH
Boeing electromagnetic effects engineer Louisa Michael and her colleagues simulate lightning effects on airplane parts.

BOEING

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IQ IS ...
Innovation Quarterly invites readers to go inside the future of aerospace with the people who make it happen.


PHOTO: TIM MCGUIRE/D.J. & COMPANY

The Path Forward

Aerospace must be sustainable, autonomous, producible and digital

As I finish my 41-year career at Boeing, this is my final post as publisher of Innovation Quarterly. It's an appropriate space to look back on what has changed over the decades, to consider what will remain the same and to look forward to the future of our industry.

Last year in IQ, I named the four greatest developments I've seen during my career: the advent of GPS, the first steps of autonomous flight, the rapid increase in computing power and the widespread use of carbon-fiber composites.

While significant, these comprise only the first chapter in the future of aerospace. Capabilities in sustainability, autonomy, producibility and the digital transformation will continue to advance. Our curiosity — inspired by our social responsibility — will be the driving force in our industry.

Aerospace has always presented the toughest challenges in engineering, and this will remain the same. That's because there's no margin for error in our work. Flying has to be safe for everyone, from global travelers to astronauts exploring space to those who defend freedom.

Solid systems engineering has been and will remain the foundation for how big problems are solved in aerospace. Breaking complex problems into smaller, more tractable ones and understanding the interfaces that connect the solutions is — and always will be — how successful product development is done.

The digital transformation underway and the complex models that will support it will provide an even greater ability to conduct trades and optimize solutions earlier in the product development life cycle. The challenge will be the precision of answers versus the accuracy of those answers. The digital transformation will never replace good engineering judgment.

Our future will be one in which flying is a more common means of transportation, so we must continue the pursuit of safer ways to fly. Urbanization of the global population will continue, and the terrestrial infrastructure will not keep up with demand. Moving people and goods with safe, efficient, autonomous aircraft will be the answer.

As I sign off for IQ for the last time, I still believe what I wrote in the first edition in 2016: IQ is about the most important element in this enterprise — the people who make the future happen. From my first days as an entry-level engineer to my final role as chief engineer, I've had the honor of working in an industry with people who change the world. I know the future of aerospace is bright, and it's in good hands. **IQ**

BOOST YOUR IQ!
Discover Greg's keys to engineering excellence.

Greg Hyslop
Chief Engineer

IQ ARCHIVE
See the first issue.

Wayne's World: Autonomy in Australia

Cobot works alongside humans

BY GEORGINA RAMIN, BOEING WRITER

When "Wayne" enters the room, people take notice. A rhythmic beeping and flashing orange light signal the entrance of this autonomous mobile collaborative robot – known as a cobot.

A welcome sight at Boeing's 787 Dreamliner production area in Melbourne, Australia, Wayne works on the shop floor together with human teammates. The cobot carries out tasks that previously caused repetitive strain injuries.

ROBOT AT THE READY

Wayne waits to pick up where Boeing Australia 787 technician Joe Cascun leaves off.

PHOTO: WOODROW WILSON/BOEING

Australia is the first Boeing site to use such technology. Since its introduction two years ago, workplace injuries in the 787 area have significantly decreased. While other safety measures were also put in place during that time, the team believes Wayne played a significant role in getting the numbers down.

“Getting the 787 wing tools or mandrels ready for manufacturing in the tool preparation area was important but repetitive work,” explained Josip Mihalik, team lead in the Boeing Aerostructures Australia 787 factory. “Now it’s all offloaded to the cobot, so we can focus on more valuable and meaningful tasks.”

SAND MAN

Technician Josip Mihalik replaces a sanding pad on Wayne’s end-effector.

PHOTO: WOODROW WILSON/BOEING

> “Getting the 787 wing tools or mandrels ready for manufacturing in the tool preparation area was important but repetitive work. Now it’s all offloaded to the cobot, so we can focus on more valuable and meaningful tasks.”
>
> **JOSIP MIHALIK**
> **BOEING AEROSTRUCTURES AUSTRALIA**

COBOT COLLAB

(From left) Boeing Australia teammates Declan Burke, Josip Mihalik, Brooke Agostino, William Ko, Ashkan Amirsadri and Dominic Wierzbicki experience the benefits of robotics every day, manufacturing airplanes next to Wayne the Cobot.

PHOTO: WOODROW WILSON/BOEING

Wayne’s World: Autonomy in Australia

CLEAN MACHINE

Wayne's primary role is to sand, clean and prepare layup mandrels that are used to produce 787 components.

PHOTO: WOODROW WILSON/BOEING

Wayne's World: Autonomy in Australia

Mihalik and his colleagues are reaping the benefits of Boeing's investment in R&D. Boeing Australia teammates have been coding the blueprint for safe and trusted artificial intelligence (AI) and autonomous behaviours in uncrewed aircraft and robotics.

Boeing Research & Technology (BR&T) aerospace engineers in Australia designed and engineered the autonomy built into many of Boeing's cobots. These teams are pushing the limits of what can be achieved in a complex factory environment.

You can find Wayne self-navigating around the 787 factory, avoiding people and obstacles, and using its handy mechanical arm to carry out sanding and cleaning along with manufacturing staff. The teams plan to implement a second cobot for 737 production.

Boeing Australia has long been a test bed of innovation for autonomous technology for The Boeing Company, thanks to a unique partnership between BR&T Australia and Phantom Works Global.

DISCOVER
Ghost Bat facts.

SCAN
ScanEagle intel here.

EXPLORE
More from Phantom Works.

PHOTO: DEPARTMENT OF DEFENCE/COMMONWEALTH OF AUSTRALIA

Australian-Made Boeing Autonomous Technologies

MQ-28 Ghost Bat

The Boeing Airpower Teaming System created the first military aircraft designed, developed and manufactured in Australia in half a century. The MQ-28 is an uncrewed aircraft made to work as a smart team with other military aircraft to expand and extend airborne mission capabilities.

PHOTO: BRUCE GIBSON/BOEING

ScanEagle

Insitu Pacific's ScanEagle detect and avoid software enhances safe airspace integration of uncrewed aircraft systems (UAS).

Machine-learning software

Phantom Works Global's uncrewed technology teaches UAS to detect, decide and act during missions.

Wayne's World: Autonomy in Australia

WATCH
Wayne work the room.

SCREEN TEAM
Machine learning specialist Dr. Zee Jan develops a digital twin demonstration for defence force customers.

PHOTO: BRUCE GIBSON/BOEING

In addition, the country offers wide-open spaces ideal for safe testing. R&D is also supported by the Civil Aviation Safety Authority and military and resource industries, all with a strong interest in integrating autonomous systems.

"Continued investment by Boeing in the region, strong government support and safety-focused regulators make Australia the perfect testing environment for new commercial and defence products," said Michael Edwards, director of BR&T – Asia Pacific.

The critical AI knowledge and coding skills required to develop autonomous behaviours and navigation are key factors in Boeing Australia's success. For example, the "brain" on board the mission system of Boeing's smaller test assets, the MQ-28 Ghost Bat and cobots like Wayne each have unique software that automates different tasks.

Phantom Works Global, the defence rapid-prototyping arm of Boeing Australia, tested autonomous behaviours in the early phases of the Airpower Teaming System (now known as MQ-28 Ghost Bat) and is expanding into multiple domains.

"Our focus is on creating systems that team together to work as one across air, land, sea and space," said Emily Hughes, director of Phantom Works Global.

"We are refining our work in autonomy and AI to provide new autonomous teaming solutions to the Australian Defence Force."

From cobots like Wayne that reduce workplace injuries to uncrewed systems protecting Australia's national interests, humans are quickly learning — as fast as the machines they make — how important these technologies are to create opportunities and confront future challenges. **IQ**

MEET
the MQ-28 Ghost Bat team and go behind the scenes (aircraft previously known as Loyal Wingman).

PHOTO: PAUL SARGAISON/BRISBANE HEADSHOTS

PHOTO: BRUCE GIBSON/BOEING

PHOTO: SIMON KO

Meet Australia's Autonomous Tech Experts

Nathan Bick
Operations analyst, Phantom Works Global

Expert in using modelling and simulation to facilitate the process of making complex decisions.

"Working on autonomous technology and pushing the boundaries of what's possible is a fantastic experience. Our team focuses on collaboration to overcome challenges and deliver a system that successfully blends human ingenuity with the capabilities of the machines the humans themselves built. This technology increases our safety and supports our future."

Natasha Moffat
Senior software engineer, Insitu Pacific

Leads autonomous software development to help safely integrate UAS into complex airspace.

"I love working in autonomy because everything has so much potential, the work always feels worthwhile, and nothing beats being able to flight test your work."

William Ko
Automation research engineer, BR&T Australia

Designs and develops advanced robotic systems that enhance safety, quality and efficiency of aerospace production systems.

"At BR&T, we push the boundaries of technology, building robotic systems you cannot find anywhere else in the world. It is deeply satisfying to solve a huge range of problems unique to aerospace side by side with engineers who are the best in their fields."

Flash Forward: Lightning Lab Enhances Safety

Boeing creates lightning to study its effects on aerospace parts

BY MAKSIM GOLDENSHTEYN, BOEING WRITER

It looks like just a storage closet. But you get a sense there's something more going on inside. A sign on the door says, "High Voltage Test in Progress. Do Not Approach Test Area."

Inside the room is a blue shipping container with metal tubes, lights and meters attached on one side. Boeing electromagnetic effects engineer Louisa Michael and her colleagues twist some knobs. Attach some wires. And double-lock the thick container doors.

Then they leave the room — out the door with the warning sign.

They're ready to make lightning.

BOLT BOX

Inside a converted shipping container, electromagnetic effects engineer Louisa Michael and her colleagues create and test novel algorithms that simulate lightning effects on airplane parts in Boeing South Carolina's lightning lab.

ALL PHOTOS: JOSHUA DRAKE/BOEING (UNLESS INDICATED)

Lightning in a Lab

Just north of Charleston, South Carolina, in one of Boeing's lightning labs, the Electromagnetic Effects (EME) team drives high levels of electric current through aerospace components large and small. The idea is to mimic the effects lightning strikes can have on airplanes and study how the parts respond.

When capacitors discharge the current, the resulting strike emits a booming pop, but without the blue plasma arc typical of the bolts seen flashing across the night sky. Those in nature carry millions of volts and billions of joules of energy. For safety and practicality, the strikes in the lab are scaled, so the results can be extrapolated mathematically to predict what might happen in the real world.

Michael and fellow researchers are part of the Boeing Research & Technology organization. They simulate these strikes through numerical modeling and by running actual current through airplane materials.

Michael and fellow researchers are part of the Boeing Research & Technology organization. They simulate these strikes through numerical modeling and by running actual current through airplane materials.

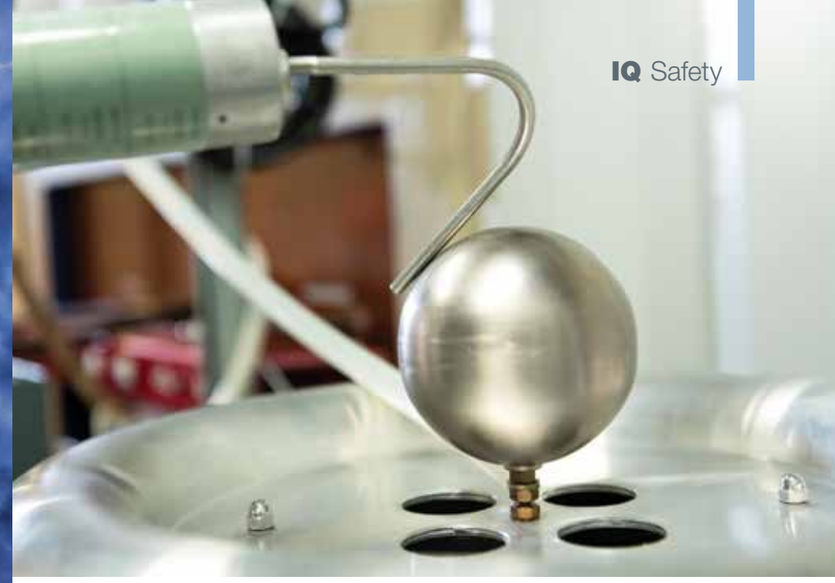
PHOTO: KAITLIN STANSELL/BOEING

SPARKING IDEAS

(Above and left) Michael sets up the lab and test fixture and validates all necessary safety measures were taken before generating lightning-like electric current to pass through composite airplane parts.

ELECTRIFIED

Ben Westin (left), an electromagnetic effects engineer, and Michael check the test fixture and turn on its voltage measurement tools.



BALL OF LIGHT

Following safety procedures after the test, all equipment is checked with a grounding rod to ensure it's safe for the team to interact with. This includes the voltage divider, the device used to set up the lightning strike at the correct voltage.

LIGHTNING ROD

Michael confirms the test fixture is no longer energized by using a grounding rod, a designated electrical path used to safely release any remaining static voltage.

ILLUMINATING

The team was able to use lab-simulated lightning to zap a fastener with high levels of electric current and study its reaction. This provides essential data for model validation.

Getting struck by lightning is a metaphor for something extremely rare. But it does happen on occasion to airplanes, so the physics at play in the lightning lab is relevant to just about every airplane in service.

Airplanes are designed to withstand lightning strikes as they soar through the clouds and through weather. And when a strike happens, ground inspections identify any potential damage and evaluate if any repairs are needed before the airplane returns to service.

Lightning protection is engineered into Boeing airplanes and their sensitive electronic components. The EME crew's research can inform how parts are designed, the recommended allowable damage limits, and maintenance and repair practices.

> "It was cool to work with detonations. And I thought I could never top that. And yet, I ended up working with lightning."
>
> **LOUISA MICHAEL, ELECTROMAGNETIC EFFECTS ENGINEER**

Collaborative Partnerships

Michael joined the EME team in 2020 with a doctorate from the University of Cambridge. Her current work is an unexpected departure from her research, which focused on sensitized explosions that could break down rock more efficiently.

It served as her first foray into multi-physics modeling, or mathematical simulation, that accounts for interactions between the four states of matter: gases, liquids, elastoplastic solids and plasma.

"It was cool to work with detonations," Michael said of her early research. "And I thought I could never top that. And yet, I ended up working with lightning."

After several industry-led projects as a postdoctoral researcher, Michael joined a new Cambridge team working in partnership with Boeing's EME group. The aim was to create novel algorithms simulating the effects of lightning on airplane parts.

While the task was different from her past projects, Michael says that mathematically, the challenge itself was quite similar: employing differential equations to describe a physical problem. Her work and research at Cambridge and the university's collaboration with Boeing led to Michael joining the EME team full time.

At Boeing South Carolina's EME lab, the experiments take place in an enclosed shield room, with Michael and colleagues observing from a separate wing of the facility. A thermal camera measures how lightning heats up each part. A high-speed camera takes footage of flying particles. And an open-shutter camera captures all light emitted: from the moment the current strikes the material and creates a spark to outgassing.

MAKING A MARK

(From left) Brian Egenriether, an electromagnetic effects engineer, Michael and Westin compare the residue products of scaled and large lightning strikes.

FLASH DRIVE

Michael (left) and Derek Tuck, an electromagnetic effects engineer, review data produced by the EME lab's lightning pulser.

PHOTO: KAITLIN STANSELL/BOEING

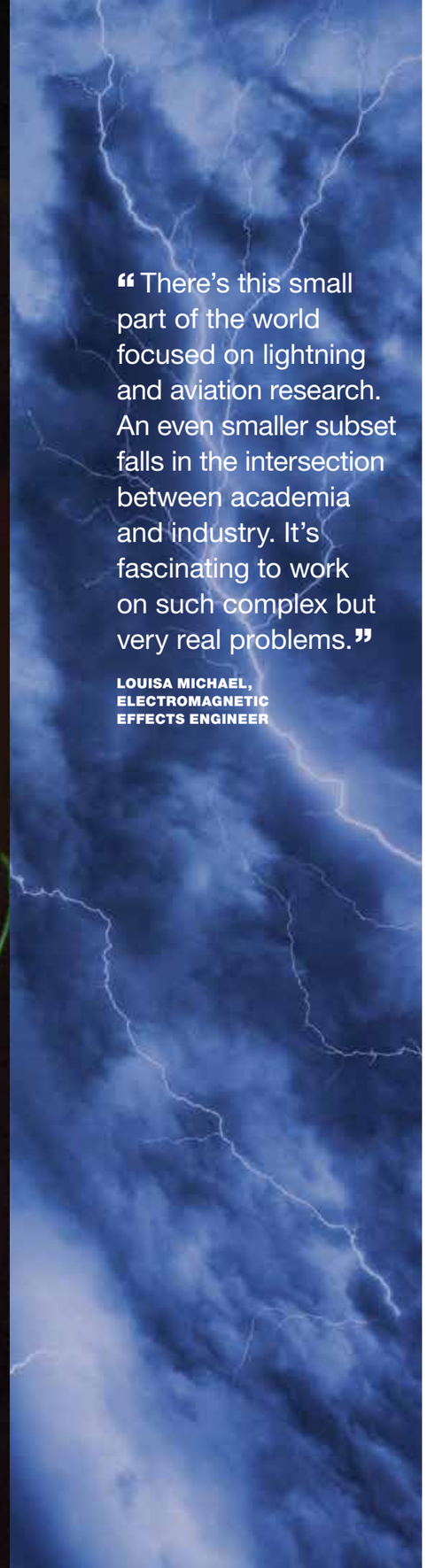
TIGHT LIGHT

Westin examines the test coupon for signs of visible lightning-induced delamination.

LIGHT SHOW

Collecting test data for lightning ignition hazards to validate numerical models, a camera inside the team's test fixture captures a flash of light.

PHOTO: EME TEAM/BOEING



> "There's this small part of the world focused on lightning and aviation research. An even smaller subset falls in the intersection between academia and industry. It's fascinating to work on such complex but very real problems."
>
> **LOUISA MICHAEL, ELECTROMAGNETIC EFFECTS ENGINEER**

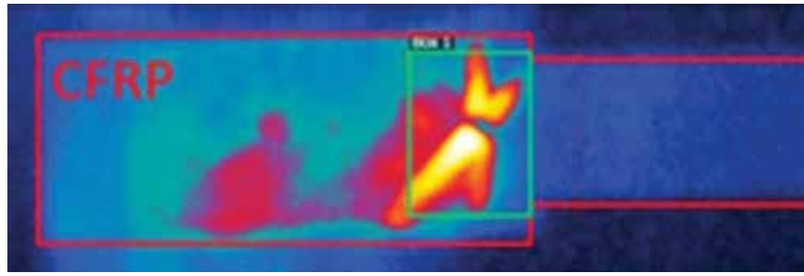
Nuts and Bolts and Volts

The Boeing-Cambridge partnership continues to shape the EME unit's approach to future research and model-based engineering. The studies can assess the impact of lightning down to an airplane's nuts and bolts. Teams will ultimately determine how Boeing might apply findings to its aerospace technology.

Now two years into her role, continuing to work with Cambridge has allowed Michael to keep one foot in both worlds — industry and academia — after finding an unexpected niche.

"There's this small part of the world focused on lightning and aviation research. An even smaller subset falls in the intersection between academia and industry," Michael said. "It's fascinating to work on such complex but very real problems.

"I get to experience them firsthand. I get to collaborate with other people around the world who share my expertise in this area," she continued. "And all this would have not been possible without the very talented Cambridge research team and my exceptional Boeing EME teammates. It's pretty exciting to see all of that coming together." **IQ**



HUED BY HEAT

The team measures composite temperatures using thermal imaging to understand the complex physics of lightning and subsequent effects. CFRP stands for carbon fiber reinforced plastics.

PHOTO: EME TEAM/BOEING

BOOST YOUR IQ!

Meet the team.
See lightning happen.

IQR

The Scenic Route to Space

Two rocket scientists overcome challenges and bring others along for the ride

Negative Turned Positive

Sandra Senegal Purdom beat the odds the day she was born.

Her mother went into labor three months early. Baby Sandra was not expected to live. Doctors asked her father, a U.S. Army officer on leave, to make the gut-wrenching decision to save his wife's life. They would try their best to save the baby, too.

Four months later, the Senegals brought their daughter home from the hospital alive, well and ready to take on the world.

"I started out fighting and have fought for everything I have my entire life," Purdom said. "I'm not about to stop now."

BOARD MEETING

Boeing engineers Sandra Senegal Purdom (left) and Patrice Hall run through the build sequence for the Space Launch System engine section Core Stage 3.

PHOTO: LIZ MORRELL/BOEING

ON THE MOVE
Space Launch System's Core Stage 1 rolls out for transport by barge from the NASA Michoud Assembly Facility in Louisiana to Kennedy Space Center in Florida in early 2020.

PHOTO: ERIC SHINDELBOWER/BOEING

"When I told him I wanted to be an engineer, **he said I'd never make it** because I didn't have what it takes."

SANDRA SENEGAL PURDOM, BOEING ENGINEERING MANAGER

Driven by Science

As a Black and Indigenous girl with a proclivity for science, Purdom understood early the challenges that lay ahead. Throughout middle and high school, her parents suggested STEM subjects and influenced her interest in becoming an engineer.

However, the encouragement Purdom received at home wasn't always reflected in the classroom. She was struggling to keep up in a challenging physics class. One of her teachers questioned if she belonged.

"He asked what I wanted to become and if I was planning to go to college," she said. Reflecting on those questions as an adult, she came to a realization. "My teacher didn't think a little Black girl was college material.

"When I told him I wanted to be an engineer, he said I'd never make it because I didn't have what it takes."

Purdom didn't hear "you don't have what it takes." She heard "game on."

"All I thought was, 'I will come back and show you,'" she said.

"That was a great day. He didn't remember what he said, but I told him **his disbelief was my catalyst.**"

SANDRA SENEGAL PURDOM, BOEING ENGINEERING MANAGER

Breaking the Mold

With the energy and determination to succeed, Purdom finished in the top percentile of her California high school class. She was accepted into California State University, Northridge, and decided to pursue chemical engineering. Of the eight students enrolled in her major, she was the only woman and person of color.

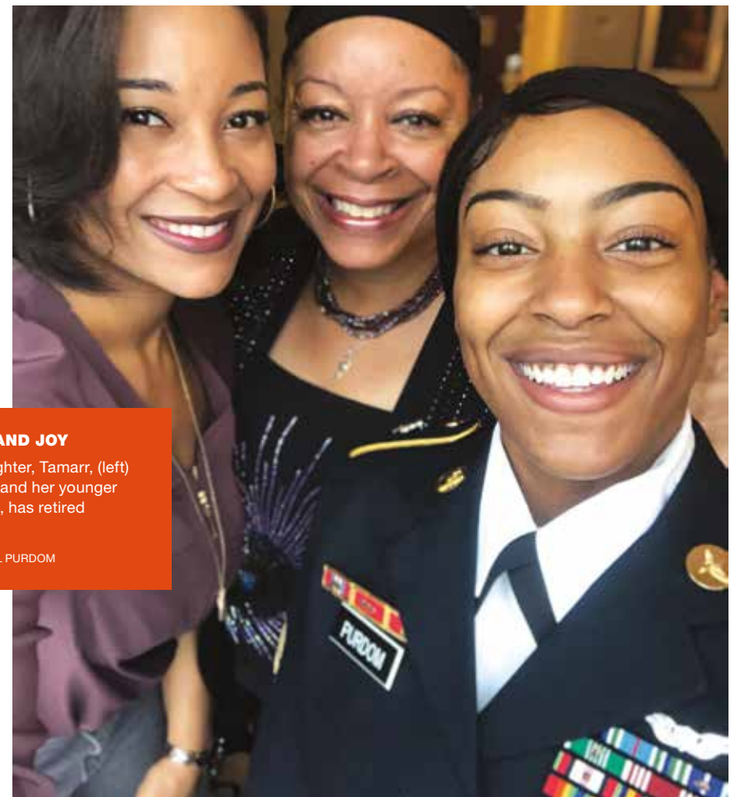
During Purdom's senior year, the school was forced to close the program due to low enrollment. Just another hurdle. Flexible and agile as ever, she switched her focus to mechanical engineering — and made another big decision.

"I got married," Purdom said. By the time she finished her degree, she also had a toddler daughter and another on the way.

"I walked across the stage eight months pregnant, but I made it," she said. "I worked full time and had a 2-year-old when I finished my degree. If you have the tenacity, fight and passion, you can do anything, no matter the circumstances."

With a newly minted college diploma in hand, she went back to her high school to visit her former physics teacher. She said she wouldn't have her engineering degree without him.

"That was a great day," she said. "He didn't remember what he said, but I told him his disbelief was my catalyst."



PURDOM PRIDE AND JOY
Purdom's elder daughter, Tamarr, (left) is a flight attendant, and her younger daughter, Samantha, has retired from the U.S. Army.

PHOTO: SANDRA SENEGAL PURDOM

A Passion for Helping Others

After college, Purdom found her way to Boeing through her work as a contract manager for the Army Corps of Engineers. This experience took her from mechanical and chemical engineering to environmental, safety and quality work.

As a production engineering manager for the company's Space Launch System (SLS) team at the NASA Michoud Assembly Facility in New Orleans, she helped Boeing build the core of the heavy-lift rocket that travels to the moon and eventually to Mars.

Now she's transitioning to a role as a product security engineering manager. She will manage the product and cybersecurity design and planning requirements for the U.S. Air Force E-7 program.

When thinking back to her early challenges and the obstacles she's overcome, Purdom is most proud of following her early instincts.

"All of these great experiences have made me who I am and solidified the passion, values and expectations that I have for myself," she said.

As she's progressed in her career, Purdom acknowledges that, while everyone has the ability to pursue their vocation, they may need help getting there. As a manager, she's focused more effort to help other minority teammates who don't necessarily have the opportunities or mentorship to reach their full potential.

Before joining Boeing, when Purdom owned and operated a consulting company, she helped new business owners understand the federal contracting world and helped Black business owners research resources set aside for historically marginalized groups. At Boeing, she volunteers at job fairs and maintains an open-door policy so young engineers feel comfortable talking about both technical topics and professional development.

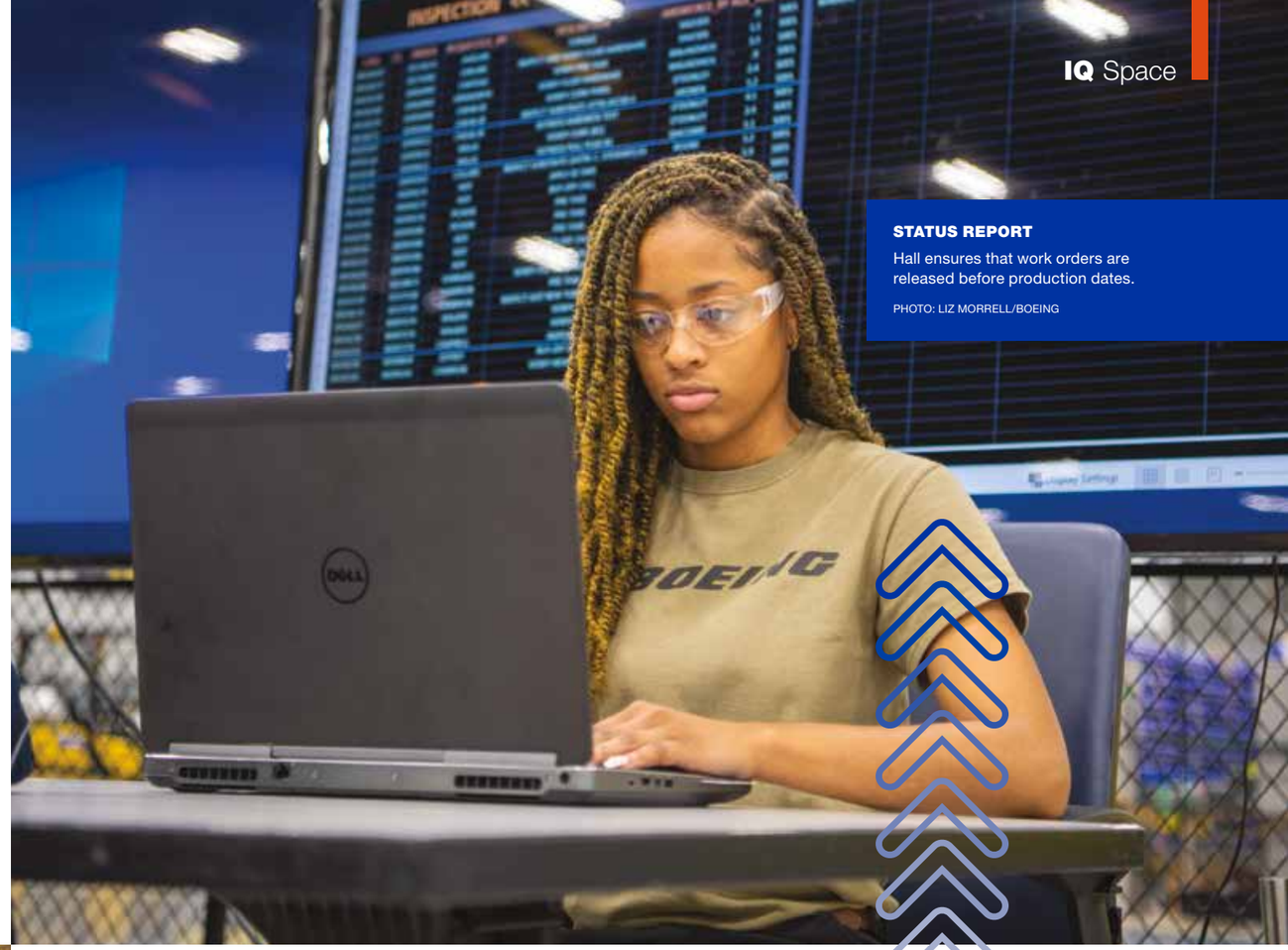
"My passion has always been helping others who aren't necessarily going to get the opportunities or advocacy to help them grow," Purdom said. "I really want to show young engineers what it means to have a manager who truly cares about them and will go to bat for them."

> "All of these great experiences have made me who I am and solidified the **passion, values and expectations that I have for myself."**
>
> **SANDRA SENEGAL PURDOM, BOEING ENGINEERING MANAGER**

DOC CHECK

Purdom (left) and Hall review documents in the shadow of the SLS engine section (behind, left) and the connected liquid hydrogen and liquid oxygen tanks.

PHOTO: LIZ MORRELL/BOEING



STATUS REPORT

Hall ensures that work orders are released before production dates.

PHOTO: LIZ MORRELL/BOEING

Engineer on the Rise

Patrice Hall considers herself lucky.

She became a first-generation college graduate after earning an aerospace engineering degree from Tuskegee University, a storied historically Black university, during the first wave of the COVID-19 pandemic in 2020. She's also one of Purdom's mentees. Hall started at Boeing as an intern then moved into a role as a manufacturing engineer on the build team for the SLS program. She is now a computing architect across the enterprise.

"Patrice is a phenomenal young woman with a bright, wonderful personality and is always looking for new opportunities to learn," Purdom said.

Answering the Call

It took Hall a while to settle on engineering. She was a high-achieving student who enjoyed a variety of subjects. But she always felt most at home with science and math. She ultimately decided to shoot for the stars.

"I've always been curious about space and what's out there," Hall said. "I thought about becoming an astronaut."

> "I've always been curious about space and what's out there. **I thought about becoming an astronaut."**
>
> **PATRICE HALL, BOEING ENGINEER**

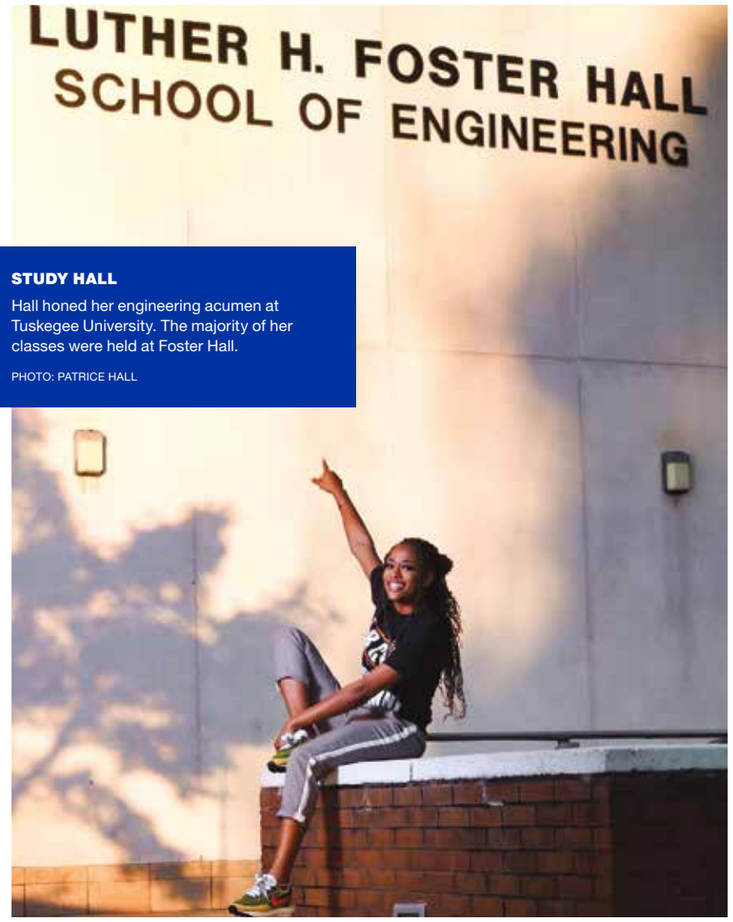
Although both of her parents strongly encouraged her educational pursuits, neither had graduated from college. So Hall began the arduous task of navigating these uncharted waters herself.

After graduating from high school, she enrolled in community college before eventually transitioning to Tuskegee University. A favorite academic counselor from the community college who was also an alum of the university strongly encouraged her to apply. Hall said it is one of the best decisions she ever made.

"I wouldn't trade my Tuskegee experience for the world," Hall said. "It made me who I am today."

Tuskegee University is the only historically Black college or university with an accredited aerospace engineering program. Hall said that further sealed the deal for her. As an alum, Hall keeps in contact with her Tuskegee engineering family, and like a family, they offer solace during hard times and celebrate their triumphs together.

"That's what makes us so tightknit," she said. "As alums, undergrads, we know the struggle, but we know we're able to rise above it. Tuskegee believes in and invests in its students. As an homage, we do the same for Tuskegee."



STUDY HALL
Hall honed her engineering acumen at Tuskegee University. The majority of her classes were held at Foster Hall.

PHOTO: PATRICE HALL

> "I wouldn't trade my Tuskegee experience for the world. **It made me who I am today."**
>
> **PATRICE HALL, BOEING ENGINEER**

GRADUATION DAY
In May 2021, Hall graduated magna cum laude from Tuskegee University with a bachelor's in aerospace engineering. Here she celebrates with (from left) her stepmom, Earllette Hall; dad Patrick Hall; mom Samantha Walden; and stepdad Anthony Walden.

PHOTO: PATRICE HALL

Pushing Forward

Although Hall drifted away from her early dreams of becoming an astronaut, her passion for space and exploring the stars remains stronger than ever. She has high hopes that one day soon she can say she helped send a crew into space.

Of all the experiences and opportunities at Boeing, she most values building relationships with mentors. "I didn't realize just how important mentorship is until I got into the real world," Hall said.

The guidance she received from these pathfinders influenced and reaffirmed her passions, values and career choice. She said this personal connection and counsel is especially important in a highly technical field.

"You never know what route you'll take. And it's important to find someone willing to embark on that journey with you," Hall said. "Seeing people like Sandra as managers, pushing forward — you just don't realize that you can be in that position until you see someone like you there." **IQ**

Diversifying Engineering

As women engineers, Sandra Senegal Purdom and Patrice Hall represent a slim demographic of STEM professionals. Women account for just 13% of all U.S. engineers, according to the Society of Women Engineers (SWE).

Those numbers get even smaller when considering specialization. Only 8% of mechanical engineers are women, according to the U.S. Census Bureau. For women of color, the number continues to shrink, as they comprise less than 2% of all engineering professionals, according to SWE and the National Society of Black Engineers.

Around the world, women remain underrepresented in engineering despite gains in overall professional and technical achievement.

The World Economic Forum published the Global Gender Gap Report 2020, which includes the gender gap as observed in five-year hiring trends on LinkedIn. According to the report, women account for nearly half of professional and technical workers around the world, but their representation lags in engineering (15%).

Boeing has committed to addressing this gap by investing in STEM education and workforce development programs aimed at diversifying the aerospace industry. In 2021, Boeing contributed approximately $44 million across 296 grants in support of STEM education and workforce development programs and reached 2.7 million young women and girls through various company-sponsored STEM programs.

At this year's Space Symposium in Colorado Springs, Colorado, Boeing became one of the 14 charter signatories of the Space Workforce 2030 Pledge. The document affirms the company's commitment to advancing diversity across the aerospace industry and beyond.

In 2021, Boeing provided $3.4 million in grants to support historically Black colleges and universities (HBCU) through scholarships, student programs and curriculum development, and Thurgood Marshall College Fund (TMCF) programs. Hall is a beneficiary of a Boeing | TMCF scholarship.

Boeing Executive Vice President and President and CEO of Boeing Defense, Space & Security Ted Colbert, a Morehouse College graduate, presented Hall with the scholarship during a gala in Washington, D.C. "At the time, it didn't feel real," Hall said. "It was really special to see him there, especially knowing he's also an HBCU graduate."

TWO ROBOTS, ONE OF A KIND

Boeing's new dual robotic antenna measurement system (DRAMS) lab, located in Seattle, is the only known 14-axis antenna range. The robot shown here is one of two in the DRAMS anechoic chamber (free of echoes and reverberation).

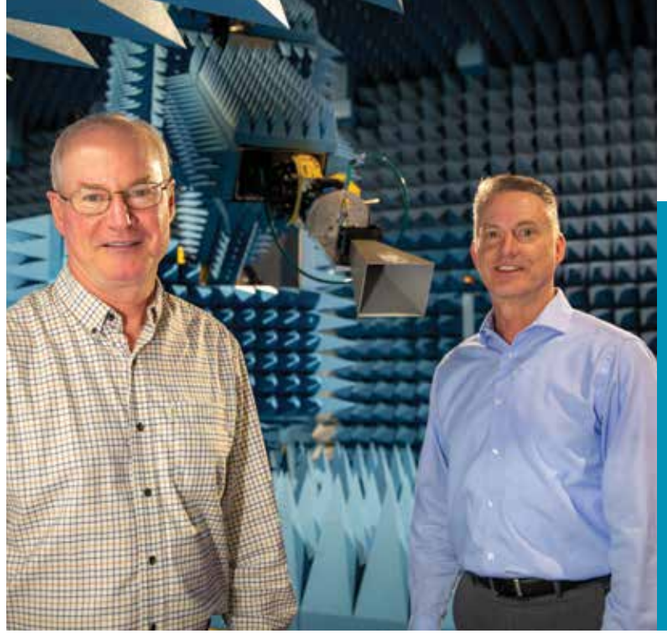
Robot Room

Dual robots provide faster, more accurate antenna testing

BY MICK BOROUGHS, BOEING WRITER

Decades ago, it was quite common to see an antenna strapped to a chimney to get the best TV reception or attached to the hood of the family station wagon to pick up a favorite song on the radio. Antennas were a silent part of everyday life all over the world.

ALL PHOTOS: DAVE SIZER/BOEING (UNLESS INDICATED)



DRAMS DREAMERS

Technician Wayne Cooper (left) and engineer Dennis Lewis are part of the team that runs the DRAMS lab in Seattle.

Though antennas may be less visually obvious in this digital age, they are still everywhere. Nearly everything designed, produced or serviced at Boeing has an antenna, from aircraft to spacecraft.

The antennas are used in the labs to test Boeing products and ensure they meet regulatory and performance requirements. Additionally, they transmit and receive information related to weather data and navigation, and they allow aircraft to communicate with other aircraft and the ground. Antennas also enable communications between satellites and GPS navigation and provide connectivity between portable electronic devices such as cellphones, laptops and tablets.

Each antenna must first be calibrated and traceable to the National Institute of Standards and Technology (NIST), the government agency that manages the antenna standards for the United States. To do that, Boeing uses antenna ranges — such as one in Kent, Washington — to measure the performance of an antenna.

More efficient technology and subsequent safety improvements, however, helped demonstrate the need for an updated calibration and developmental testing center — one that could also drive business results by allowing future consolidation of other existing labs into this new facility.

In May, Boeing opened its new dual robotic antenna measurement system (DRAMS) lab, following four years of planning and development. The lab fits into existing laboratory space in Seattle.

> “This is the Boeing precision antenna lab. … All other Boeing labs derive their accuracy from the antennas calibrated here. This gives Boeing the technological advantage, as it is one of the most state-of-the-art ranges in the world.”
>
> **WAYNE COOPER,**
> **DRAMS LAB LEAD TECHNICIAN AND**
> **BOEING ASSOCIATE TECHNICAL FELLOW**

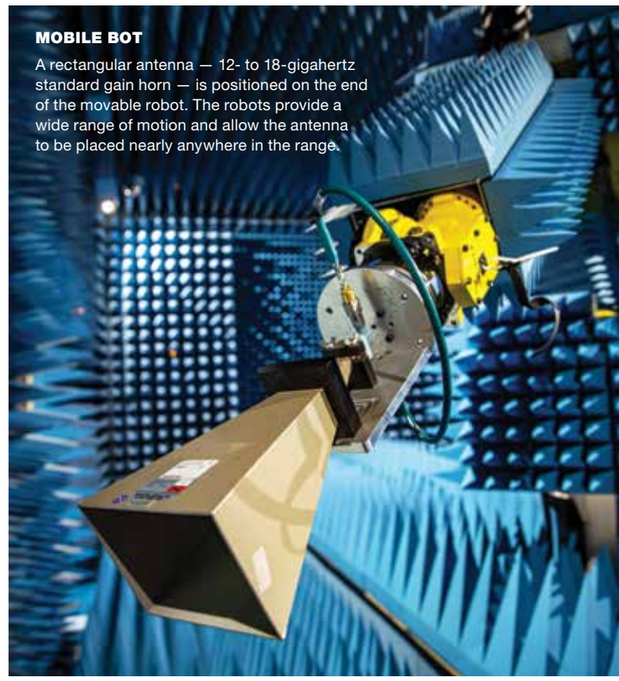
ROOM TO ROAM

The robot on the left moves on a 30-foot (9-meter) track. The robot on the right remains in a fixed position. The floor and the robots can be covered with radar-absorbing foam.

PHOTO: BOEING

MOBILE BOT

A rectangular antenna — 12- to 18-gigahertz standard gain horn — is positioned on the end of the movable robot. The robots provide a wide range of motion and allow the antenna to be placed nearly anywhere in the range.



“This is the Boeing precision antenna lab. This is where Boeing standards are directly compared to NIST standards,” said Wayne Cooper, DRAMS lab lead technician and a Boeing Associate Technical Fellow. “All other Boeing labs derive their accuracy from the antennas calibrated here. This gives Boeing the technological advantage, as it is one of the most state-of-the-art ranges in the world.”

WELCOME TO OUR PAD

This is one of two doors to the anechoic chamber.

The lab includes a 40-by-25-foot (12-by-8-meter) anechoic chamber and comes equipped with a stationary robot on a fixed pedestal. A second robot moves along a 30-foot (9-meter) track. The chamber is covered floor to ceiling by cone-shaped, radar-absorbing foam.

Each cone is filled with polyurethane and carbon to absorb electromagnetic energy. The anechoic chamber is used to keep out unwanted electromagnetic energy, such as cellphone transmissions. The chamber also effectively contains any energy created.

“When the door is closed, nothing gets into that room and nothing gets out,” Cooper said. “It is completely shielded.”

The lab supports multiple types of tests, including remote testing. It is also adaptable to test new technologies while providing more accurate and faster results.

“We can measure an antenna in a much smaller space — so instead of using a large outdoor testing range, we can measure it in a facility this size,” Cooper said. “Anytime you want to know how much electromagnetic energy you have, whether it be antenna gain or volts per meter, you have to have a calibrated antenna.”

In the lab’s chamber, Cooper steps up 6 inches (15 centimeters) to easily attach the antenna to the robot’s arms while the robot is positioned at the chamber’s door. At the soon-to-be decommissioned

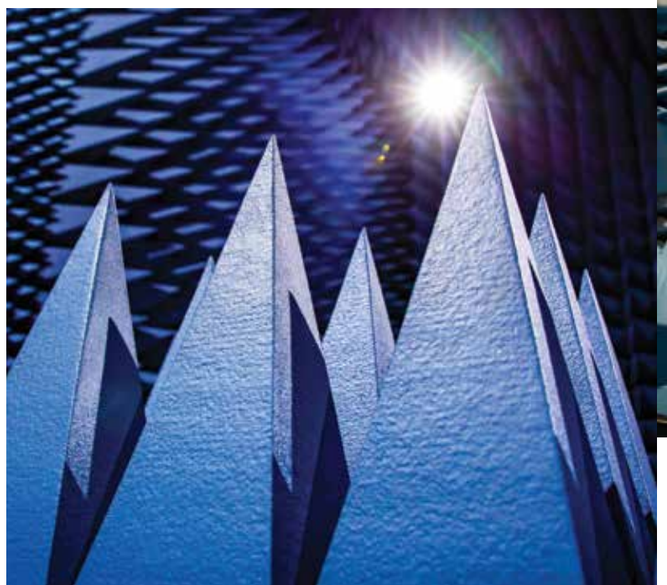
> “When the door is closed, nothing gets into that room and nothing gets out. It is completely shielded.”
>
> **WAYNE COOPER, DRAMS LAB LEAD TECHNICIAN AND BOEING ASSOCIATE TECHNICAL FELLOW**

DOOR NO. 2

The larger door into the chamber is 8 feet tall by 10 feet wide (2.4 meters tall by 3.1 meters wide), accommodating large equipment.

MUFFLING MOUNTAINS

The entire chamber is lined with cone-shaped foam to absorb electromagnetic energy.



FLEXIBLE ON THE FLY

In the DRAMS lab, unlike at many ranges, technicians can easily access the robots to make adjustments.

> “There is a lot of interest in the antenna community about robots because they are so flexible. We used to have to align the antennas to the room geometry, but that can all be done through the robots now. Before, the axis of motion was fixed. But now with the robots, we can have the axis wherever we want. Previously, we could move one antenna across one straight line. Now we can move that straight line anywhere in the chamber.”
>
> **DENNIS LEWIS,**
> **PROJECT TECHNICAL LEAD AND**
> **BOEING TECHNICAL FELLOW**

Kent range, Cooper and others would need to be safely harnessed before climbing a 15-foot (4.6-meter) platform to set up the calibration. “This is now so much safer and also less expensive to maintain,” he said.

Robots also offer a wider range of capabilities, said Dennis Lewis, project technical lead and a Boeing Technical Fellow.

“There is a lot of interest in the antenna community about robots because they are so flexible,” Lewis said. “We used to have to align the antennas to the room geometry, but that can all be done through the robots now. Before, the axis of motion was fixed. But now with the robots, we can have the axis wherever we want. Previously, we could move one antenna across one straight line. Now we can move that straight line anywhere in the chamber.”

When the lab chamber is in use, the door is shut, and the technician monitors the results on a fully automated control panel. Closed-circuit cameras rotate views from inside the chamber. Array patterns shown on the screen mark the calibration’s progress.

“You can monitor everything from this panel,” Cooper said. “You set up your frequencies, the polarization, and the distances and technique. Those are all important to think about before you run your calibration.”

Over time, a calibrated antenna will need recalibration — sometimes within three years. Parts become worn or damaged, and repairs can change the quality and characteristics of an antenna.

While the calibration is underway, the operator can perform other tasks and return to it when the test is done. “I can process data from a previous run while this is occurring,” Cooper said. “Calibrations that took three days at the Kent range take a few hours at the Seattle lab.”

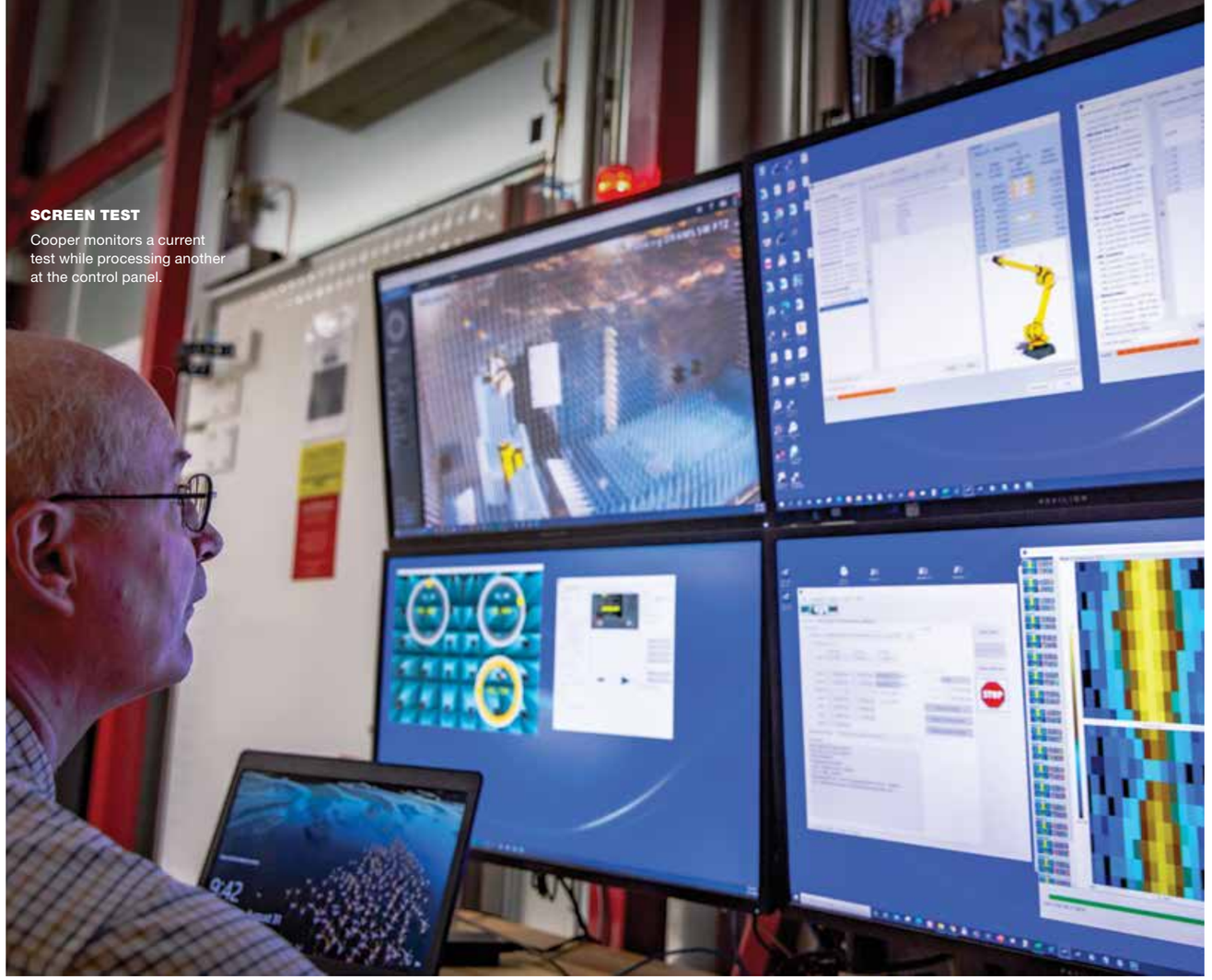
The test team can also use model-based engineering (MBE), allowing them to run a variety of simulations on the lab’s computer. Using computer-aided design (CAD) models of the chamber, robots and antenna together with electromagnetic simulation software, the antenna can be “tested” digitally before ever entering the test chamber.

PRETEST PREP
Cooper manipulates the robot using a device called a pendant, which controls all seven of the movable robot’s axes and allows a greater range of motion than software alone.

This simulated test, a digital twin, allows the team to analyze the data and the potential electromagnetic impacts of the chamber and robots before the actual antenna ever reaches the lab, potentially saving time and cost.

Another example of how the team uses MBE is analyzing the logistics of bringing a large antenna into the lab. Perhaps a large antenna is scheduled for delivery to the lab from another site. The antenna's dimensions are 5 feet by 5 feet (1.5 meters by 1.5 meters). "We know that results in a 7-foot-wide [2-meter-wide] diagonal array. We didn't want to bring it down here, only to find out it wouldn't fit," Cooper said.

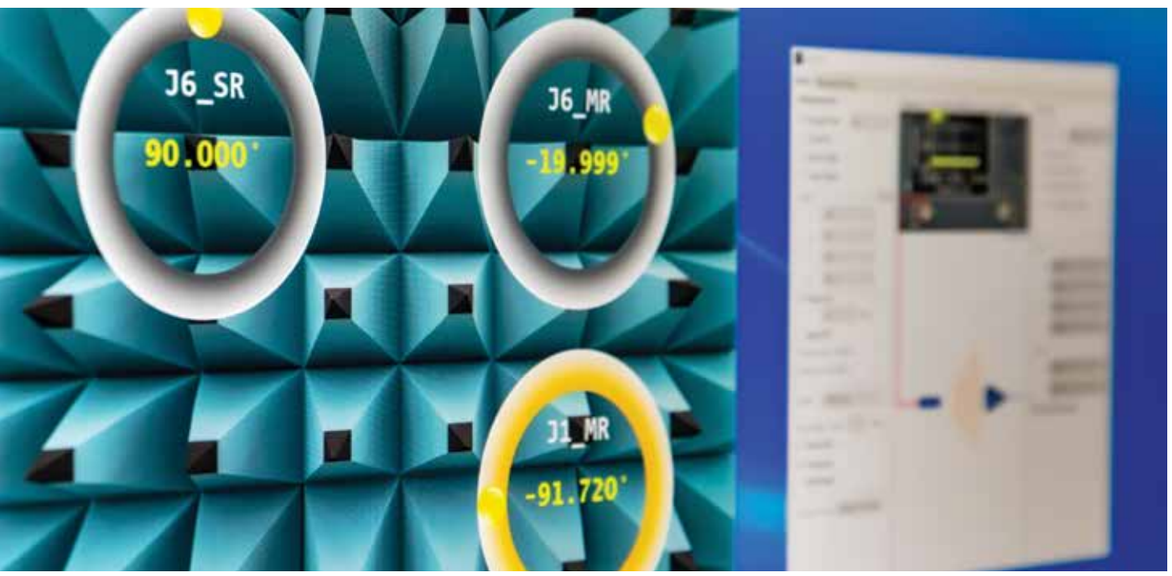
Antennas are shipped to the lab from around the world. While most antennas are from Boeing sites, some of those to be calibrated are from other companies and suppliers.



SCREEN TEST

Cooper monitors a current test while processing another at the control panel.

This simulated test, a digital twin, allows the team to analyze the data and the potential electromagnetic impacts of the chamber and robots before the actual antenna ever reaches the lab, potentially saving time and cost.



FULL CIRCLES

This control screen tracks robots' positions, and the operator can click on the gray circles to move robots within the range. The numbers show the rotational position of the SR (stationary robot) and MR (movable robot). The yellow circle (lower right) represents the antenna attached to the MR.

"It's not a big part of our business, as most companies have their own ranges or use a commercial range," Cooper said. "There has to be a compelling reason to send it here. A lot of times it's part of a joint program with Boeing. They know we can do it more quickly."

The lab's future capabilities will include material measurements and electro-optics. It can also test antennas in motion to simulate tracking radar, which was difficult to do in previous testing facilities.

In 2023, the lab will expand to commercial and military radome qualification testing and servicing. Radomes are protective structures on an aircraft that are transparent to radio waves, such as those on a nose cone of an airplane where weather radar is located.

What gives Cooper, now in his 37th year at Boeing, the most job satisfaction?

"That's easy," he responded. "It's innovation like what we're able to do now in this new lab, and that's followed closely by customer satisfaction." **IQ**

BOOST YOUR IQ!

Video: Meet the team. See the robot in action.

The Cascade Effect

How Boeing's net-zero modeling tool maps the future of sustainable flight

BY QUEENA JONES, BOEING WRITER

Navigators know alternate routes exist for most destinations, but a map helps them see their options.

As the global aviation industry charts the path to its goal of net-zero carbon emissions by 2050, Boeing is taking the guesswork out of decarbonizing aerospace by creating a map.

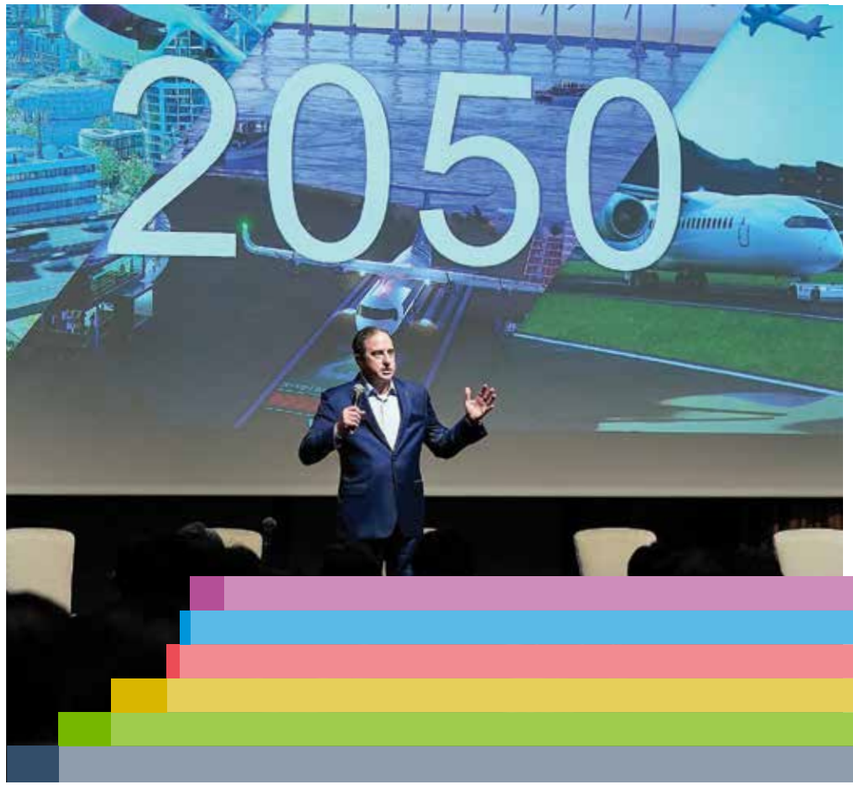
Called the Cascade data modeling tool, it identifies the effects different sustainability solutions have on carbon emissions. It examines the full life cycle of alternate energy sources, from production through distribution and use. And it quantifies the power of multiple strategies to cut emissions.

FUTURE FUEL

Boeing's Cascade modeling tool shows sustainable aviation fuel (SAF) as the most effective near-term strategy to reduce emissions. The Boeing ecoDemonstrator program has been flying with and testing SAF since 2012.

PHOTO: PAUL WEATHERMAN/BOEING

> “The Cascade model allows the industry to visualize for the first time the real climate impact of each of Boeing’s major paths to decarbonize aviation and to inform the most probable and effective strategies to reach net-zero by 2050.”
>
> **CHRIS RAYMOND, CHIEF SUSTAINABILITY OFFICER**



TOKYO TOUR

Sharing Cascade at the opening of a sustainability research facility in Tokyo, Chief Sustainability Officer Chris Raymond explains how the modeling tool projects the multiple paths to net-zero carbon emissions.

PHOTO: BOEING

“The Cascade model allows the industry to visualize for the first time the real climate impact of each of Boeing’s major paths to decarbonize aviation and to inform the most probable and effective strategies to reach net-zero by 2050,” said Chris Raymond, Boeing’s chief sustainability officer. “All this allows data to be front and center of the conversation as airlines and governments discuss priorities and enablers for decarbonization.”

The efforts align with the industry’s long-term goal of achieving net-zero carbon emissions by 2050, an initiative the International Civil Aviation Organization recently adopted as well.

In 2019, the civil aviation industry generated 900 million tons (816 metric tons) of carbon emissions, which is 2.6% of the world’s total emissions and 12% of transportation emissions.

To reach net-zero aviation emissions, Cascade highlights four strategies as the most impactful:

- **Fleet Renewal**
  New airplanes provide significant efficiency gains, as each generation reduces fuel use and emissions between 15% and 25%. Flying the latest-generation airplanes is the most significant contribution to carbon emissions reduction available over the next decade.

- **Operational Efficiency**
  Future flight must be safe and sustainable. More efficient air traffic management operations — such as continuous descent approaches — can reduce emissions by about 10%, according to Eurocontrol, a collaboration to make aviation in Europe safer, more efficient and more cost-effective, with minimal environmental impact.

- **Renewable Energy Transition**
  Renewable energy is critical to reducing carbon emissions, both in industry operations and in products and services. For Boeing products, renewable energy can include sustainable aviation fuels (SAF), green hydrogen and batteries. After 15 years of research and testing, SAF is widely accepted today as a drop-in replacement for conventional jet fuel. SAF works with existing airplanes and offers the greatest potential to reduce carbon emissions in all aviation segments by 2050.

- **Advanced Technology**
  Meeting the industry’s net-zero commitment by 2050 will require more than SAF. Boeing research, testing and partnerships are developing the “SAF and” technologies necessary for sustainable aviation. These include the latest digital design, test and production tools, along with new airframe, propulsion and systems technologies. Alternate power and energy solutions will apply to various markets and different aircraft sizes.

One of the variables that Cascade assesses is how different types of renewable energy impact the environment throughout their life cycle. This includes the emissions required to produce, distribute and use energy carriers such as hydrogen, electricity and SAF.

WHAT IF

Steve Altus, Boeing Technical Fellow, runs different sustainability strategies through Cascade during a GreenBiz Group event in California.

PHOTO: MONICA ZIMMER/BOEING

“Cascade helps airline operators, industry partners and policymakers see when, where and how different fuel sources affect their sustainability goals,” said Neil Titchener, Cascade program leader. “The tool shows how incremental changes can cut emissions in commercial aviation.”

Cascade models indicate that electric- and hydrogen-powered aircraft are likely to have limited impact on sustainability by 2050. Range constraints will diminish the market potential of electric aircraft. Hydrogen, when made from renewable energy sources, has the potential to improve the production of drop-in SAF and to evolve into a low-carbon-impact fuel for use with future propulsion, flight and infrastructure technologies. But, long development cycles, certification timelines and production ramp-up times will restrain the near-future influences of hydrogen aircraft. Further studies will determine the sustainability of these and other energy sources.

“Cascade highlights the importance of calculating emissions across the entire life cycle of the energy source, not just at the point of use,” said Titchener. “The total climate impact of a solution’s cumulative emissions determines its sustainability. Zero tailpipe emissions is not the only goal.”

Origin Story: Where Does SAF Come From?

A variety of feedstock sources give power to SAF

Oils and fats	Crops	Residues	Waste	Waste gases	Renewables
Food byproducts	Nonedible sugars, grains and seeds	Agricultural and forestry	Solid and industrial	Carbon monoxide and carbon dioxide	Solar, wind, hydro and nuclear

GRAPHIC: BOEING
PHOTOS: GETTY

Cascade

In a Cascade demonstration using a sample of 2019 global flight data, Raymond showed how replacing previous-generation jets with current airplanes would reduce global carbon emissions by 17%. Operational efficiencies, such as winglet retrofits and air traffic management improvements, would drop carbon another 6%. Converting to a half-SAF blend alone would more than match those numbers, with a 29% emissions-reduction benefit.

“Clearly, SAF offers the most immediate and greatest potential to reduce carbon emissions in aviation over the next 20 to 30 years,” said Raymond. “Depending on the feedstock, or the SAF source, carbon emissions over the fuel’s life cycle can be lowered by up to 80%.”

BY THE NUMBERS

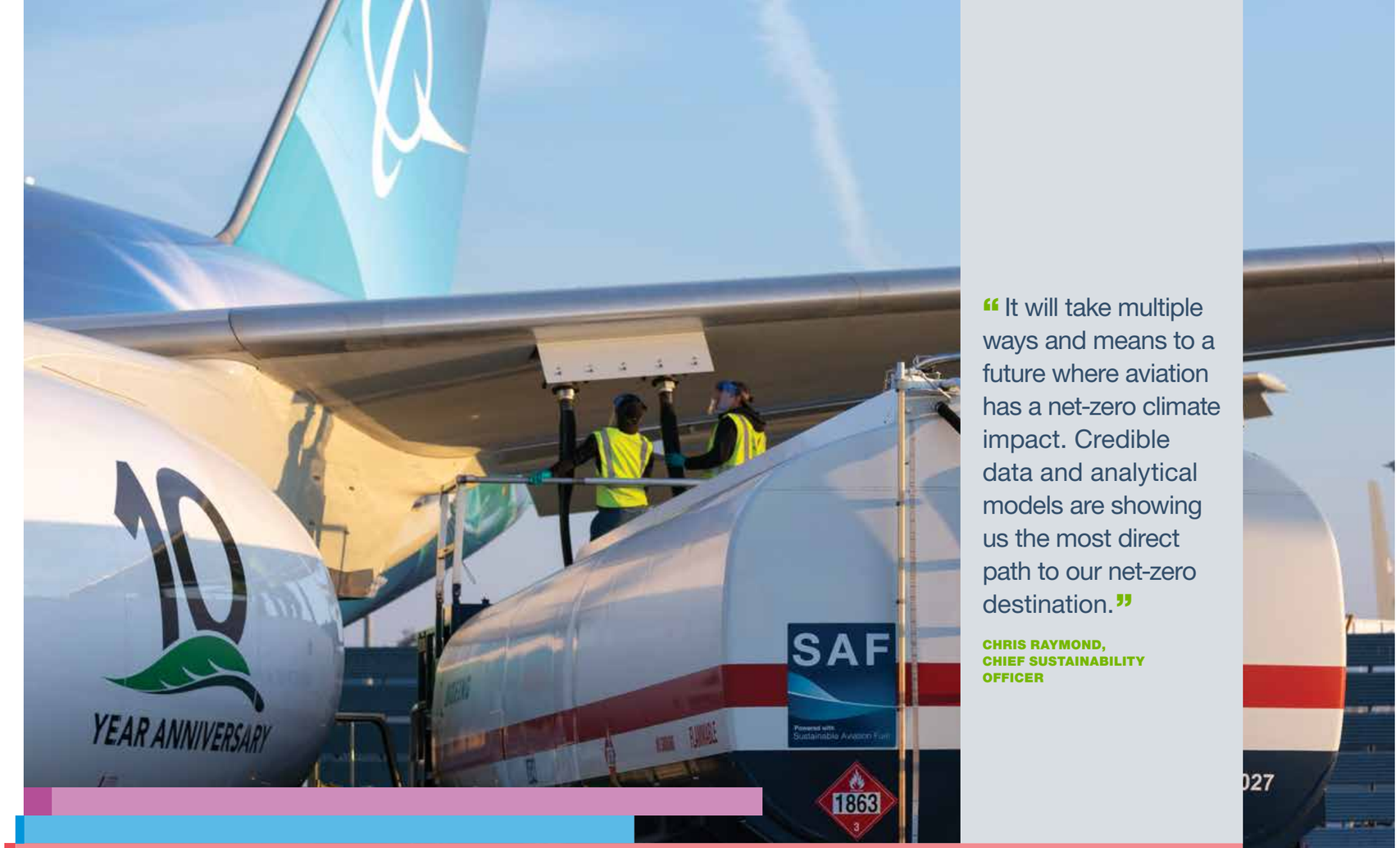
A global group of Boeing engineers, analysts and software developers designed Cascade to calculate the effects of multiple variables on carbon emissions. As a user enters data, Cascade immediately projects potential impact.

IMAGE: BOEING

> “Cascade helps airline operators, industry partners and policymakers see when, where and how different fuel sources affect their sustainability goals. The tool shows how incremental changes can cut emissions in commercial aviation.”

**NEIL TITCHENER,
CASCADE PROGRAM LEADER**

PHOTO: JOSH GREEN/BOEING



FILL IT UP

Aviation maintenance technicians Peter Nease and Clarence Santiago fuel the 2022 Boeing ecoDemonstrator, which flies on a 30/70 blend of SAF and conventional jet fuel.

PHOTO: BOEING

SAF can be made from various materials, called feedstocks, including nonedible plants, agricultural and forestry waste, nonrecyclable municipal waste and industrial plant off-gassing. The fuel's production requires multiple feedstocks to meet the demand, Raymond said. And its development and production create jobs across multiple industries and drive economic growth around the world.

Non-drop-in fuels and energy carriers such as hydrogen can complement SAF in our efforts to decarbonize aviation, according to Titchener. However, there is a lot of uncertainty as they will require radically different designs, new safe certification approaches, and systemwide ground and network infrastructure updates.

Modeling tools like Cascade can help us evaluate the opportunities and challenges of these diverse approaches under various scenarios with different assumptions — and ultimately help us meet our sustainability goals.

"It will take multiple ways and means to a future where aviation has a net-zero climate impact," Raymond said. "Credible data and analytical models are showing us the most direct path to our net-zero destination." **IQ**

> "It will take multiple ways and means to a future where aviation has a net-zero climate impact. Credible data and analytical models are showing us the most direct path to our net-zero destination."
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> **CHRIS RAYMOND, CHIEF SUSTAINABILITY OFFICER**

BOOST YOUR IQ!

See Cascade's powers of prediction in action.

The Power of Cascade

Chris Raymond, Chief Sustainability Officer

The aviation industry connects people and cultures, ships goods to people's doorsteps, provides humanitarian relief and national security and takes people to space. To put it mildly, our industry does amazing things.

Collectively, as we maintain and grow those societal benefits, our goal is to have zero impact on our planet. When it comes to industry decarbonization, we believe it will take "everything for zero."

Everything includes a mix of four strategies: fleet renewal, operational efficiency, renewable energy and advanced technology.

However, it can be daunting to think about those approaches and the complexity around them. There are a lot of potential technologies we could use to achieve our industry's goal to reach net-zero emissions. It's not always clear how any one of those technologies, when inserted into the fleet, actually impacts total life cycle emissions.

In order to start to bring to life our four strategies with respect to the technologies and the products that we're building or will build in the future, we produced Cascade.

Where Cascade is really powerful is not just in providing operational statistics, but in actually inserting different technology interventions — such as hydrogen or electric aircraft — into the fleet to see how much of a life cycle climate impact they have.

We intend to make this tool available to the community, to policymakers, to customers, to engineers, to anyone who wants to use it to understand how these technologies and strategies will affect the fleet.

Cascade is helping to put data front and center in the conversation about decarbonizing aviation — and that's exciting.

CHRIS RAYMOND

Chief Sustainability Officer

PHOTO: LARRY CANNER

IQ in your inbox

Join **Team IQ** as we share Boeing's story of innovation.

You'll receive emails with up-to-the-minute articles, photos and videos that invite you inside the future of aerospace with the people who make it happen.

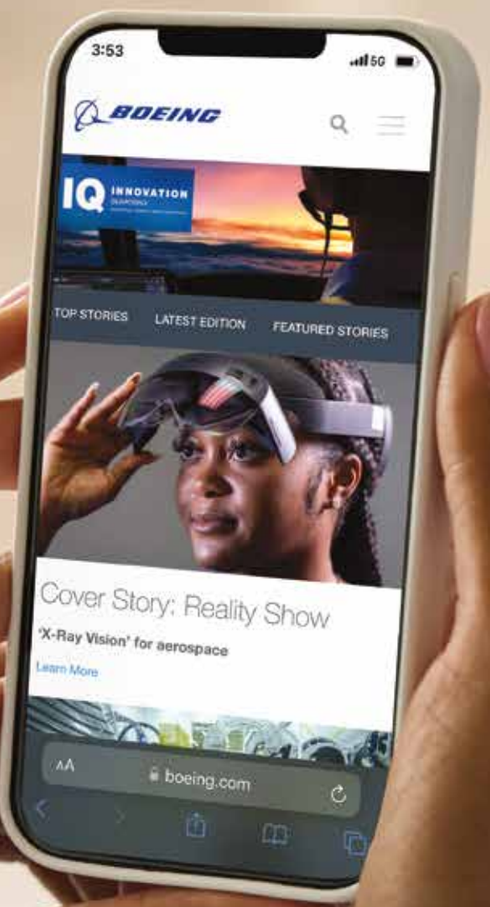

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PHOTO: INSTA_PHOTOS/GETTY

Meet the experts:

New Executive Technical Fellows

Excellence, Technically Speaking

The newest class of Boeing Executive Technical Fellows possesses expertise in a variety of areas spanning the full life cycle of all Boeing products, processes and services, including flight deck architecture, vehicle health management, additive manufacturing, avionics software and infrastructure, product security engineering, human engineering and quantum technologies.

"The breadth and depth of our Technical Fellowship is unique to the industry, and we count on our fellows to be stewards of technical excellence across the enterprise," Boeing's Chief Engineer Greg Hyslop said. "I am confident this group will continue to strengthen our company and industry and help change the world."

Following a rigorous candidate evaluation process, 21 Boeing Technical Fellows advanced to become Senior Technical Fellows (STFs), and nine became Principal Senior Technical Fellows (PSTFs).

Recognized as technology leaders inside and outside the company, the honorees assumed new roles in the executive tier of the Boeing Technical Fellowship, which represents less than one-tenth of 1% of the technical workforce. They are trusted consultants, advisers and mentors, and they will play an even more important role in the future as drivers of the company's design practices.

PHOTOS: BOEING

Senior Technical Fellows

Raenaurd Turpin
Digital Sensors and Computing System Design

I was inspired by my parents' military, aerospace engineering and athletic backgrounds; these led me to connect my passion for electronics to futuristic missions and concepts at an early age. My parents also impressed upon me that it takes vision, hard work and a great team to deliver results.

Each day, I have the privilege of inspiring, empowering and integrating diverse teams comprised of the world's greatest experts. We connect and protect globally, ultimately enabling opportunity, transparency and access to education through the application of innovative technologies and systems.

I am blessed and honored to have been selected as a Senior Technical Fellow. The Boeing Technical Fellowship provides an unrivaled opportunity and responsibility to learn, mentor and coach alongside individuals of exceptional stature as we fulfill our roles as stewards of Boeing technical priorities.

The emergence of new technologies and the accelerating pace of innovation will transform our world in ways that we cannot imagine over the next 20 years. Advanced microelectronics and photonics, coupled with machine learning, will bring new materials, medicines, computational power and missions within reach.

ELECTRONIC AND ELECTRICAL ENGINEERING

Stephen Coombes
Electromechanical Packaging Design and Analysis

As a student engineer, I was introduced to electronic systems and their associated mechanical design and analysis. I found it fascinating that these systems required solutions across all classical mechanical engineering domains: thermal, dynamics, fatigue, material science and manufacturing processes. Because of that engineering variety, I chose to pursue a career in electronic product design and analysis.

I love the diversity of products for which I get to design, from satellites and manned spacecraft to tactical aircraft, commercial aircraft and watercraft. Each product design is interesting and offers a new and different engineering challenge.

I am blessed to work with such a group of highly talented, gifted engineers. Being part of this Fellowship gives me an opportunity to share my talents and learn from my colleagues.

I have the ability to drive and influence technologies that protect our fellow citizens, allow us to travel on Earth and beyond, and enable a safer, more productive life for all people.

FLIGHT ENGINEERING

Darren Fricker
Aerodynamics and Computational Fluid Dynamics

I was fortunate in high school to have a teacher who invested in me and gave me an appreciation for the fields of math and science, which led me to pursue a degree in engineering. My passion further blossomed in college with an opportunity to perform graduate student research by doing computational fluid dynamics (CFD) development and analysis under a contract with NASA. This laid the groundwork for me to land a job doing very similar work at a time when CFD was still in its infancy.

It is gratifying to see my hard work take flight and perform as intended. What excites me most is the opportunity to deepen my existing relationships and build new ones as we work together to ensure the technical excellence of our future product offerings.

It is a tremendous honor to be selected as a Senior Technical Fellow. I am grateful to the managers and teammates across Boeing who have supported me along the way and encouraged me to stretch, at times further than I thought possible.

Friedrich (Rick) Wilhelm Künzler
Optical Systems Engineering

Several generations on my father's side were opticians in Heidelberg, Germany. My father was the director of research and development at a prominent optical health company. He always brought home neat things like an early helium-neon laser. With my curiosity piqued, I did a book report on holography in the fourth grade and have remained fascinated ever since.

They say if you truly love what you do, you never work a day in your life. I really enjoy tackling complicated problems and collaborating with diverse teams to make a long-term vision a reality.

It is truly an honor to be in the Fellowship program. I am energized by artificial intelligence and digital engineering. We have a lot to learn, and we need to pursue the codification of the next generation of tools and methods. I am excited to be part of that.

Dave Krug
Propulsion and Fuels

As a youth enthralled by aerospace, I aspired to design amazing vehicles. Although aerospace seemed a world away, programs such as the space shuttle provided inspiration to pursue my dream. Once in college, my professors introduced me to the complexities and extremes of propulsion systems. I never looked back.

The most rewarding aspect of my work is the opportunity to collaborate, innovate and solve complex problems with talented teams from around the world. Being a part of the 777 and 787 development teams gave me those initial experiences, which I have leveraged throughout my career.

It is an honor to be recognized as a Senior Technical Fellow. The responsibility to promote and ensure technical excellence in all we do is foundational to our success.

Being on the team that develops, scales and industrializes advances in propulsion is what excites me most about our future. It is these expansions that will enable many of our future products and their capabilities.

INFORMATION TECHNOLOGY AND DATA ANALYTICS

Joshua A. Taylor
Computing Infrastructure Operations

During my senior year of high school on a career day, someone came to talk to us about programmable calculators. That experience led me to change my major to computer science. Since entering the field, I have been fascinated by how we can create the networks that allow all the end systems to communicate.

Now, I am excited about the possibilities technology brings. When I started my career, we had punch cards and mainframes. Today, we have mobile computers that we use to make calls. I believe we have a bright future integrating this technology into how we build and design our products.

Being a part of this elite group is both humbling and daunting. I appreciate the recognition for my accomplishments. I also recognize that there is so much more I can to do ensure that Boeing remains an avionics and industrial leader.

Ali Yousefiani
Next Generation Structural Materials and Manufacturing Technologies

I always wanted to develop products that would help solve the big problems and make our world a better place for generations. Since materials science and engineering is at the crossroads of multiple disciplines, a deep understanding of the field can have a significant impact and yield solutions for large challenges across the board.

The most rewarding aspect of my work has been the ability to align my field of expertise to appreciably advance materials and manufacturing technologies for the aerospace industry. I also get to work with a diverse team of excellent engineers from around the world to learn, teach, coach and mentor.

I am excited about the next generation of materials and manufacturing technologies that promise to provide energy savings, carbon reduction, improved durability and reduced cost, especially as they relate to extreme environment components associated with supersonic/hypersonic flight, atmospheric reentry, rocket/aircraft propulsion, integrated power/thermal management and energy storage. As a Senior Technical Fellow, I feel better equipped to help position Boeing at the forefront of these industrial breakthroughs.

MATERIALS, PROCESSES AND PHYSICS

Talion Edwards
Measurement and Metrology

I was first introduced to 3D measurement as an engineer applying model-based engineering concepts to our legacy aircraft, whose designs were done on paper, in 2D computer-aided drawings. My work enabled me to be part of a technical community with deep roots spanning our engineering, tooling, production automation, alignment, inspection, quality and test functions.

I am honored to be recognized as a Senior Technical Fellow. To me, it signifies that this technical area is a valuable contributor to Boeing's priorities. It also highlights the continued need for technology and resource development in this field.

Dimensional measurement is required to quantitatively connect our digital thread to physical products. In order to close the model-based systems engineering loop that is at the heart of our digital tool set vision, we will need measurement technology and people able to wield it. I am excited to be part of a team that helps Boeing realize its digital vision at scale.

MECHANICAL AND STRUCTURAL ENGINEERING

Robert (Bob) Clark Jr.
Dynamics and Controls, Fluid Transient Analysis

When I was hired in 1988, I was immediately assigned to the space shuttle team. Next thing I knew, I was analyzing regulators and rocket engines. It turned out to be a unique skill that I found engaging and aligned with my education, and it also happened to be in demand across the enterprise.

The most rewarding aspect of my work is watching a system complete a successful test that it previously failed and realizing I was part of the team that made it possible.

The opportunity to serve as an STF for a company that has been building aircraft for over 100 years is incredibly humbling. It is such an honor to be recognized for my contributions and future value to the company.

There is so much to be excited for in the future — trips to the International Space Station, the moon and Mars; protecting our country; safe and reliable air travel; and the continued involvement of Boeing at the leading edge of it all.

Holly Thomas
Composite Materials, Fabrication and Bonding

As a young liaison engineer in St. Louis, I did not know much about composites. But I was surrounded by mechanics and engineers who were passionate and willing to teach. Eventually, I decided that field was where I wanted to stay.

I am fortunate that I get to see my designs come to life in the real world. I truly enjoy working through challenging issues and being around my teammates and our products. It is so satisfying to see airplanes in their final stages of completion that then fly off for delivery.

I have worked both for and with many highly capable people over the years, building a network across the enterprise and beyond. I am honored to be part of the group of leaders who will engage the next generation of our technical workforce and guide them in their career development. I am encouraged by the new engineers joining Boeing — their zeal is infectious!

Dan Zierten
Vehicle Management Systems

I did not choose aerospace as my career, it chose me. While working on my civil engineering degree, I found an affinity for the study of hydraulics. Upon graduation, my heart almost pounded out of my chest when I got to work on the space shuttle in the hydraulic system and fly-by-wire actuation group. Eventually, I landed at Boeing working on hydraulic systems and flight control actuation within Vertical Lift.

I have always loved my career in aerospace. I think the most rewarding aspect has been working multiple programs from the conceptual stage to first flight. It is always so exciting.

Becoming a Senior Technical Fellow provides me with new opportunities to guide Boeing's future in Vehicle Management Systems. Aerospace offers us an ever-expanding frontier that is ours for the taking. It only needs our imagination and desire to fuel its future.

PRODUCT SECURITY

Kelly N. Edwards
Product Security Engineering

Growing up within the foster care system, I have always had a strong personal awareness of the need for trust, safety and security. This, coupled with my natural inclination toward technology, made for a logical transition into cybersecurity. My U.S. Air Force service and subsequent Boeing career have allowed me to witness firsthand the disruption cyber events can cause, jeopardizing quality and safety.

I am genuinely invigorated by our innovations that strive to future-proof the security of our platforms in a dynamic and global cyber environment. I am fortunate to observe new engineers defend and articulate their product security innovations, and it is rewarding to see this tangible transition in our engineering culture.

I am honored to be a part of the Fellowship and excited about the challenge that lies ahead to innovate new cyber resiliency practices. I look forward to expanding the cybersecurity narrative past “if” statements to include analytics surrounding the “when.” Then, we can more adeptly react and more actively prevent future attacks.

SAFETY AND AIRWORTHINESS ENGINEERING

Bernhard Muster
Systems Engineering — Airworthiness and Regulatory Standards

I remember my first flight over the Atlantic at nine years old when the pilot invited me to sit in the jump seat for part of the flight. That experience left me with a passion for flying and aircraft. I became intrigued with the challenges of certifying our products in such a highly regulated environment. I have turned that intrigue into learning and developing skills in my technical specialty.

It is so rewarding to work with such a talented workforce with everyone bringing their best to developing solutions for some of the most complex problems we face.

There is arguably more opportunity now than at any other time in history to be part of innovations that will impact the world we live in for the good of our families, communities and humanity as a whole.

It is an honor to be recognized as a Fellow and to share what I have learned over the course of more than 30 years.

PRODUCT SUPPORT

Antony Hunt
Modeling and Simulation

I came into this specialty by chance when the first company I worked for out of university bought a flight simulator manufacturer. I had an interest in airplanes and a background in the Royal Air Force Air Cadets, where I was introduced to the field. Now, after decades of creating commercial and government flight simulation products, I cannot imagine doing anything else.

The training and simulation products we create at Boeing are critical to safely operate and service our aircraft. Knowing that our aircraft are safer because of what we do is extremely satisfying.

Outside of Boeing, I lead an industry group looking at how to type certify eVTOLs and air taxis that will potentially change how we travel over short distances. It is this transformation that keeps aerospace engineering exciting. I look forward to seeing, and traveling in, what the new generations of engineers create.

It is an honor to be a Fellow and to be surrounded by the immense talent and knowledge this group possesses. It is humbling to influence how my particular area of expertise evolves and helps Boeing position itself for the future.

SOFTWARE ENGINEERING

Gordon Putsche
Safety Critical Software Development and Certification

My degree taught me about embedded computer systems and software. My Air Force career as a computer systems engineer taught me how to read and navigate government policy, regulations and industry standards. I draw on both in my engineering work at Boeing. This experience has kept me technically current, and I have been fortunate to have leading roles in aspects of software certification policy, procedures and activities throughout my career.

It is an honor to be part of this elite group. I must admit it is a bit intimidating when I look at the immense talent surrounding me. Teaching and mentoring are so rewarding. The best thing I can do at this point in my career is to share the knowledge I have accumulated over three decades.

Software plays a critical role in current and future commercial aviation, and it is exhilarating to see the synergies we are finding with an enterprisewide focus on vertical software development, common software design practices and technology.

Jim Orlet
Support Equipment (Commercial and Government)

Lying in the grass watching planes fly overhead and witnessing the Apollo missions on TV as a child provided the inspiration for me to pursue aerospace. Early on, I was exposed to many varieties of aerospace electronic systems and subsystems. I discovered they all need some kind of test or maintenance equipment.

Near the beginning of my career, I had the opportunity to spend a year at a remote site as a field engineer with equipment that I designed. Understanding how the equipment was used and the people who use it permanently changed my view of design, product support and the role of maintainability in our products.

The Technical Fellowship captures the passion and expertise of Boeing’s most brilliant minds. I am honored, and I hope I can add to the enormous knowledge base it already encompasses.

I am excited to be a part of the acceleration of technology, combined with data analytics, model-based engineering and additive manufacturing increasing the speed and depth of innovation. The only limitation is our imagination.

SYSTEMS ENGINEERING

Ratan Khatwa
Flight Deck Human Factors

I have always been fascinated by the science of flight, having grown up near London’s Heathrow Airport. By the age of 13, I was taking flying lessons as a member of the UK Royal Air Force Air Cadets. That cemented my interest in aviation and influenced my decision to study aeronautical engineering at university.

The most rewarding aspects of my work are the very direct and positive impact on aviation safety and the role flight deck systems have played in addressing the industry’s most pressing safety challenges.

The linking of emerging flight deck technologies with a contemporary design language will transform the way pilots interact with our aircraft. The innovation space will enable us to develop systems that are more intuitive for the future generation of pilots, support enhanced safety and expand the operational capability of our aircraft.

It is an absolute honor and privilege to be a member of the Boeing Fellowship. As the “technical conscience of the Boeing Company,” we have a profound responsibility to provide technical guidance and an obligation to support the development of our growing workforce.

Ronald (Ron) Koontz
Avionics Software and Infrastructure

After engineering graduate school, I wanted to apply my knowledge of control systems to design and build airborne avionics systems. I started out working on unmanned rockets. I saw exciting new challenges associated with implementing these control laws in flight software. As my passion came into focus, my skills overlapped with growing industry demand to design new avionics systems and periodically upgrade and enhance legacy airborne platforms.

I always derive deep satisfaction from seeing the physical result of our technical contributions that lead to successful outcomes.

Software is at the core of every product we deliver. As a new software STF and steward of engineering excellence, I am humbled and excited to interact at this elevated level on our journey to make Boeing the premier aerospace software development company.

David Zeitouni
Flight Deck and Pilot Integration

As a boy, I used to go to the Newark airport where my father worked to watch airplanes take off and land. I built and flew model airplanes, which led me to the Air Force Academy to study aeronautical engineering. I then had the opportunity to fly C-17s and eventually found my way into Boeing's Flight Deck Engineering organization. It is the pinnacle of my love of airplanes — flying and engineering the flight deck for the pilot.

Every day, millions of people board Boeing airplanes and are safely transported to destinations all over the world. Flight deck functionality and the integration of the pilot with the machine play a crucial role. I cannot think of anything more rewarding than helping to lead the team that does that.

The aerospace industry is at a critical juncture, with the evolution of the role of the pilot in modern commercial aviation and autonomous air vehicles for commercial applications. I am humbled by the part I help play in defining the vision, strategy and products for these momentous changes in our industry.

Kevin Swearingen
Vehicle Health Management

When I was 10, a simple gift of an electronics experiment kit permanently moved me from the cowboy/astronaut career path to engineering. Coming to Boeing to work on automated test equipment for the AV-8B Harrier II was heaven. It has been a short step, and a lifetime career, to go from detecting equipment faults to diagnosing and predicting faults across fleets of vehicles.

Like any engineer, I enjoy solving problems — navigating over-constrained spaces to arrive at an elegant design to keep our aircraft available to fly. But I get even more satisfaction from sharing what I know and helping people understand something new.

It is a unique, exciting time to be in this field. As computers become ubiquitous, autonomous behavior becomes more robust, and machine learning and computational intelligence become mainstream, amazing new capabilities become feasible. We have a real opportunity to shape the future as we create new ways to predict what might happen during flight and react intelligently, automatically and safely.

I am humbled and grateful to be recognized this way and energized to justify it.

Principal Senior Technical Fellows

Michelle Taylor
Product Development and Electrical Design Integration

Growing up, I was always interested in space and flying, and I enjoyed solving problems and learning how things worked. My parents taught me that I could do anything if I worked hard enough. This passion and drive led me to engineering and the aerospace industry.

My favorite aspect of my job is helping our engineering teams be successful. Whether leading a team or mentoring individuals, it is rewarding to watch their growth and accomplishments. And, working with smart, innovative and diverse people, I am able to continually gain knowledge and expertise.

I am honored and grateful to be recognized for my contributions. I am thankful to the incredible mentors who saw value in my work and helped me develop my skills and utilize them in ways that have enhanced our teams and the company.

Technology is constantly changing, and our products continue to get more complex and exciting. I have been a part of amazing teams and historical events throughout my career, and I am excited to continue working with exceptional people to continuously improve, achieve the unachievable and leave a legacy that makes our families and company proud.

ELECTRONIC AND ELECTRICAL ENGINEERING

Arun Ayyagari
Networked Systems

I chose this field out of a passion for learning, technology, understanding how things work, creating and making things better.

I am excited about helping to broaden the sphere of technical leadership and vision at Boeing, and to continue to shape and contribute to the amazing products and services we create every day.

It is an honor to be part of this elite group and to have the ability to provide the technical vision and leadership in technology development.

Jay Lowell
Physics and Systems Engineering

In college, I decided to major in physics because it was all about understanding how nature works. It turns out that I was also interested in figuring out how to turn that understanding into devices that take advantage of nature in new and valuable ways. That has led me to a long, diverse career developing new technology.

I am lucky to be able to work on rich, interesting projects early in development. I get to spend time figuring out how to do things that have not been done before. It is rewarding to be able to look back at the end of a project and know I helped create something that can make the world a better place.

It thrills me to think about the quantum technology that we are researching and prototyping today that will turn into new products and capabilities that will transform future Boeing platforms, processes and services.

I feel privileged to be recognized as part of the Technical Fellowship by my peers and leadership. It is an honor that motivates me to go to work every day and to try to do even more.

Tim Williams
Platform Survivability

My father spent 34 years in the military as a surgeon, taking care of our people in uniform and their families. I wanted to do my part to help, work in aerospace in a challenging and rewarding field, and contribute to national defense. I have been lucky to have the opportunity to do all of that while making our products more effective and protecting the people who use them.

The day-to-day interaction with such high-quality people working together to create outstanding products is very rewarding. Knowing that the products we design and build have a concrete, positive impact on the effectiveness of our mission makes the job worthwhile and satisfying.

Being promoted to the executive level of the Technical Fellowship is a tremendous honor, one I never thought was realistically achievable for me. I am excited to help guide Boeing's efforts in developing new and advanced products, both now and in the future.

Harold Schall
Electro-optical/Infrared and Vision-based Mission Systems

Growing up, I enjoyed math and science, which led me to study physics and chemistry in college and then laser spectroscopy in graduate school. After gaining hands-on experience applying state-of-the-art laser technology for basic research, I was hooked on pursuing a career in lasers and electro-optics.

It is truly a great honor to be a part of this group as well as a significant responsibility to provide the utmost technical leadership to ensure engineering excellence across Boeing.

Whether it is the development of the Airborne Laser pathfinder directed energy system or upgrading the KC-46 remote vision system, the most rewarding aspect has been working with multidisciplinary teams in close collaboration with our customer and end user/operator to establish new or improved capabilities.

I am excited about the wide range of features that will be enabled for both commercial and defense applications as we leverage synergies between vision-based mission systems, machine learning and autonomy.

INFORMATION TECHNOLOGY AND DATA ANALYTICS

Paul Dodd
Cybersecurity

I was drawn to the compelling intersection of human behavior and technical systems. Cybersecurity is an emergent and nascent field where the most critical problems are defined by the ingenuity of human adversaries, not principles of physics.

Like safety, cybersecurity relies on standards of risk management that must be distributed to enable everyone to protect themselves and each other. Embedding security into system design to help people understand risk early is rewarding.

It is inspirational that the company demonstrates its commitment to inclusion in the pathways to technical leadership. We are at a tipping point where our digital systems are about to become truly global to meet the conflicting needs of data sovereignty restrictions for compliance and global data replication for performance. Boeing is at the leading edge of this work.

John Sullivan
System Architecture and Development

I have always been drawn to large-scale challenges. And it is most rewarding for me when I get to see concepts become reality.

It is an honor to be a part of Boeing's Technical Fellowship, as it facilitates focus on technical innovation and integrity. There is an endless supply of opportunities for innovation. I cannot wait to see what future generations create.

Guijun Wang
Digital Enterprise Systems and Technologies

I found my passions in computer science and aerospace. I have been fortunate to be at the forefront of using computer science to advance aerospace processes and products, including large-scale mission-critical systems, software/systems engineering products and global-scale systems and technologies for engineering, manufacturing, quality and supply chain.

It has been a rewarding experience to work on technology innovations, large-scale system designs and analyses, solution implementations, and knowledge exchanges in collaboration with many talented individuals and teams throughout the enterprise and industry/academia communities. But the most satisfying aspect of my work is mentoring and teaching opportunities that help others grow and succeed.

I am honored to be a member of the Fellowship. As the aerospace industry undergoes a digital transformation, I am excited to help Boeing define and mature the digital enterprise systems and innovate technologies for the design, manufacturing and support of digitally advanced aerospace products across the life cycle.

Emily L. Howard
Human Engineering

I have long been fascinated by human behavior, and I knew at an early age that I wanted to study behavioral science. I have always enjoyed solving complex problems, and humans are undoubtedly some of the most complex elements of our world.

I was also strongly influenced by the Gemini, Apollo and space shuttle programs, which opened up new frontiers for human exploration and simultaneously strengthened our connections to each other and our ability to enrich life here on Earth. Ultimately, human engineering has allowed me to combine my love of technology with my passion for enhancing human experiences.

I am excited by the human dimension of autonomy, robotics and artificial intelligence. By learning how humans interact with these technologies, we can improve our products and operations to be safer and more efficient while respecting the unique value that only humans contribute.

It is a tremendous honor to be a Principal Senior Technical Fellow. What we do at Boeing makes a positive difference in the world. Working with the brightest minds in our industry, along with the coolest innovations, inspires me every day.

Jill Seebergh
Chemical Materials and Processes

Growing up, I did not know anyone who was a scientist or an engineer, and college was not the default pathway for a lot of my peers. Fortunately, I had a high school chemistry teacher who saw my potential, encouraged me to pursue engineering and found ways for me to build my skills and confidence. It was a master class in mentoring, and I am forever grateful.

Every time I step onto a Boeing airplane, I cannot help but be proud of the technologies that I helped to invent and develop that ended up there. The most rewarding aspect is the amazing teams of people I have worked with throughout my 25-year career to transition those technologies from the laboratory to aircraft.

It is an honor and a privilege to be a Fellow, and I am deeply proud to be included in such a talented group. It is also a tremendous responsibility to ensure that the culture of engineering excellence extends into the future. I have been fortunate to have many Fellows as mentors over the years, and their wise counsel influenced the arc of my career and enabled me to have a positive impact for Boeing.

Excellence, Technically Speaking

MOMENT OF REFLECTION

Fueled by the Boeing-built core stage, NASA's Space Launch System speeds toward the moon during the Artemis I mission from Kennedy Space Center on Nov. 16, 2022.

PHOTO: JOHN PROFERES/BOEING

BOOST YOUR IQ!

Video: See super slo-mo of the launch.

IQR

Weld Done: A Century of Sparks

World War I lessons inspired a new arc-welding process

BY ANNIE FLODIN AND MICHAEL LOMBARDI, BOEING HISTORICAL SERVICES

Sparks flew 100 years ago, and aircraft production would never be the same. In the time of wood and fabric biplanes, timber baron Bill Boeing showed his pioneering vision by ushering in planes made with metal and bonded by arc welding. World War I had demonstrated aviation's usefulness and propelled engineers to work on designing more practical and efficient aircraft. Traditional stick, wire and fabric construction gave way to welded steel framework and duralumin, an early aluminum alloy.

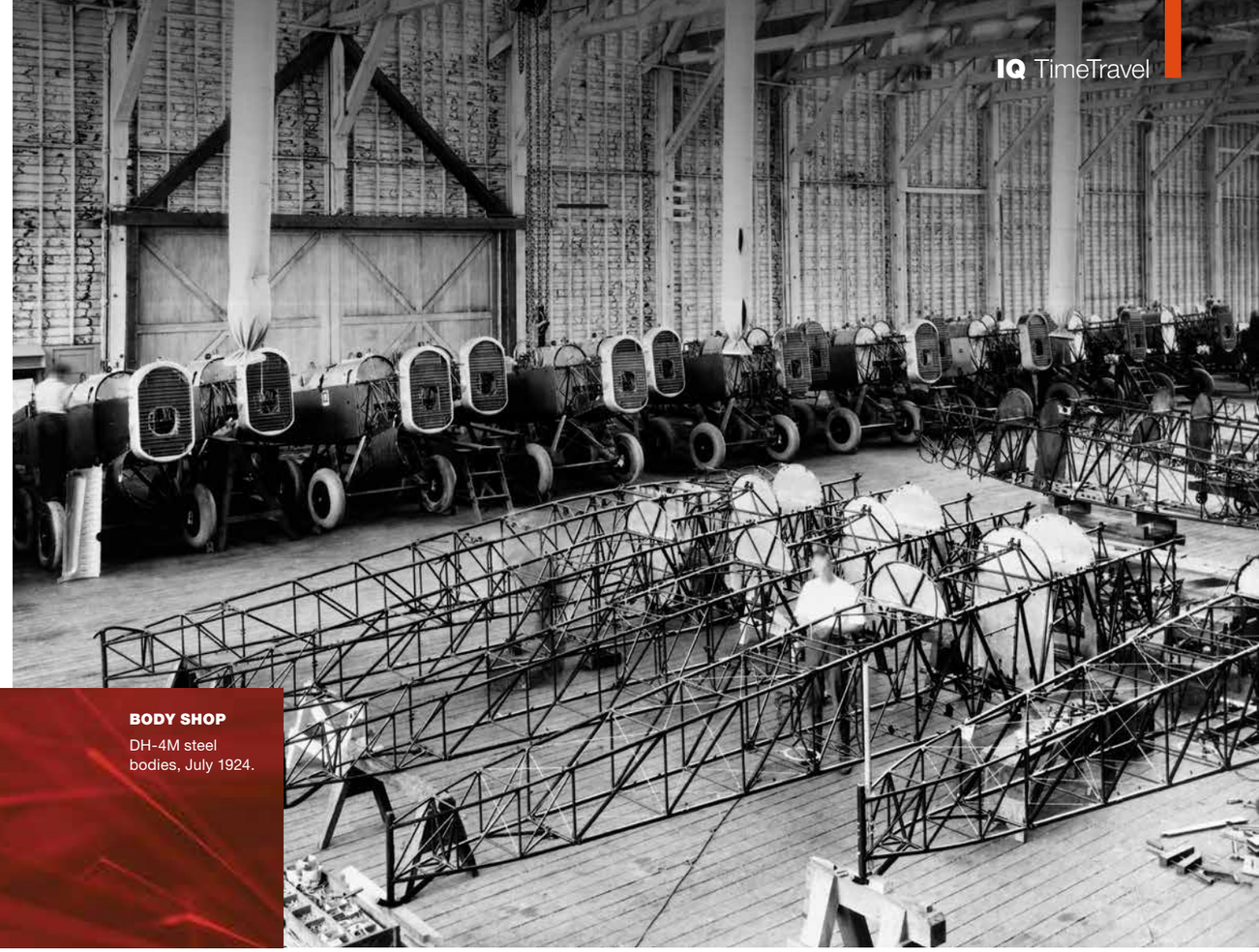
ARC SUPPORT
Workers perfect the Boeing-developed arc-welding technique inside the company's first factory, March 1922 in Seattle.

PHOTOS: BOEING ARCHIVES

In February 1923,

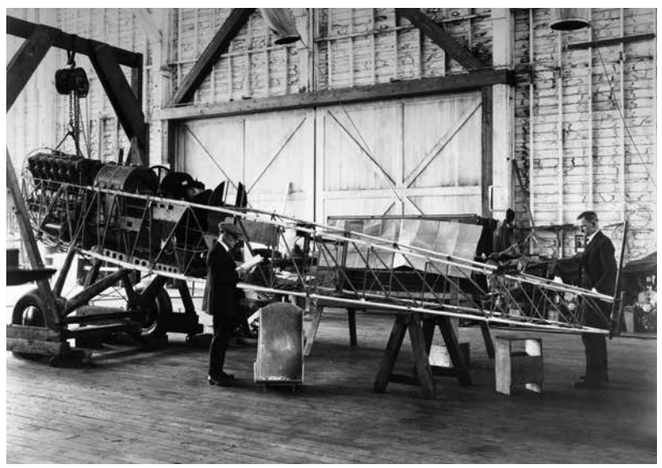
Boeing's newly developed arc-welding process was used for the first time to equip three remodeled de Havilland DH-4s with steel tube fuselages. From 1923 to 1925, Boeing modified 186 airplanes using the method. These aircraft were designated DH-4M (M for modernized).

Arc welding was used extensively in the following years and was crucial in the development of the first Boeing-designed fighters. The technique was eventually adopted for landing gear and other steel structures. **IQ**



BODY SHOP
DH-4M steel bodies, July 1924.

MAN OF STEEL
Working on a DH-4M fuselage wing frame, March 1923.



EARLY METAL FRAME
A DH-4M frame in a jig, April 1923.

MULTIPURPOSE BIPLANE
The only U.S.-built aircraft to see combat during World War I, the de Havilland bomber later served as an air ambulance, photographic plane, trainer, target tug, forest fire patroller, mail carrier and even an air racer.

The Queen Has Left the Building

747

LAST OFF THE LINE

The 1,574th and final “Queen of the Skies” airliner as seen through the pencil, pen and paint of Jeff Barlow of Boeing Creative & Digital.

BOOST YOUR IQ!

Video: See the artist colorize the sketch.

BOEING 747

The Final 747 Rolls Out
Dec. 6, 2022
Everett, Washington

PHOTO: PAUL WEATHERMAN/BOEING

We're hiring manufacturing and quality professionals in the Puget Sound region. Join us and work with advanced aerospace technology. #TeamBoeing is proud to be named one of LinkedIn's Top Companies in the U.S.

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