2023 Q4 | Volume 7 | Issue 26

IQ INNOVATION QUARTERLY

INNOVATION. INSIGHT. INSIDE AEROSPACE.

Eyes on Autonomy

Inspectors close in with cameras and connectivity

PLUS: X-66A
Bracing for the next big wing

VIRTUAL BECOMES REALITY

Augmented reality and autonomous tech connect Boeing operations analyst Jared Parker to aircraft operators and maintainers around the world.

BOEING

IQ INNOVATION QUARTERLY

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

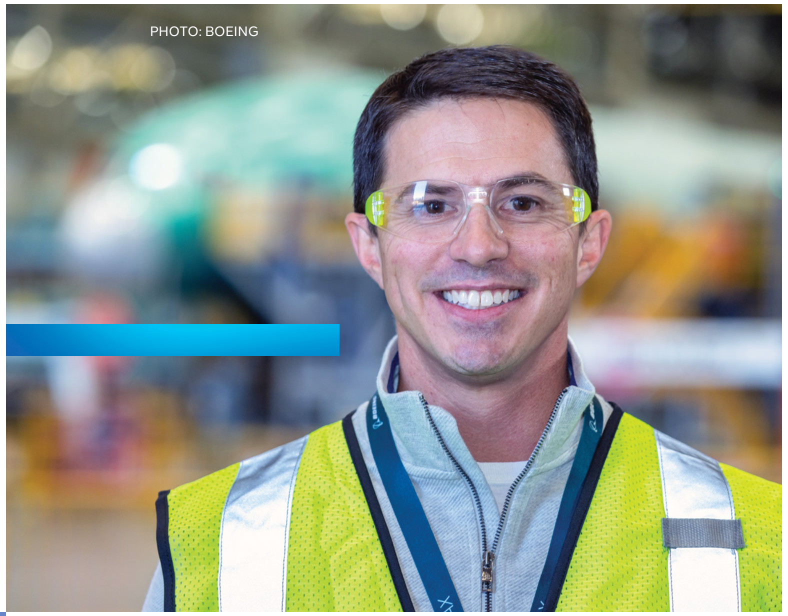


PHOTO: BOEING

Running Lean

Small steps to stability

Our production system is complex, but Lean is simple.

Lean means listening to the people who do the work, understanding their constraints and removing those constraints. That's exactly why we're embracing Lean, and not just on the factory floor. Lean applies to every walk of Boeing life. Some think Lean merely implies cutting costs, but the fact is, implementing Lean principles is how we relentlessly eliminate waste, create increased capacity, and reduce flow time in any given task.

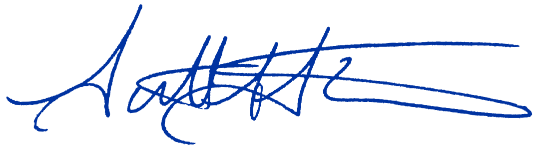
Lean and safety go hand in hand. As we lean out our processes, production becomes more stable, and safety and quality improve. With this stability comes predictability, which is meaningful for our employees and our customers. That all stems from Lean — a way of thinking that yields continuous improvement.

In this issue of Innovation Quarterly:

- Snapshots show how small steps lead to real improvements in production quality and efficiency.
- Safety specialists share stories of patented inventions that help our teammates work safer and smarter.
- Small drones help simplify work on big aircraft.
- Insiders reveal one of the big ideas we're working on — the transonic truss-braced wing.

Throughout this edition of Innovation Quarterly, you'll see that Lean is simple, yet powerful.

Learn how Boeing is doing the little things better. Through Lean, we're steadily building predictability, consistently achieving high quality and attaining excellence in all we do. IQ



Scott Stocker
Vice President, Boeing Commercial Airplanes
Manufacturing & Safety,
Chair, Manufacturing Operations Council

INSPECTOR GADGET

A drone surveys the surface of a massive C-17 Globemaster, sending vital data to technicians nearby and finishing a first-pass inspection in minutes, not hours.

PHOTO: BOEING

Eyes on Autonomy

Inspectors close in with cameras and connectivity

BY KARINNE CILENTO AND BARRY EDWARDS, BOEING WRITERS

A military aircraft needs immediate repair while deployed in a remote and contested environment.

Inspectors can’t see the top of an aircraft, so they can’t see what repairs may be necessary.

Thousands of miles separate maintainers from Boeing service experts, delaying inspections and repairs — and the aircraft’s return to service.

Boeing is solving these problems and more with new autonomous technologies.

> “ We’re not trying to replace the human inspector. We’re trying to inform them. When they do go on the tail, they’re not guessing. They know exactly what to expect, and they know exactly what to do to get the aircraft back into service.”
>
> **SCOTT BELANGER,**
> **BOEING GLOBAL SERVICES TEAM LEADER**

DRONING ON

Equipped with 5G connectivity, a drone examines a C-17 Globemaster and sends a diagnostic report to the cloud for instant accessibility.

PHOTO: BOEING

How It Works

In a strategic partnership, Boeing, Near Earth Autonomy and the U.S. Air Force are deploying drones to capture real-time imagery of military transport planes, enabling faster and safer inspections, maintenance and service.

Particularly useful in remote locations, these autonomous aircraft are equipped with cameras and wireless network connectivity. Flying over and around massive aircraft, the drones inspect the plane’s exterior, collect aircraft data and securely store the information in the cloud.

That allows operators and Boeing service representatives to access 3D models of the aircraft from anywhere in the world, at the same time.

Three Big Things About Little Drones

Autonomous aircraft inspections decrease downtime, improve quality and enhance safety.

1. Decrease downtime

“A human-only inspection of just the tail of a C-17 can take six hours,” said Scott Belanger, Boeing Global Services team leader. “In early tests, this technology cuts the initial visual inspection time to as short as 30 minutes.”

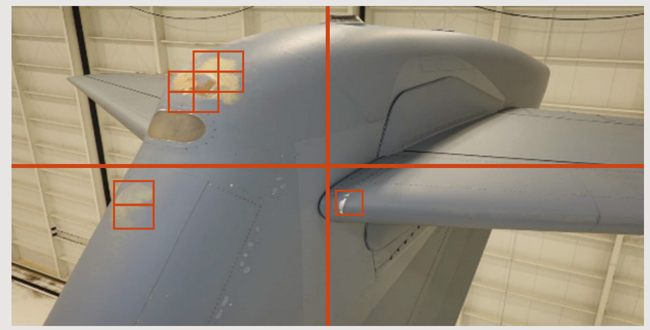
2. Improve quality

“We’re not trying to replace the human inspector. We’re trying to inform them,” Belanger said. “When they do go on the tail, they’re not guessing. They know exactly what to expect, and they know exactly what to do to get the aircraft back into service.”

Belanger said autonomous inspections are showing impressive results already, detecting about 25% more damage than a visual inspection.

3. Enhance safety

The drone-assisted workflow reduces the need for airmen to climb on top of planes, lifts or scaffolds to inspect surfaces.



ABOVE AND BEYOND

Flying high over large aircraft, drones capture detailed views of an aircraft’s exterior. Damage detection software captures close-up images of areas maintainers can’t see from the ground.

PHOTOS: BOEING

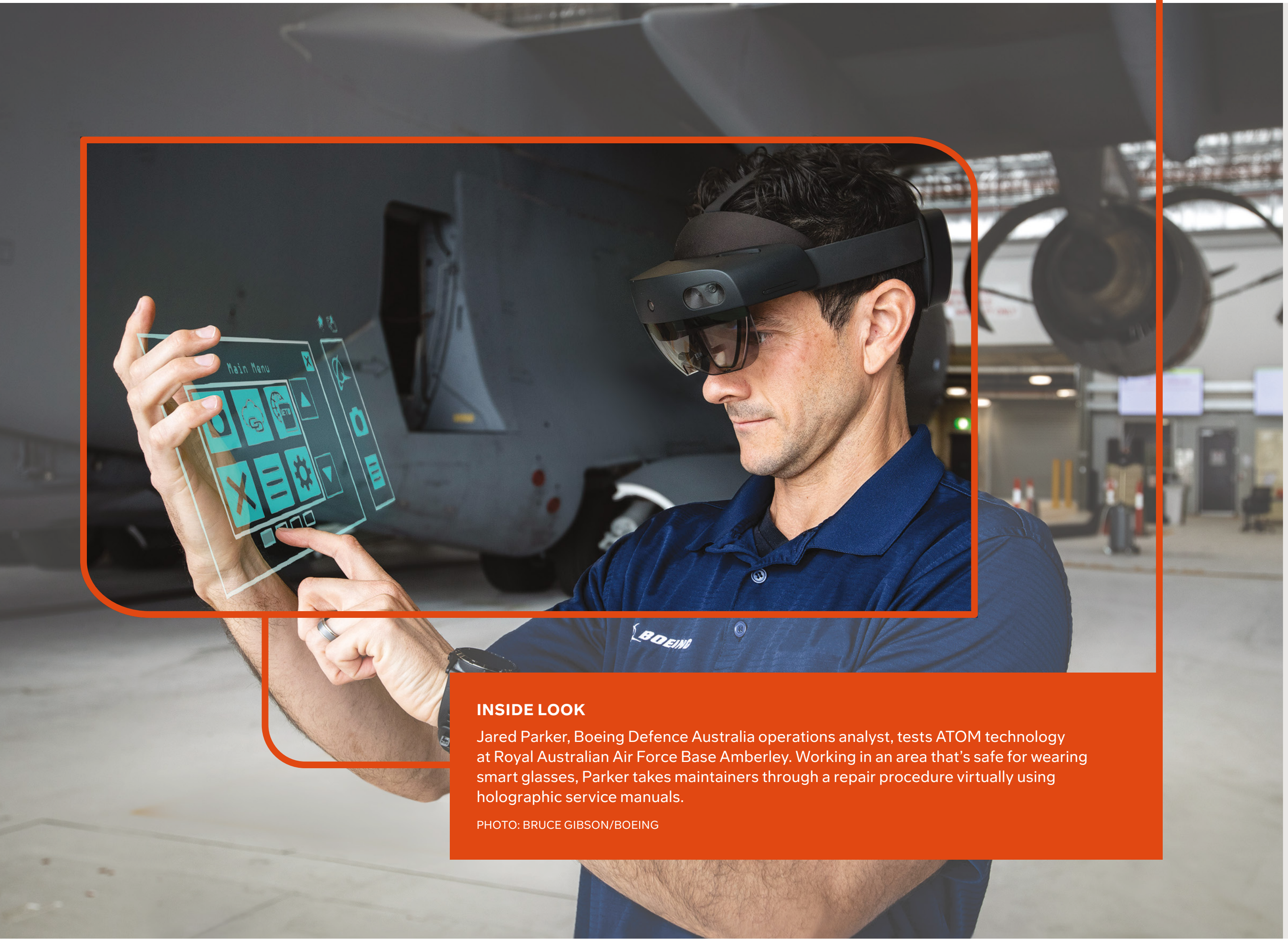
What's Next

With promising test results, Boeing plans to add more military aircraft to the autonomous inspection roster.

"You'll be able to pull up a tail number, click anywhere on the 3D model of that aircraft, and see a history of images of that exact part you clicked on," said Alli Locher, Near Earth Autonomy senior product manager. "And, you'll be able to do that from anywhere in the world."

By seamlessly integrating human expertise with powerful autonomy, the future of aircraft inspection, maintenance and transportation is safer, faster and even more reliable. **IQ**

Autonomous inspections are showing impressive results already, detecting about **25% more** damage than a visual inspection.



INSIDE LOOK

Jared Parker, Boeing Defence Australia operations analyst, tests ATOM technology at Royal Australian Air Force Base Amberley. Working in an area that's safe for wearing smart glasses, Parker takes maintainers through a repair procedure virtually using holographic service manuals.

PHOTO: BRUCE GIBSON/BOEING

Virtual Becomes Reality

Secure wireless networks are enabling Boeing Global Services to support defense operations worldwide using augmented reality.

With Augmented Training, Operations and Maintenance technology, Boeing field service representatives diagnose maintenance needs virtually, share service manuals through holograms and guide operators through repair procedures remotely. Connecting operators, airmen and service representatives around the clock, ATOM enables diagnostics and repairs to be made from anywhere in the world.

X-66A: Bracing for the Next Big Wing

Years in the making, a demonstrator airplane with a truss-braced wing configuration may go big in the next decade

BY MAKS GOLDENSHTEYN

CONFIGURATION CONCEPT
This is an artist's rendition of the Boeing Transonic Truss-Braced Wing configuration — a possible idea for commercial use in the 2030s.

IMAGE: NASA

Don't tell his landlord. Zach Hoisington built his own wind tunnel — in a courtyard at his apartment building in California. With the help of 16 box fans and plywood walls, the young aerospace engineer tested sections of his paraglider prototype after work.

So when Hoisington found himself in a room with nine like-minded engineers in Boeing's Huntington Beach, California, offices in late 2007, seven years after he joined the company, he felt right at home.

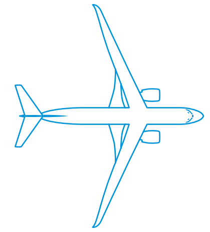
Challenged by since-retired Boeing Technical Fellow Marty Bradley, the small Boeing Research & Technology team looked for novel ways to lessen the environmental impact of commercial aviation.

With whiteboards lining the conference room walls, the attendees pitched designs that ran the gamut of aircraft concepts and technology ideas.

DIGITAL BRAINSTORM

Engineers Marty Bradley, Christopher Droney and Zach Hoisington reviewed an early idea around 2010.

PHOTO: BOEING



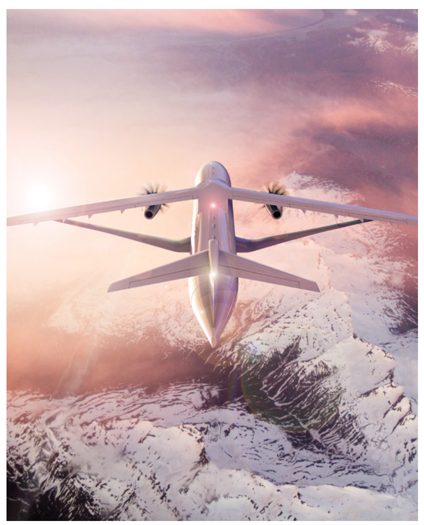
Hoisington floated the idea of an airplane configuration with high, long, thin wings that could be braced by diagonal struts, or trusses, attached to the lower part of the fuselage.

"I've always been drawn to lighter, externally braced structures," Hoisington said recently.

Part of the draw was a childhood interest in paragliders, which are essentially wings with strings, the simplest form of external bracing. At age 14, he took paragliding lessons with his father.

X IS FOR EXPERIMENT

X-planes are experimental U.S. aircraft designed to test and evaluate new aerodynamic concepts. They are intended to test technologies that can be adopted into other aircraft designs, not serve as prototypes for full production.



IDEA IMAGES

Early aircraft concepts became known for their transonic flying speeds and truss-braced wing airframe configuration, gaining the name Transonic Truss-Braced Wing.

IMAGES: BOEING

FUTURE FIRST X

A Boeing MD-90 flies to Palmdale, California, to begin its transformation into the first X-66A.

PHOTO: NASA

GRANDMOTHERLY INSPIRATION

In the early 1950s, Grace Bambauer Butler worked three jobs so she could afford flying lessons. After getting her license, she bought an inexpensive, storm-damaged Piper J-3 Cub. After fixing it, she sold the plane in the late 1950s. It later became an inspiration for her grandson Zach Hoisington, a Boeing engineer.

PHOTO: COURTESY OF ZACH HOISINGTON

It also happened that Hoisington's grandmother, a pilot, had once restored a Piper J-3 Cub, a type of strut-braced monoplane produced between 1937 and 1947. Hoisington heard stories about the restoration growing up.

Part of the plane lived on his grandmother's RV, as the altimeter found a permanent home on the dashboard. In 2007, Hoisington took her paragliding after she turned 90.

A Formidable Challenge: Size and Speed

Like Grandma Butler's J-3, several smaller, slower-flying, externally braced airplanes — both monoplanes and biplanes — debuted starting in the early 20th century. Some of the wings were braced by struts, others by cables.

Yet, translating the aerodynamic efficiency benefits to a commercial airliner-sized aircraft flying at transonic cruising speeds was a challenge for the aerospace industry.

Engineer Christopher Droney, who also attended Bradley's 2007 brainstorm, said the limited computing power available before the late 1990s was a primary reason. It was difficult to model the effects of real-world operating conditions — including payload, speed and altitude variations — on aerodynamic performance and operability.

"I don't think we had the computing capability to solve the structural dynamics and aerodynamics problems simultaneously," Droney said. "And by the early 2000s, it was only going to be a matter of, 'Who is going to get there first with enough fidelity and seriousness to solve it?'"

High-Flying History: The Long and Thin of It

The principle that longer, thinner wings may reduce drag and add lift for overall aerodynamic efficiency has long been established in the world of aviation.

Maurice Hurel
One notable example of a concept that incorporates elements of both is the Hurel-Dubois HD.31 prototype designed and flown by French naval pilot and airframer Maurice Hurel in 1953.

PROTOTYPE PIONEER

The only HD.31 built was on display at the 1953 Paris Air Show.

PHOTO: NATIONAL ARCHIVES CATALOG

Hurel's wind tunnel tests showed that monoplanes with long wingspans supported by lift-inducing struts could more than offset the weight penalty associated with the longer, heavier wings. Many of his prototypes, including the propeller-powered HD.31, were referred to as "flying letter openers."

Werner Pfenninger
In 1954, Swiss-born aerodynamicist and member of the NASA Hall of Honor Werner Pfenninger established that an airliner with a truss-braced wing configuration flying at transonic speeds* would see improved aerodynamics and lift compared to an airliner with a traditional cantilever wing configuration.

*Mach 0.80 is a typical cruising speed for single-aisle commercial airplanes today that approaches the speed of sound.

Good Timing: NASA Requesting Ideas

In early 2008, Bradley's team reconvened to refine their ideas. They dubbed their project the Sustainable Ultra Green Aircraft Research program, or SUGAR. This groundwork came at an opportune time.

Later that same year, NASA Aeronautics issued a solicitation for advanced-aircraft research ideas. Each concept was evaluated for its potential to influence reductions in fuel burn and emissions.

"This seemed like a perfect fit for what we had funded internally and what NASA was now asking for," Bradley said.

In late 2008, NASA awarded initial research contracts to a Boeing-led team that included various industry and university partners. NASA adopted the SUGAR moniker for this first phase, though the "Sustainable" in Boeing's version of the acronym was switched to "Subsonic" to match NASA's solicitation language.

> "This seemed like a perfect fit for what we had funded internally and what NASA was now asking for."
>
> **MARTY BRADLEY,**
> **RETIRED BOEING ENGINEER**

The work lasted through March 2010, at which point the Boeing-led team focused on the two most promising approaches, each coupling a truss-braced wing configuration with other carbon-reducing technologies. The concepts were called SUGAR High and the hybrid-electric SUGAR Volt.

News of the SUGAR Volt concept helped popularize the idea of pursuing hybrid-electric technology in aviation.

Within Boeing, the aircraft concepts became synonymous with their airframe configuration and the speed at which they would be flown — becoming known as the Transonic Truss-Braced Wing, or TTBW. The research also included advanced propulsion concepts.

TAKING SHAPE

In 2013, Hoisington shared the small-scale model of the concept vehicle.

PHOTO: BOEING

MODEL BEHAVIOR

In 2013, engineers Timothy Allen, Droney and Bradley worked with an under-construction truss-braced wing concept model ahead of wind tunnel testing at NASA's Langley Research Center.

PHOTO: BOEING

> "Adding the truss underneath the wing makes a big triangle. It stabilizes the whole inner part of the wing. The part that's deflecting the most is the part outboard of that. The center is more rigid and the outboard part is more flexible, which mirrors what you see on regular airplanes with cantilevered wings that come out of the fuselage."
>
> **MARTY BRADLEY,**
> **RETIRED BOEING ENGINEER**

Studies around the SUGAR High and SUGAR Volt efforts became the basis for a second NASA contract, SUGAR Phase II.

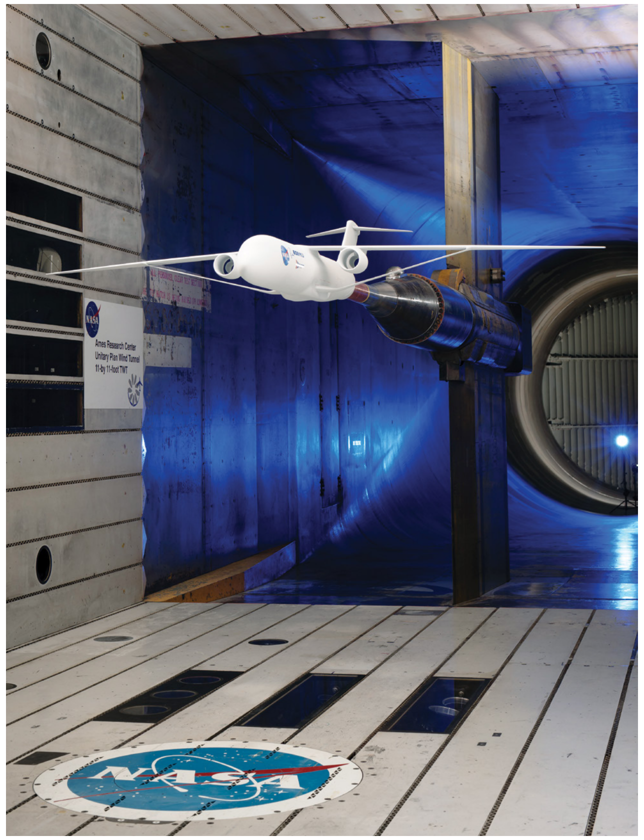
Phase II: Model Behavior in the Wind Tunnel

The Phase II team, including technical lead Droney, continued to define the TTBW airplane's architecture and configuration from 2012 to 2014. With a better understanding of its drag and structural characteristics, they built a first wind tunnel model out of fiberglass.

At the Transonic Dynamics Tunnel at NASA's Langley Research Center in Hampton, Virginia, Boeing tested a 15% scale model without trusses to understand the wing design's baseline aeroelasticity, or flexibility, in flight conditions. Afterward, the trusses were secured, and the same tests were performed again.

The results were promising.

> **“** We surprised ourselves, because the performance actually got better. That’s a classically harder thing to go do, the faster you go. But we kept getting smarter on the problem.**”**
>
> **CHRISTOPHER DRONEY,**
> **ENGINEER,**
> **BOEING RESEARCH & TECHNOLOGY**



SUSPENSE

From 2014 to 2016, Boeing teams tested a truss-braced wing model at NASA’s Ames Research Center to simulate Mach 0.745 speeds.

PHOTO: NASA

“Adding the truss underneath the wing makes a big triangle,” Bradley explained. “It stabilizes the whole inner part of the wing. The part that’s deflecting the most is the part outboard of that. The center is more rigid and the outboard part is more flexible, which mirrors what you see on regular airplanes with cantilevered wings that come out of the fuselage.”

In 2014, Boeing began studying the idea of a TTBW-based flight demonstrator under NASA’s Ultra-Efficient Subsonic Transport plan, setting the stage for future developments.

Phase III: Idea Comes to Life

Encouraged by the initial findings, the team took what had once been a kernel of an idea and transformed it into a testable concept in Phase III.

Until this point, detailed aerodynamic and structural designs had not been completed. It was time to translate textbook theory into a functional design — and during wind tunnel testing, to see whether it could actually demonstrate the expected performance gains.

During this phase of SUGAR, from 2014 to 2016, researchers used digital modeling to advance the shape of the wings, the struts and their interaction — including airflow in the narrow channel between them — to ensure aerodynamic efficiencies were in the target range without incurring extra drag.

“If you’re looking to make performance estimates for a regular airplane, well, we’ve built tons of those,” said Neal Harrison, Boeing TTBW principal investigator and the program manager for multiple phases of SUGAR.

“We know how to estimate their performance and get really close. But with the truss-braced wing, there’s really no available information on which to make those guesses with a high degree of confidence. We had to actually shape all of this from scratch.”

Boeing designers tested a new model during a low-speed test at NASA’s Ames Research Center, but at Mach 0.745, slower than the typical cruising speed of today’s airliners.

TUNNEL VISION

Boeing engineer Neal Harrison checks a model ahead of Mach 0.80 wind tunnel testing at NASA’s Ames Research Center in 2019.

PHOTO: NASA

Phase IV: Speed Surprise

As the configuration concept matured, the SUGAR team optimized the aircraft cruise speed to better match the demands of the market. By Phase IV, conducted from 2016 to 2020, the team again tested wind tunnel models at Mach 0.80 — including a first test of a high-lift system.

“We surprised ourselves, because the performance actually got better,” said Droney, who led Boeing’s work on the contracts for SUGAR Phase III and part of Phase IV. “That’s a classically harder thing to go do, the faster you go. But we kept getting smarter on the problem.”

By this point, one of the key learnings was that a single-aisle aircraft designed with a truss-braced wing configuration could see fuel consumption drop by more than 5%. Future studies would show the predicted benefit to be 10% or even higher, depending on the mission and the advanced technology paired with the airframe.

The theoretical concept vehicle being tested had a wing-span of 170 feet (52 meters) and included a folding wingtip to account for existing airport taxiways and to fit within a standard gate. Improvements included changes to the sweep and thickness of the wings, as well as re-aligning the trusses from the center of the wings to their rear.

WINDS OF CHANGE

Boeing engineers Harrison, Niko Intravartolo and Eric Dickey with NASA aerospace engineer Greg Gatlin in 2021 at NASA's Langley Research Center.

PHOTO: NASA

Increasingly, Boeing Research & Technology teams were collaborating with colleagues from the Boeing Commercial Airplanes Product Development team, requiring a coordinated effort across sites and business units.

Phase V: Detailing a Demonstrator

SUGAR Phase V included high-speed buffet testing to check against vibrations incurred at Mach 0.80 and faster, including the highest speeds the aircraft would experience (like during an emergency maneuver). Given the configuration's unusual geometry, it was important to assess airflow between the wing and the truss.

Phase V also included more low-speed testing, which looked at the effects of icing and the performance at takeoff and landing.

With this phase complete, Boeing anticipated an opportunity to validate years of development and testing with a full-scale demonstrator vehicle through NASA's Sustainable Flight Demonstrator (SFD) program.

> “We've answered many of the biggest conceptual questions. Now you have to take a big step forward in detail and really start actually designing parts — literally down to the nuts and bolts.”
>
> **NEAL HARRISON, ENGINEER, BOEING RESEARCH & TECHNOLOGY**

> “Along with NASA and our partners, we're building a flying test bed to validate technologies that we've seen great promise in for some time. This is how we're creating the capabilities to address the needs of our customers and the wider industry.”
>
> **MIKE SINNETT, SENIOR VICE PRESIDENT AND GENERAL MANAGER OF PRODUCT DEVELOPMENT, BOEING COMMERCIAL AIRPLANES**

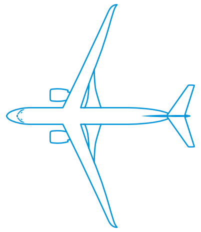
The Real Deal: Flight Tests This Decade

In January 2023, NASA announced its award of a $425 million Funded Space Act Agreement to Boeing and industry partners — to design and build an SFD with a TTBW configuration. Boeing and its partners will contribute an estimated $725 million to fund the endeavor.

In June, the U.S. Air Force conferred an X-plane designation for the demonstrator vehicle, with the name X-66A. NASA and Boeing applied for this designation because the SFD will continue a long history of one-of-a-kind experimental aircraft brought to flight to validate a breakthrough design.

The demonstrator is expected to take to the sky for flight tests in 2028 and 2029. Boeing is using elements from existing MD-90 airplanes and will integrate them with all-new components.

“We've answered many of the biggest conceptual questions,” Harrison said. “Now you have to take a big step forward in detail and really start actually designing parts — literally down to the nuts and bolts.”



The TTBW airframe allows the demonstrator to have more underwing space than a typical airliner, allowing it to accommodate an advanced propulsion system. Combined with expected improvements in propulsion, materials and systems architectures, the TTBW configuration could yield up to a 30% reduction in fuel consumption and emissions relative to today's most efficient single-aisle airplanes, depending on the mission.

Together with Boeing's other work on future-flight concepts, such as studying hydrogen and hybrid-electric propulsion, advanced technologies like those demonstrated aboard the SFD are parts of several key levers that Boeing believes will be required to achieve commercial aviation's goal of net-zero emission by 2050.

“Along with NASA and our partners, we're building a flying test bed to validate technologies that we've seen great promise in for some time,” said Mike Sinnett, senior vice president and general manager of Product Development for Boeing Commercial Airplanes. “This is how we're creating the capabilities to address the needs of our customers and the wider industry.”

The SFD's first flight test will represent the culmination of a two-decade effort on the part of numerous engineering teams and individuals, including those who gathered for that 2007 impromptu brainstorm session. It will have added meaning for those who have advocated for the idea from the initial concept to its current stage. This includes Droney, now the SFD deputy chief engineer, and a host of others who helped sustain the project within Boeing Research & Technology and Boeing Commercial Airplanes.

“This will certainly go down in my book as probably the career accomplishment,” Droney said. “Certainly something I've been chasing and pushing for so long.”

Technical challenges remain before the SFD takes flight, and not every outstanding question can be answered through the flight-test program alone. Boeing is currently under contract for SUGAR Phase VI, during which teams will continue to examine aspects of the TTBW configuration that set it apart from typical tube-and-wing aircraft.

The SUGAR Phase VI, SFD and Boeing Commercial Airplanes Product Development teams are working in parallel to mature the TTBW technology and develop the data and analysis needed to determine its viability in the market.

For Bradley, who retired from Boeing in 2020 and now works as an aerospace consultant and a lecturer at the University of Southern California, news of the Boeing SFD award in early 2023 seemed like a good teaching moment. In a class he led a few days after Boeing received the award, Bradley took students down memory lane to the heady days that started it all.

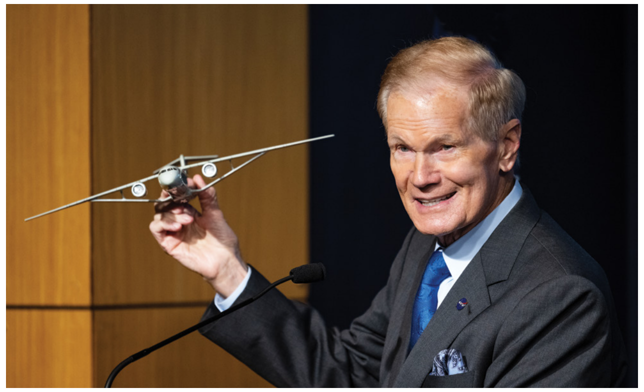
"It was a lesson about the time it takes to bring good ideas to fruition," he said. **IQ**

FUTURE FLIGHT PLANS

NASA Administrator Bill Nelson, right, discusses the X-66A with Boeing teammates Grace Lee, Samuel Jayagaran, Nate Bakala and Susan Champlain in 2023. To build the X-66A, Boeing will convert an MD-90 into a full-scale demonstrator aircraft.

PHOTO: BOEING

In Their Words



PHOTOS: NASA

At NASA headquarters in Washington, D.C., leaders celebrate NASA's 2023 selection of Boeing and its industry team to develop and flight-test a full-scale Transonic Truss-Braced Wing demonstrator aircraft.

"One of the key outputs of this activity is really the learning, the knowledge. What, at the integrated airplane level, will the benefits be? The results of this effort and market conditions, that'll dictate whether this shows up on the next commercial product."

Todd Citron,
Boeing Chief Technology Officer

"We've been advancing and exploring these advanced technologies, and we've been testing them at simulations at NASA wind tunnels. We're now moving to that next stage — demonstrating this promising technology in-flight."

Bob Pearce,
Associate Administrator,
NASA Aeronautics Research
Mission Directorate

"That is a revolutionary design, and this is going to be flying in 2028. It's our plan to demonstrate this extra-long, thin wing, stabilized by the braces. And in addition to the design, the Sustainable Flight Demonstrator will integrate multiple other related green technologies."

Bill Nelson,
NASA Administrator

Mag Bags and Dutter Cutter

BY MICK BOROUGHS, BOEING WRITER

There's a story behind every tool in the box.

Francis Leprozo, a composite fabricator, talks up the importance of a Mag Bag — a plastic bag that closes securely with a magnetic lock to contain fumes from used cleaning rags.

James Harris touts the benefits of ergonomic tool handles, saying he no longer has sore hands and shoulders at the end of his shift.

Jason Dutter tells how the "Dutter Cutter" drill attachment speeds up the process of removing seal caps and spares knuckles from scrapes.

SAFETY SHOW

Craig Morgan shares safety tips with employees at the Everett, Washington, Safety Dojo.

ALL PHOTOS: MARIAN LOCKHART/BOEING

One Stop: Safety Shop

The tale of each tool begins in the Safety Dojo in Everett, Washington.

Dojo is a Japanese term that defines a center for sharing and learning. At Boeing, Safety Dojos are training and solution centers where ideas can become standard tools or practices to improve workplace safety, quality and efficiency.

The Everett Safety Dojo is an important stop for new Boeing teammates during their orientation and onboarding tours.

As Environment, Health & Safety (EHS) specialist Ken Murphy tells new teammates, the Safety Dojo exists to help them — and every employee — understand and address workplace safety concerns.

“If you have an idea, discuss it with your manager, then bring your idea to the Safety Dojo,” Murphy said. “You can always come here and talk with us. We’re the hub for safety information, and we’re open to everyone.”

On her first day with the company, composite fabricator Chansamonh Phonthana listened to Murphy. “I’m glad they have this dojo here,” she said after her orientation. “It’s very informational for new hires and visitors especially.”

Phonthana was particularly interested in ergonomic tool handles that lessen the risk of carpal tunnel injuries. “That’s one of the top concerns for people doing repetitive work,” she said.

From Injured to Inspired

Craig Morgan wishes there had been a Safety Dojo 35 years ago when he joined Boeing as a structures and door mechanic. Early in his career, repetitive use of high-powered rivet guns injured his hands and led to carpal tunnel surgeries.

In 1994, he slipped on a cargo floor roller and broke his back. He’s also recovered from multiple surgeries on his feet and undergone two ankle reconstructions.

WAY TO DOJO
Composite fabricator Chansamonh Phonthana shows the way to the Safety Dojo in Everett, Washington. More than 58,000 visitors have stopped by since it opened in 2016.

Dojo is a Japanese term that defines a center for sharing and learning. At Boeing, Safety Dojos are training and solution centers where ideas can become standard tools or practices to improve workplace safety, quality and efficiency.

TOP COVER
(From left) Ali Jahansouz, Francis Moreno and Morgan lay covers over metal rollers inside a 777 Freighter in 2019. The plastic covers Morgan developed help guard against slips and prevent injuries for the mechanics who work inside aircraft.

“Maybe I wouldn’t have had to go through the surgeries and all the downtime spent in physical therapy,” Morgan says today.

When the first Safety Dojo opened in Everett in 2016, Morgan stepped away from the manufacturing line, accepting an offer to lead the dojo. Since that time, he’s been encouraging teammates to learn from and share ideas through dojos across the enterprise.

Affected by his injuries and moved to help others, Morgan worked with a tool designer to create a roller cover that helps eliminate the slip hazard that broke his back. The plastic device has a U.S. patent and is now part of the Boeing standard tool manual.

A true believer in workplace safety and healthy ergonomics, Morgan also appreciates the business benefits of safety innovations and improvements. “Safety solutions help increase productivity, improve quality, reduce costs, eliminate foreign object debris and lean out our processes,” he said.

“In the Safety Dojo, we believe we have the best job in the factory,” Morgan said. “Every day we help our teammates get home safely.”

COVER STORY
Morgan shows the roller cover he developed so mechanics wouldn't slip and suffer injuries like he did.

Clear Air and Clean Wings

At Everett's Composite Wing Center, Leprozo and his teammates clean 777X blade stringers — long, composite T-shaped structures that become part of the wing. Composites deposit residue that must be removed when the stringers are put in place. Leprozo uses a stack of acetone-soaked rags to clean and dry the stringers.

"A couple of years ago, we created the Mag Bag, which has a magnetic latch to keep the plastic storage bag sealed," he explained. "If the storage bag was left open, employees could breathe in acetone fumes."

When finished, the plastic bags of dirty rags and used gloves are disposed of into a sealed container. Only the Mag Bag clip is used again, attached to a new plastic bag.

Leprozo credits the Mag Bag not only with cutting the acetone fumes but also for reducing potential foreign object debris.

"In the Safety Dojo, we believe we have the best job in the factory. Every day we help our teammates get home safely."

CRAIG MORGAN,
SAFETY DOJO LEADER

RAGS TO BAGS
Composite fabricator Francis Leprozo puts used cleaning rags into a bag that shuts tight with a magnetic clip, sealing up acetone fumes and eliminating debris in the Composite Wing Center.

SAFE SCRAPE
Ergonomic tool handles ease hours of physical strain for assembly installer James Harris as he works inside airplanes.

Harris, a 777 assembly installer, used to go home with achy hands, arms and shoulders after an eight-hour shift using hand scrapers. Now his scraping tools have ergonomic and adjustable handles, making the job more comfortable.

"The handles eliminate minor — but reportable — hand injuries we've had in the past," said Harris.

"The Safety Dojo is one of the best things at Boeing," Harris said. "It focuses on the safety of the workers, and it's a place where we can learn and share with each other."

EHS safety specialist Dutter joined the Safety Dojo team in 2020. In his previous role as a fuel cell mechanic, his arms, hands and fingers ached from scraping sealant inside the fuel tanks. Sometimes the pain would last for weeks, he said, leading to a surgery on his hands.

So, he created the Dutter Cutter, a drill attachment that reduces the time to remove a cap seal from about 15 minutes to mere seconds. Dutter covered the outside of a socket with sharp, plastic rods.

As a motorized drill attachment, those tiny rods strip off the cap seal quickly. Instead of using hand tools to scrape the sealant, mechanics now use the Dutter Cutter, saving their knuckles and hands from cuts and injuries.

Sharing Safety Successes

Since opening in 2016, more than 58,000 visitors have toured the Everett Safety Dojo, including dozens of airline customers, suppliers and tool developers.

True to the dojo spirit, Boeing shares many of the tools with partners and customers around the world. Some tools are replicated in-house with additive manufacturing, or 3D printing. Pacific Tool of Redmond, Washington, produces some of the specialized tools and distributes them through Boeing's Parts & Distribution Services.

Safety dojos are open in Everett and Renton, Washington, and San Antonio for teammates, partners and customers. Three 24-foot (7-meter) trailers serve as mobile dojos in Washington and South Carolina.

"When a teammate needs help, we're ready to develop or replicate the tool they need," Morgan said. "Across the enterprise, we're expanding the dojos and creating solutions that advance employee safety, eliminate waste and save time, while improving the quality of our products and our teammates' lives." IQ

STRIP AWAY
Jason Dutter (left) strips away a cap seal without scraping his hands and knuckles like he used to before he invented the Dutter Cutter. At the Safety Dojo, Dutter and Mark Sarault (right) help teammates find solutions to workplace safety challenges.

"The Safety Dojo is one of the best things at Boeing. It focuses on the safety of the workers, and it's a place where we can learn and share with each other."

JAMES HARRIS,
777 ASSEMBLY INSTALLER

India Magnified

Measures, metals and minerals on a micro level

BY SOUMITRA ROY, BOEING WRITER

Innovation never sleeps. At Boeing's engineering and technology campus in Bengaluru, India, more than 4,500 employees create technologies that are advancing the aerospace industry worldwide.

IMAGE: GETTY/ROMAN STUDIO

PRECISE AND PORTABLE
Mastering a portable coordinate measurement machine, Vyshnave Vinayak and Suman Murugesan recover and measure the 3D features of Boeing airplane parts and components.

ALL PHOTOS: JOSHUA DRAKE/BOEING

WHEN TEAMS GEL
(From left) Mounika Shanigarapu, Chandrakant Patil and Ankita Hegde prepare metal samples for analysis. At the same time, Ramanna Jakkanagoudar, Dipanwita Chatterjee and Pradeep Premkumar prepare a sol-gel coating to apply on metallic substrates. Sol-gel coatings offer unique advantages, including low processing temperatures, safe handling, and desirable mechanical properties and flexibility for coating complex shapes.

MEASURING UP
Neha Kadyada Chandrashekar and Manpreet Singh guide a light that scans and measures small components in 3D.

LIGHT METAL
Ram J. Omar applies gold-palladium coating to metal samples as part of a metal plasma process.

LEANING IN

(From left) Josh Sutton, Joshua Hodel and Bobbie Sagun helped design a drill that simplifies the installation of sidewall pockets inside an airplane cabin. The team cut the installation time nearly 90% while also reducing foreign object debris.

PHOTO: MARIAN LOCKHART/BOEING

Lean on the Line

5 tips for going lean on a global scale

Who couldn't use one more hour in the day?

The 737 team in Renton, Washington, created time when they standardized the task of installing sidewall pockets on the 737 MAX. Using a new drill that is safer, faster and cleaner, installers can cut holes in the sidewall and install a pocket in under 10 minutes. That's an improvement from 90 minutes, saving the team more than an hour on the task.

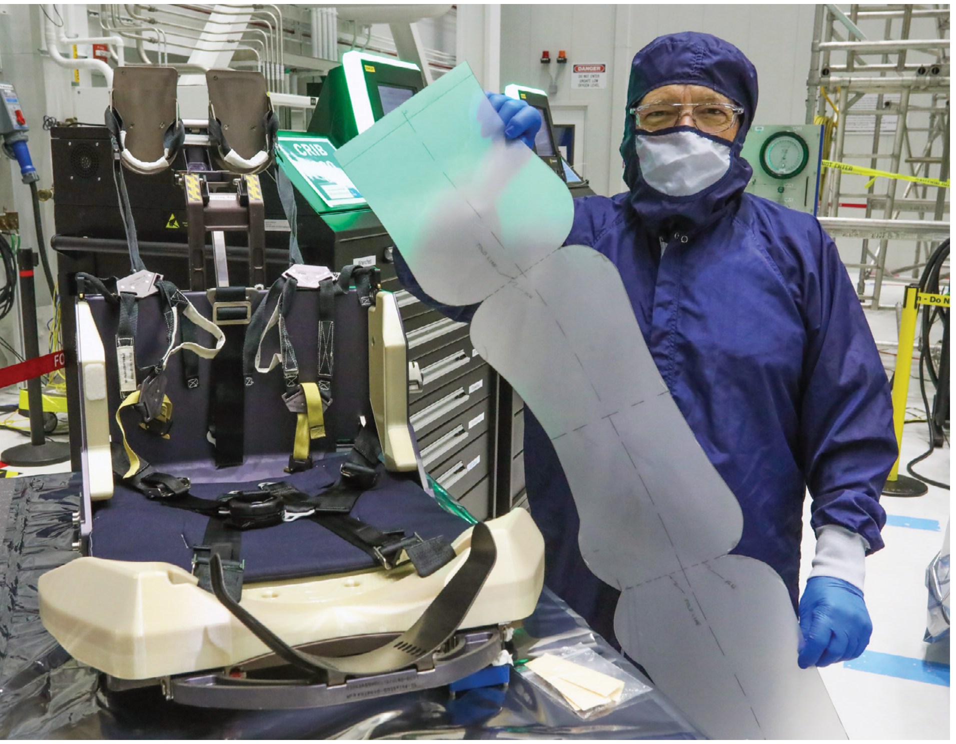
That's the power of Lean, and it's why Boeing Vice President Scott Stocker is passionate about the effort.

IQ: Simply put, what is Lean?

SS: Lean is a way of thinking and acting that enables teams to solve problems and make continuous improvements. It's about listening to the people who do the work, cutting waste and growing more efficient and predictable. Lean is not just a mantra; it's a fundamental principle of engineering excellence and operational stability.

IQ: Why are Lean principles important for the aerospace industry in particular?

SS: By reducing waste and streamlining processes, Lean helps increase efficiency and productivity. Every Lean improvement — from manufacturing to design and customer support — helps us deliver on our quality, safety and on-time delivery commitments to our customers.



MEASURE ONCE, CUT ONCE

Technician Oscar Vilches uses templates to measure and cut the fabric for the CST-100 Starliner crew seats. Accurate measurements save time, allowing Vilches to focus on making the seats nice and comfortable for the astronauts who will fly on Starliner.

PHOTO: JOHN PROFERES/BOEING

ROOM TO GROW

Tool and fixture specialist Sienna Wilferd inspects a pneumatic drill used to assemble 737 MAX engine inlets at Propulsion South Carolina. Empowered to lean out the inlet assembly process, teams have created room to expand their work to support 787 engine buildup, B-52 commercial engine replacement and aftermarket services.

PHOTO: JOSHUA DRAKE/BOEING

IQ: What are the challenges of Lean for a global workforce?

SS: Let's talk about some common challenges, but more importantly, how to overcome them.

1 **Cultural alignment:** Foster a common Lean culture by providing training and mentorship. Emphasize the shared vision and benefits of Lean, highlighting its positive impact on daily work. Encourage leaders to act as Lean champions and drive change within their teams.

2 **Communication and coordination:** Use digital communication platforms and collaboration tools to communicate and share ideas across different locations. Regular virtual meetings, webinars and shared online spaces can help align teams and share best practices. Consolidate Lean initiatives and track the progress to ensure consistency and avoid redundancy.

3 **Change:** Involve employees at every level when implementing Lean principles. Seek their input, feedback and ideas to engage everyone in the improvement journey. Provide training and support to help teammates adapt to Lean principles. Show them how Lean benefits their daily work and expands their skills and competencies, which could lead to new career opportunities.

4 **Standardization:** Start with pilot projects in specific areas, and use them as models to scale Lean practices gradually. Identify early successes and share them across the organization to build momentum. Implement a robust training program for new hires to embed Lean principles in the organization's culture from the beginning.

5 **Continuous improvement:** Promote Lean thinking as an ongoing process rather than a one-time initiative. Encourage others to share improvement ideas and celebrate their successes. Establish regular performance review and feedback mechanisms to track progress and make step-by-step improvements.

IQR

INSIDE IQ

Meet Maddox, Sienna Wilferd's medical alert dog.

IQ: How are Lean improvements driving innovation?

SS: We're challenging ourselves to crush bureaucracy. We're questioning what processes are redundant, and rethinking what hinders creativity and innovation. As teams, we're working together to identify and eliminate bureaucratic practices, streamlining decision-making processes, and empowering one another to take ownership of our work. Reducing unnecessary administrative burdens energizes teams to be creative and find new solutions for the complex problems of the aerospace industry. And that's driving innovation. **IQ**

PHOTO: BOEING

> "Lean is a way of thinking and acting that enables teams to solve problems and make continuous improvements. It's about listening to the people who do the work, cutting waste and growing more efficient and predictable."

SCOTT STOCKER,
VICE PRESIDENT, BOEING COMMERCIAL AIRPLANES MANUFACTURING & SAFETY,
CHAIR, MANUFACTURING OPERATIONS COUNCIL

Contact Centennial

100 years of aerial refueling, and counting

BY PAT CHIESA , BOEING WRITER

In 1923, the U.S. Army conducted the first successful aerial refueling by passing gasoline through a 50-foot (15-meter) rubber hose.

In the century that followed, the U.S. Air Force and Boeing evolved this capability into the backbone of military aviation.

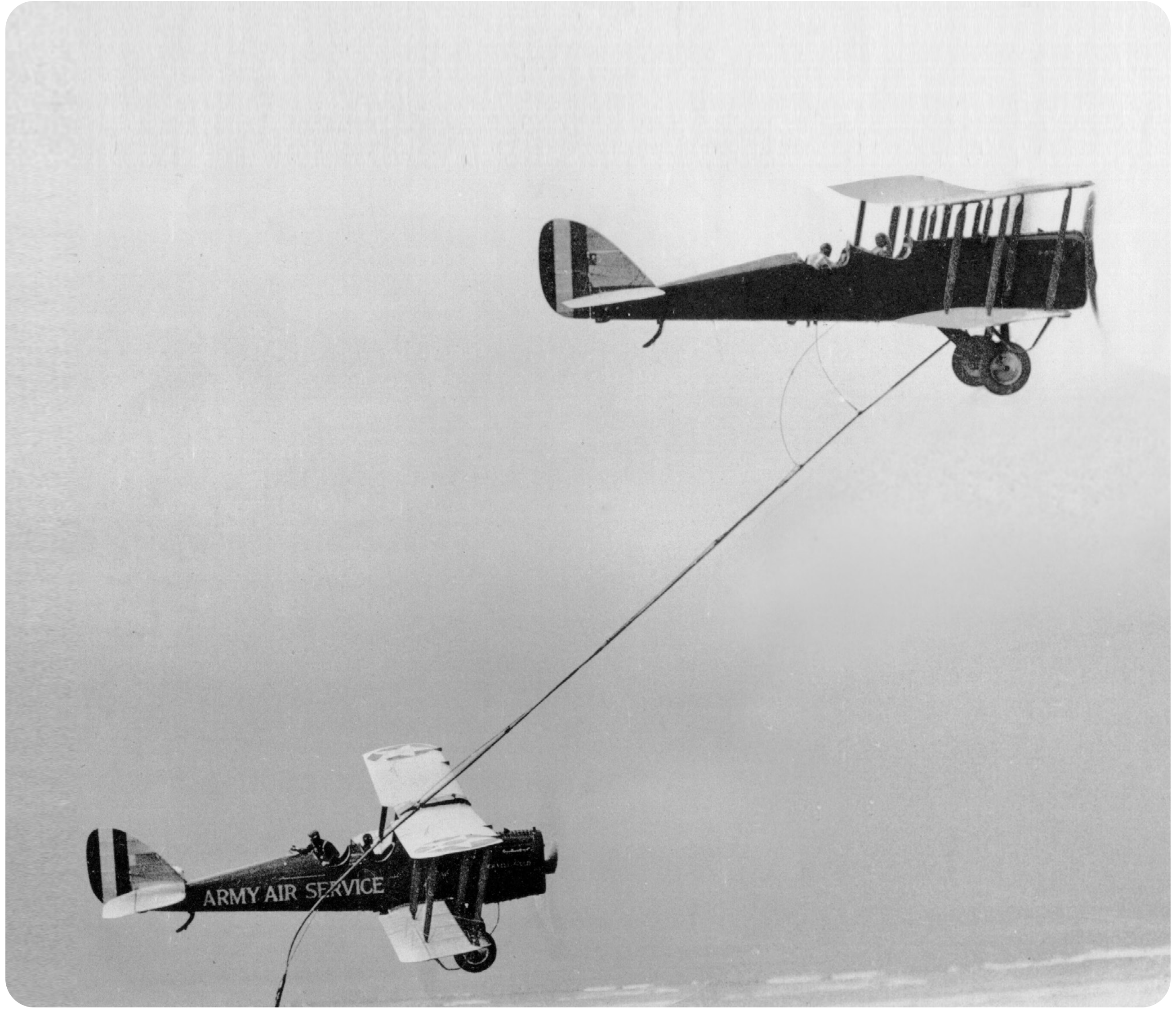


PHOTO: U.S. AIR FORCE

1923

Two DH-4B biplanes conducted history's first aerial refueling exercise on June 27, 1923, over Rockwell Field in San Diego. First Lt. Virgil Hine piloted the tanker while 1st Lt. Frank W. Seifert held the hose in the rear cockpit. Capt. Lowell Smith flew the receiving aircraft as 1st Lt. John Richter connected the hose to pass fuel.

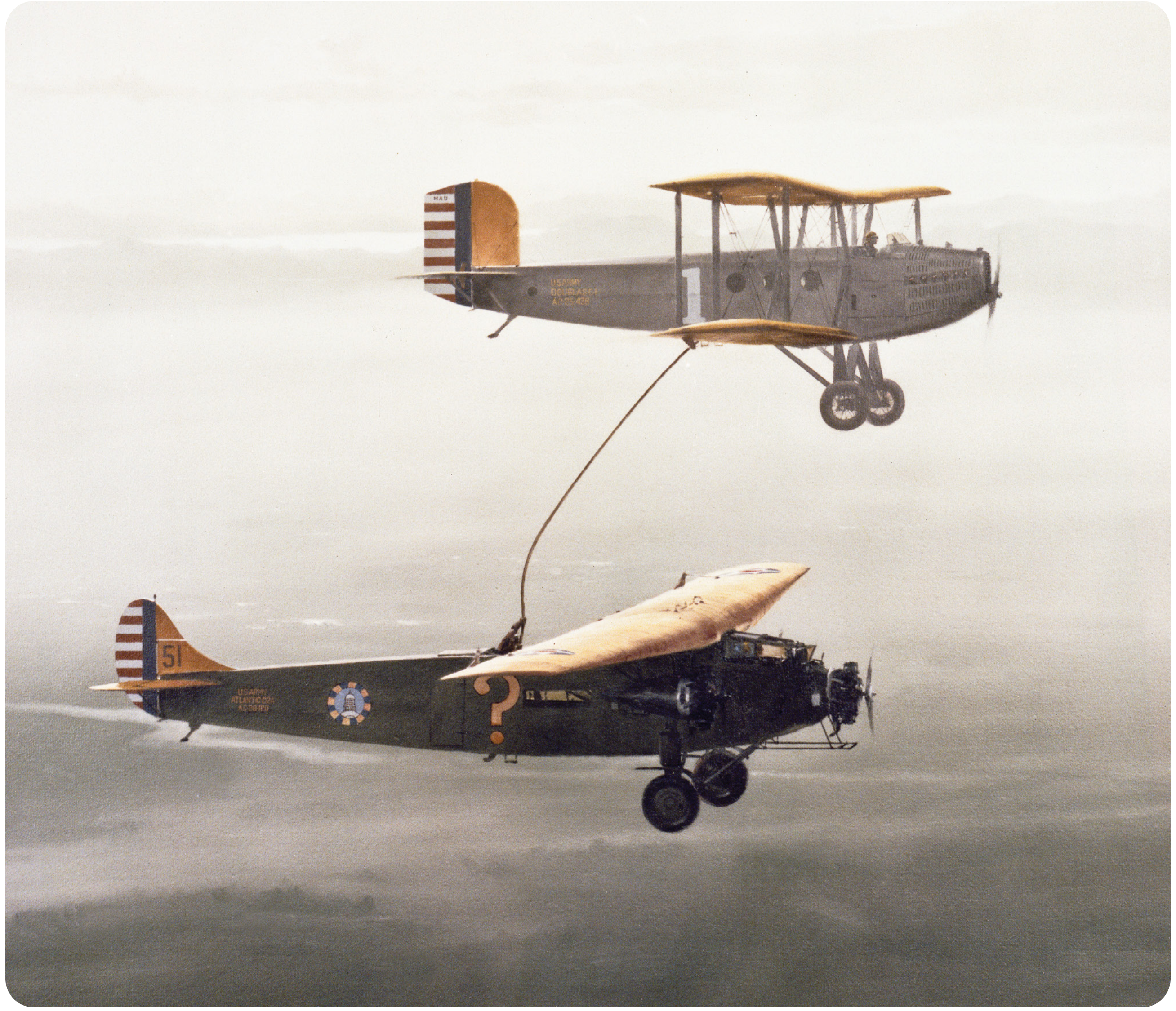


PHOTO: BOEING ARCHIVES

1929

Boeing played a role in a pivotal moment in aerial refueling history with the flight of the “Question Mark,” Jan. 1-7, 1929. The U.S. Army Air Corps C-2A, built by Boeing heritage company Atlantic Aircraft, flew for nearly 151 uninterrupted hours and made 43 contacts with a C-1 tanker aircraft, built by Boeing heritage company Douglas Aircraft, setting numerous endurance records.

PHOTO: BOEING ARCHIVES

1948

Boeing reactivated its Kansas plant to convert B-29 Superfortress bombers into KB-29M tankers. In 1950, the KB-29P tankers, equipped with a flying boom, began operation. Between 1948 and 1951, 208 B-29s were converted for aerial refueling.

PHOTO: BOEING ARCHIVES

PHOTO: BOEING ARCHIVES

1950

The four-engine, propeller-powered B-50 bomber first flew in 1947. Converted to the KB-50 tanker in 1950, some KB-50s served until 1965 and acted as refueling tankers during the Vietnam War.

1951

The C-97 received its KC-97 designation when it was equipped with the Boeing-designed flying boom for aerial refueling. The boom had controls so the boom operator could literally fly the end of the boom from the KC-97 aerial tanker into the receiving aircraft.

PHOTO: BOEING ARCHIVES

1953

Two converted B-47Bs conducted the world's first jet-to-jet refueling by connecting the drogue, or cone, of the refueling aircraft to the probe on the receiving aircraft. Flight crews referred to the KB-47G tanker (right) as "Maw" and the YB-47F receiver aircraft (left) as "Paw."

PHOTO: BOEING ARCHIVES

1956

Introduced to replace the KC-97, the KC-135 still comprises the majority of the U.S. Air Force's tanker fleet, with nearly 400 aircraft currently in service. It was the first aircraft designed specifically for aerial refueling.

PHOTO: BOEING ARCHIVES

1980

The McDonnell Douglas KC-10 Extender can perform airlift and refueling missions simultaneously. The KC-10's hose-and-drogue system allows the refueling of the U.S. Navy, U.S. Marine Corps and most allied aircraft, all in one mission. It is still in service today.

PHOTO: BOEING ARCHIVES

2019

The world's most advanced multimission aerial refueler is approved by the U.S. Air Force for global deployments, including combat operations. Today, the KC-46A is delivering fuel, data and multimission capability for the U.S. and allies around the world.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