



INNOVATION QUARTERLY

INNOVATION. INSIGHT. INSIDE AEROSPACE.



Beyond Books

**Pilot training with
more show, less tell**

SIMULATION EDUCATION

Boeing instructor Oscar Paredes (left) offers guidance from the observer's seat in a Boeing 737 full-flight simulator in Miami.

PLUS: Clearly Safer

A cross-functional team developed software that aids V-22 Osprey pilots' vision when landing



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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: JOANNA MOSLEY/BOEING

Ingenuity

The pathway
to possibilities

Ingenuity is an essential element in the discipline of engineering that brings dreams of flight to life.

Behind every Boeing innovation are visionaries who see our customers through their toughest challenges. With an eye for originality, our sights are set on lean, agile and digital-driven solutions across the globe.

Ingenious approaches are apparent on every page of this edition of Innovation Quarterly. The cover story spotlights advances in pilot training. Immersive learning and high-tech instruction aids are augmenting the training experience and enhancing the safety of air travel.

Safety is strengthened further for military pilots through new software developed for the V-22 Osprey. The display provides “eyes” on the ground for reduced-visibility landings.

We look ahead to a horizon that includes 5G technology. Engineering leaders aim to further advance aviation safety by determining how 5G affects radio altimeters and exploring solutions for compatibility.

We invite you to read on, page by page, as we highlight ingenuity at every turn. **IQ**



Tony Hagen

Vice President and Chief Engineer,
Boeing Global Services

UNCLEAR AND PRESENT DANGER

A V-22 Osprey kicks up dust as U.S. Marines train in Romania.

PHOTO: SGT. PAUL PETERSON/U.S. MARINE CORPS

Clearly Safer

A cross-functional team developed software that aids V-22 Osprey pilots' vision when landing

BY ED MUIR, BOEING WRITER

V is for vertical in V-22 Osprey.

But it might as well also mean versatility. Military customers are drawn to the multirole combat aircraft for its ability to vertically take off and land in tight spaces like a helicopter, while also providing — with its tiltrotor design — the long-range flight and speed capabilities of an airplane.

But a potential issue that arises with many vertical landings is known as rotor downwash. The rotor blades from a descending vehicle can disperse so much dirt and dust from the ground that it sometimes becomes a safety issue.

“The rotor downwash can create severe ‘brownout’ conditions for a pilot,” said Doug Fischer, a human factors engineer for the V-22 program. “That can be quite stressful and disorienting as they’re trying to land in a relatively small area.”

V-22 OSPREY



DIRT ROAD DROP-IN

The V-22 Osprey is known for its ability to operate in a limited landing area. But that can result in decreased visibility, depending on the terrain.

IMAGE: U.S. MARINE CORPS

As a result, a cross-functional team of about 20 engineers came up with a solution to help combat reduced-visibility landings. The Reduced Visibility Landing Symbology (RVLS) team created software that significantly aids pilots during touchdown.

“This solution allows pilots to land both faster and more accurately in limited visibility without adding the burden of configuring the system or formally designating a landing zone,” said Jacob Kowalski, a flying qualities engineer for the V-22 program. “It’s also easier to monitor and teach other pilots.”

With the new software, pilots now see a more detailed picture of where the aircraft is going. There’s a moving map display in the cockpit with added symbols and cues that guide pilots. The display activates about 3 miles (5 kilometers) away from the landing area to within 100 feet (30 meters) of the desired spot. All this integrates seamlessly with the computing, display and sensor hardware available on even the earliest Ospreys.

“It used to be that pilots would need to shift their focus between the cockpit display and the landing area, while at the same time calculate necessary changes in speed and altitude,” said Fischer. “The RVLS, however, provides visual cues on how to manage flight controls so the pilots can better maintain a safe descent profile. The result is an intuitive solution that allows the pilot to focus more on display symbology without shifting visual scan outside of the aircraft.”

CLOUDING VISION

Service members from the U.S. Air Force, Army and Marine Corps conduct training using a V-22 Osprey in Djibouti.

PHOTO: TECH. SGT. JOSHUA J. GARCIA/U.S. AIR FORCE



DESERT DUST

A V-22 Osprey lands at an airfield in Kuwait.

PHOTO: SGT. AARON HENSON/ U.S. MARINE CORPS

“This solution allows pilots to land both faster and more accurately in limited visibility without adding the burden of configuring the system or formally designating a landing zone. It’s also easier to monitor and teach other pilots.”

**JACOB KOWALSKI,
FLYING QUALITIES ENGINEER,
V-22 PROGRAM**



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**DOUG FISCHER,
HUMAN FACTORS ENGINEER,
V-22 PROGRAM**

INSIDE OUT

RVLS contributes to a more efficient arrival and departure. Here, U.S. Marines conduct training from a V-22 Osprey in North Carolina.

PHOTO: CPL. ETHAN PUMPHRET/U.S. MARINE CORPS



PILOT-APPROVED

Pilots say RVLS significantly enhances safety. Here, an Osprey preps for takeoff aboard the USS *Iwo Jima*.

PHOTO: CPL. ISAIAH CAMPBELL /U.S. MARINE CORPS



A military test pilot said, “This is where RVLS really shines — the pilot could not visually identify the landing zone far out but was able to get on and stay on profile until later in the approach when the zone became visible again.”

An operational pilot said,
“RVLS is a game-changing capability.”

The RVLS team worked on the project for four years, including many hours of flight testing to validate the software in day, night and varied levels of brownout conditions.

Kowalski said it’s gratifying to make a difference. “Quite simply, we improved safety by making both pilots’ jobs easier.” **IQ**

Safe Flight for a 5G World

Global experts address potential effects

BY ED MUIR, BOEING WRITER

A global effort is underway to ensure that new 5G cellular technology can safely coexist with the operation of aircraft of all types — from the largest jumbo jets to the smallest civilian aircraft and everything in between.

Wireless network providers are rolling out 5G — the fifth-generation cellular network offering increased high-speed data — which uses a range of radio frequencies known as C-band. The global aviation industry has been analyzing the potential effects of 5G interference on radio altimeters, which also use the C-band and are on nearly every aircraft in the sky, including commercial, defense, regional, general aviation and helicopters.

Radio altimeters use radio wave signals to provide data about an aircraft's height above the ground, which is critical to many airplane systems and functions — automatic landing, flight controls, primary displays, crew alerting, surveillance and other systems, depending on airplane model. These differ from standard altimeters, which provide an aircraft's altitude above sea level by measuring atmospheric pressure.

In the U.S. and around the world, the 5G power limits authorized for cellphone towers can potentially interfere with radio altimeters on aircraft. As a result, regulators, telecommunications companies, radio altimeter manufacturers, airlines and aircraft manufacturers — including Boeing — have been working together to address the issue.

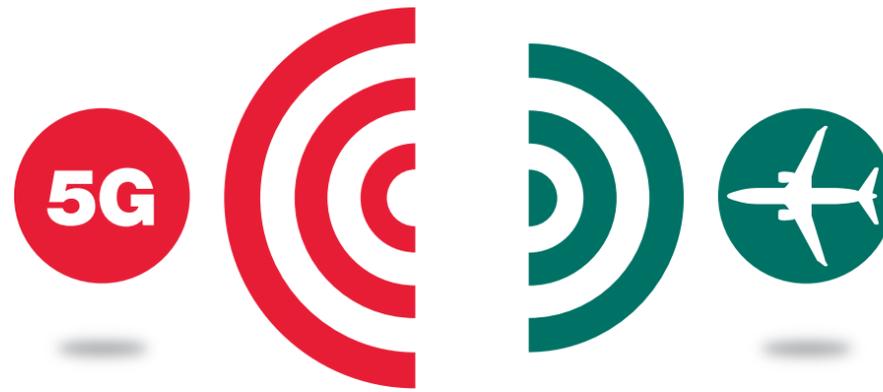
The U.S. Federal Aviation Administration (FAA) has taken a series of steps to protect aircraft operating in 5G environments, including issuing operational restrictions for aircraft and airports in areas where interference is possible. Work on interim measures continues, and the FAA recently proposed rulemaking that will require all aircraft to have an altimeter approved for 5G environments.

Altimeter Experts: Boeing Team Taps Into the Tech

Data from Boeing research and testing — in both labs and real flight tests — has helped inform regulatory agencies and others as they take steps to protect the safety of flight in 5G environments.

“Advancements in wireless technologies are continuing,” said Howard McKenzie, Boeing chief engineer and executive vice president of Engineering, Test & Technology. “While industry, regulators and airlines are rigorously partnering to address the introduction of 5G towers in proximity with airport operations now, we’re also focused on applying what we learn here to get ready for future developments.”

Here are just a few of the many Boeing teammates around the world providing expertise in this new future:



“While industry, regulators and airlines are rigorously partnering to address the introduction of 5G towers in proximity with airport operations now, we’re also focused on applying what we learn here to get ready for future developments.”

HOWARD MCKENZIE, CHIEF ENGINEER AND EXECUTIVE VICE PRESIDENT OF ENGINEERING, TEST & TECHNOLOGY



BEN IVERS
Autonomous Systems Director
PHOTO: BOEING



JENNIFER HOLDER
Regulatory Affairs Director
PHOTO: BOEING



MATT HARRIS
Systems Engineer
PHOTO: PAUL PINNER/BOEING

BEN IVERS co-leads Boeing’s 5G radio altimeter response team with the FAA that collaborates with regulators, the telecommunications industry, suppliers and other key aviation stakeholders around the world.

With an extensive technical background in airplane avionics, he understands how technologies like radio altimeters and other complex systems are integrated on an airplane. His experience working on different Boeing products and with industry partners has been essential to Boeing’s approach to finding technical, regulatory and operational 5G solutions.

“When we first learned there was a 5G safety concern, it wasn’t hard to find the right people at Boeing. In the middle of the pandemic, the vast majority of our work was completed remotely around the world, including Australia, Europe and the U.S. — across all time zones. Collaboration was the glue that kept us together.”

JENNIFER HOLDER co-leads the 5G radio altimeter response team with the FAA, focusing on finding safety solutions that mitigate potential effects of 5G interference. She helped bring together Boeing experts in various disciplines in order to conduct technical analysis and risk assessment.

Previously, she worked extensively on the 737 MAX where she led effects analysis with an emphasis on resource systems, like radio altimeters, that provide flight-critical data to the flight control and auto-throttle systems as well as to the flight crew. The team’s 5G research has helped the industry better understand the issue and propose potential solutions.

“Our job is aviation safety, and we take that very seriously. Our team mobilized hundreds of people to pull together the data and information to ensure the safety of those flying on our airplanes.”

MATT HARRIS, a Boeing Technical Fellow, specializes in radio navigation systems and has been working on 5G testing and data collection for more than two years.

With deep knowledge of radio frequency systems and integration, Harris led an enterprisewide technical team tasked with collecting and interpreting data from 5G and radar altimeter testing.

Harris provided key technical inputs to an industry team that developed an alternative method of compliance (AMOC) methodology. The AMOC methodology allowed the FAA to check each airplane’s altimeter installation against each active 5G base station for compatibility, allowing most airplanes to continue without operational restrictions while assuring continued safety.

“Aviation is making progress on developing new standards with our partners at the FAA, the FCC (Federal Communications Commission) and in the telecommunications industry,” said Harris. “We know this is an important issue, and Boeing teams will continue to work toward the safe and efficient solutions needed now and into the future.”

JOE CRAMER leads Boeing’s 5G radio altimeter response team, collaborating with the FCC, the telecommunications industry and its regulators, suppliers and other stakeholders around the world. His background as both a mechanical engineer and lawyer specializing in spectrum management enables him to understand both sides of the situation – from the effects 5G signals have on airplanes to the regulatory and radio frequency spectrum issues at hand.

As someone who understands the regulatory and technical nuances of 5G’s potential effects on airplanes, he can translate that knowledge to those regulators who are not engineers. He also works with international telecommunications and aviation regulators and even the United Nations on telecommunications issues.

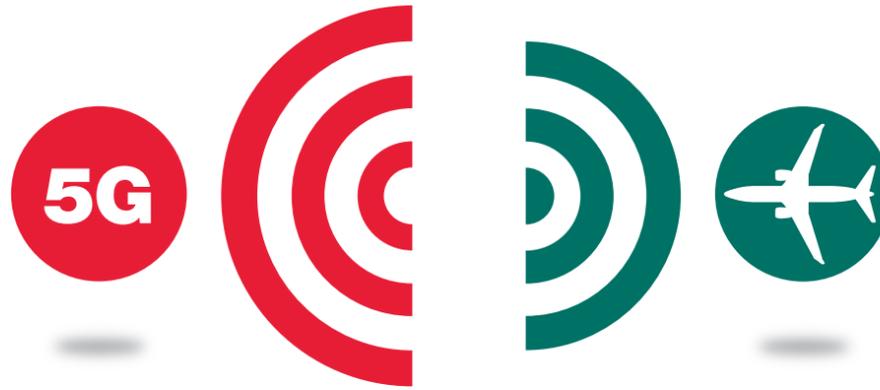
“So much has changed in this area in recent years, but we will get to a solution that ensures safe travel for the flying public,” Cramer said.

TIFFANY PETTIT led the 5G airplane-level effects analysis for Boeing. With her expertise in flight controls and those systems that consume radar altimeter data, she was able to assess the potential 5G effects on sensor behavior.

That information helped regulators in their efforts to ensure the continued operational safety of aircraft flying in 5G environments.

As an expert in autoflight design, safety and certification, Pettit also led the detailed hazard and risk assessment process for all Boeing commercial airplane models.

“Innovation has driven significant advances in airplane systems performance and safety across the Boeing fleet. However, the more that sensors are leveraged to extend capability, the more vital an accurate understanding of our operational environment is,” Pettit said. “5G is a reminder that environments can and do change. Thankfully, our 5G team showed that collaboration with our regulators, industry groups and standards communities can allow innovation to progress without compromising safety.”



JOE CRAMER
Regulatory Affairs Director
PHOTO: BOEING



TIFFANY PETTIT
Flight Controls Engineer
PHOTO: BOEING



MATT SUNDAY
Avionics Engineering
Senior Manager
PHOTO: BOEING

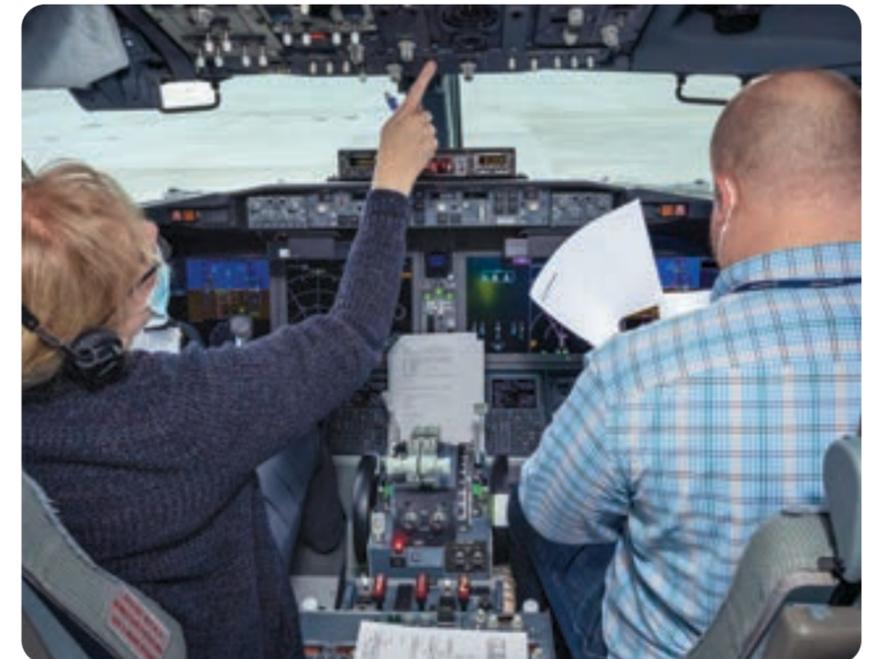
“ So much has changed in this area in recent years, but we will get to a solution that ensures safe travel for the flying public.”

**JOE CRAMER,
REGULATORY AFFAIRS
DIRECTOR**

MATT SUNDAY co-leads a team working to develop, manufacture, certify and deploy hardware to limit 5G interference on Boeing products. His experience in avionics development, test and manufacturing, and certification methods has been critical in this fast-moving environment.

“Once industry and regulators identified a path forward for near-term equipment needs in the fleet, the broader Boeing team jumped right in,” Sunday said. “We’ve worked with Supply Chain, Engineering, Customer Support, Boeing Research & Technology and others to face the challenge head-on.

“We’ve helped lead the industry to ensure the continued safety of our products.”



DATA ON DECK

Jennifer Henderson (left), Commercial Airplanes Production chief pilot, and Kevin Zeznick, flight test pilot, configure the airplane for test conditions.

PHOTO: BOEING



FLY BY

A 737-7 passes above Ogden, Utah, near a 5G signal to determine how an airplane might respond.

PHOTO: GARY STUCK/BOEING



TAXI TO TEST

A 737-7 heads toward the runway at Boeing Field in Seattle.

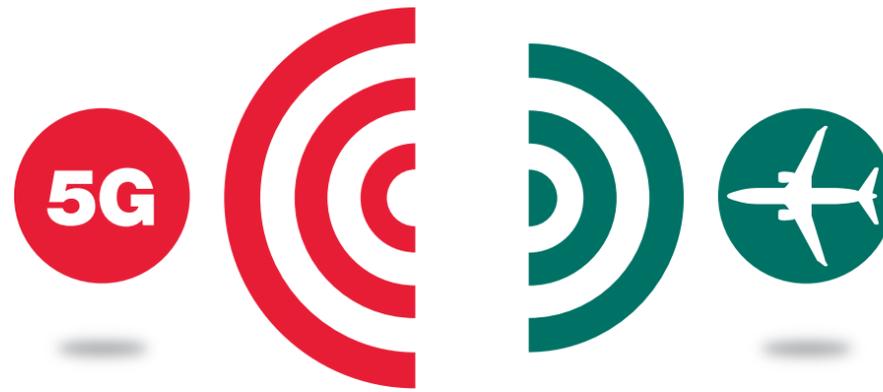
PHOTO: BOEING



UP AND RUNNING

A 5G cellular communications tower for mobile phone and video data transmission.

PHOTO: BILL OXFORD/GETTY



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FLIGHT CONTROLS ENGINEER**

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**MATT SUNDAY,
AVIONICS ENGINEERING
SENIOR MANAGER**



TRAY TABLE TESTING

Josh McCormick (left), from the Flight Test Engineering Analysis team, and Chan Luy, a navigation systems engineer, collect and monitor real-time data during a flight test.

PHOTO: BOEING



TOWER POWER

A mobile cellphone tower base station emits a 5G signal to aid testing, as a 737 (not pictured) flies nearby.

PHOTO: GARY STUCK/BOEING



Beyond Books: More Show, Less Tell for Pilots

Competency-based flight training enhances student learning

BY QUEENA JONES, BOEING WRITER

Over nearly 40 years of flying, Ann Kieffer has sat in every classroom seat, as a student pilot, as a flight instructor and now as a training center examiner.

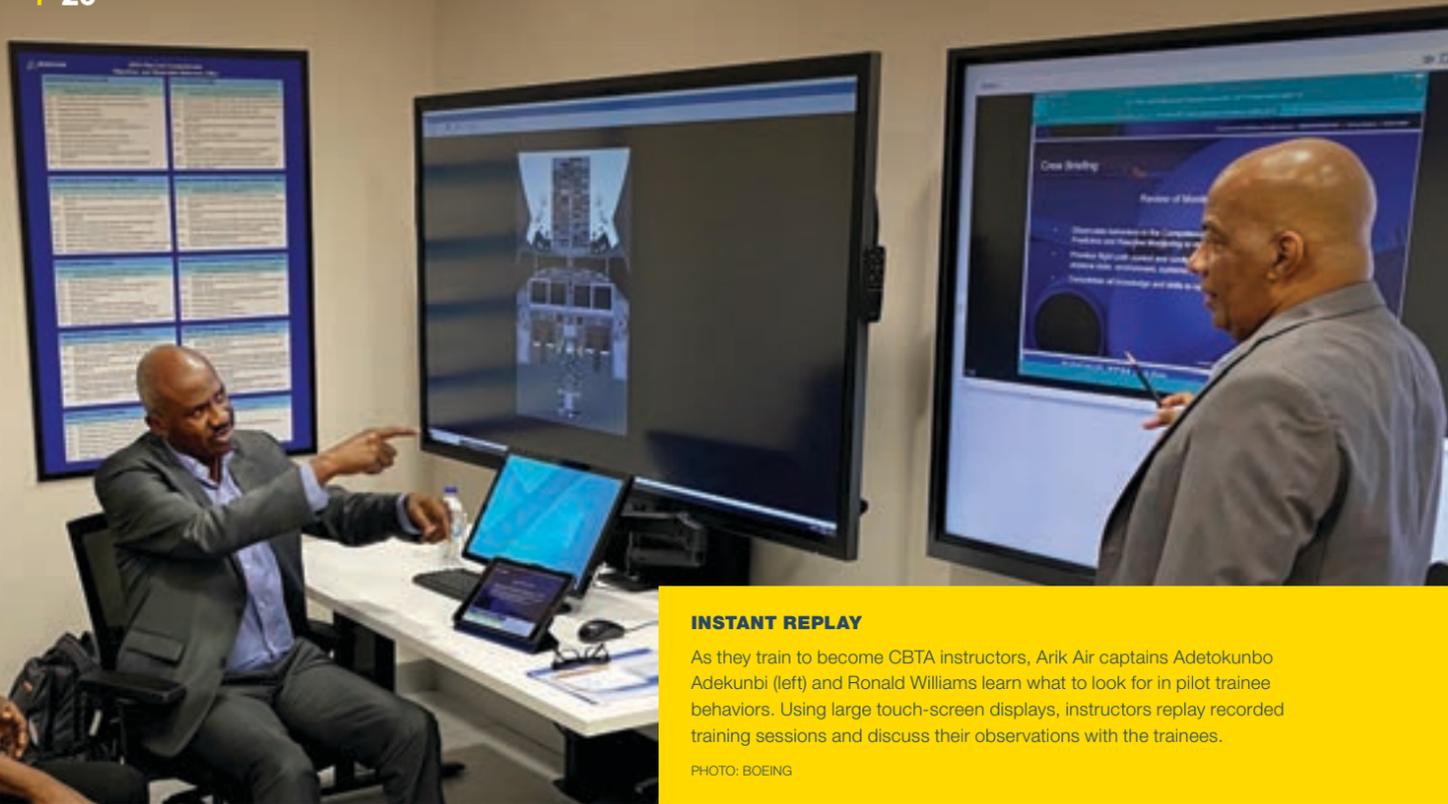
“For decades, flight instruction was predominantly lecture, not dialogue. Before simulators, I spent about 40 days in a classroom preparing for a check ride in a commercial jetliner,” said Kieffer, recalling her early experiences as a pilot trainee.

Today, instructors take a distinctly different approach known as Competency-Based Training and Assessment (CBTA). Instructors and student pilots spend more time together in briefing rooms, which offer desktop simulations, training videos and other immersive learning aids, enabling competency development before ever entering a simulator.

HANDS-ON TRAINING

(From left) Brazilian carrier GOL Linhas Aéreas Inteligentes chief instructor pilot João Carlos Pretto Centeno talks with GOL Airlines pilots Frederico Koff and João Galvão Ribeiro in a Boeing 737 full-flight simulator in Guarulhos, Brazil.

PHOTO: TIM REINHART/BOEING

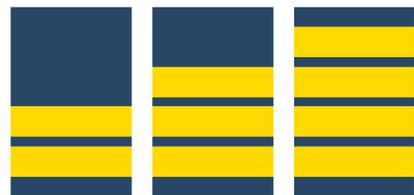


INSTANT REPLAY

As they train to become CBTA instructors, Arik Air captains Adetokunbo Adekunbi (left) and Ronald Williams learn what to look for in pilot trainee behaviors. Using large touch-screen displays, instructors replay recorded training sessions and discuss their observations with the trainees.

PHOTO: BOEING

**More Show,
Less Tell for Pilots**



Once inside high-fidelity full-flight simulators, pilot trainees interact with their instructors and examiners — and sometimes their regulatory authorities — in an environment that is identical to an actual airplane flight deck. This realistic platform enables the trainees to work through real-world scenarios, which are similar to task-based training approaches, as they hone their competencies and behaviors as pilots.

From their jump seat in the simulator, instructors observe and record the trainee's behaviors, decisions and interactions. As they watch the trainee perform the various maneuvers, they are not lecturing or directing the trainee's actions. They are taking notes, offering guidance and assessing the pilot's behaviors, preparing for the conversations and feedback sessions that will follow.

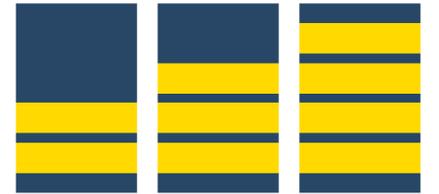
Through this observation, facilitation and dialogue that are the hallmarks of CBTA, the examiners assess the pilot's behaviors and consistently rate their proficiencies in teamwork, communication, decision-making and crew management.

As Kieffer explains it, instructors are transitioning from lecturing to moderating training briefings and guiding students' learning. "Instead of telling the pilots what to do step by step, I ask them to show me what they know already. That allows me to see their experience level, then shape the training accordingly."

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**ANN KIEFFER,
TRAINING CENTER
EXAMINER**

**More Show,
Less Tell for Pilots**

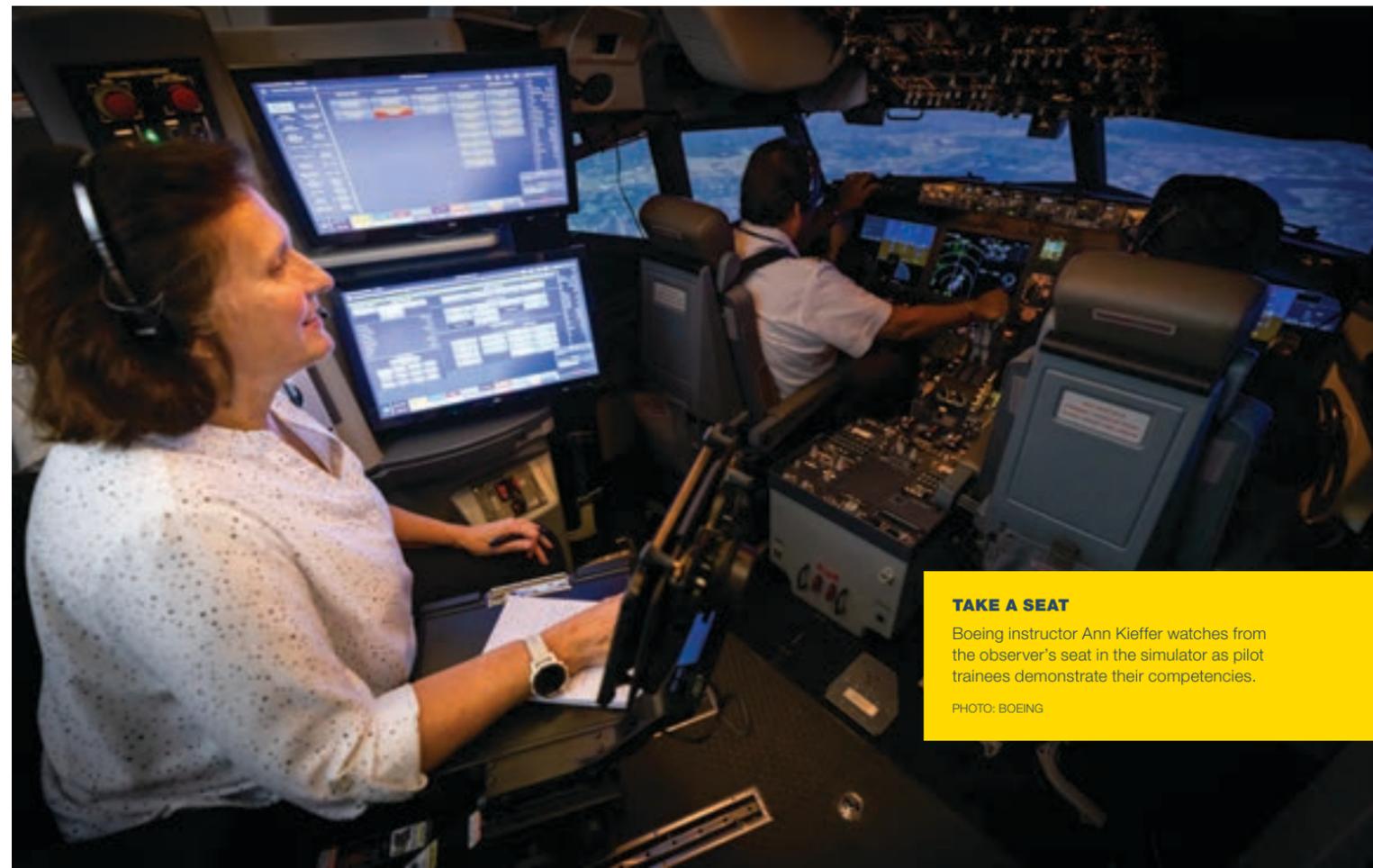


Following guidance set forth by the International Civil Aviation Organization, Boeing developed a CBTA program that standardizes pilot training to enhance the safety of air travel. Since early 2020, Boeing has worked with airline customers, pilot unions and regulatory authorities to create an immersive training curriculum, certify dozens of instructors and provide access to high-tech training tools at campuses around the world.

Each training session is grounded in relevant data, and every effort is made to enhance the learning experience for pilot trainees who are earning their type ratings and qualifications to fly Boeing airplanes.

With continuous advances in airplane technologies, pilots not only need technical instruction on how to fly an airplane, but also training that enhances their skills in problem-solving and decision-making, situation awareness, communication, leadership, teamwork and workload management. Industry has turned to CBTA programs as a way to impart the core competencies that complement and maximize the technical knowledge pilots have of their airplanes.

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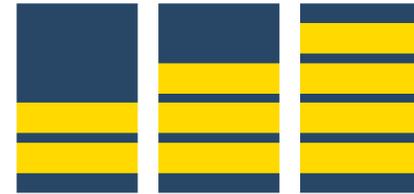


TAKE A SEAT

Boeing instructor Ann Kieffer watches from the observer's seat in the simulator as pilot trainees demonstrate their competencies.

PHOTO: BOEING

More Show, Less Tell for Pilots



Airplane operators are working to establish individual CBTA programs, but there is no global standard for instruction, including for how to analyze streams of airplane data and flight statistics or to meet the distinct requirements of various regulatory authorities.

Ultimately, airlines and regulators are responsible for determining pilot training requirements. But, as an airplane manufacturer, Boeing recognized its obligation to help develop a comprehensive and standardized training package that would strengthen safety through advancing Boeing's training offerings and serving operators worldwide.

"We're working with operators to identify, develop and assess the competencies pilots need in order to safely operate today's airplanes," said Lacey Pittman, vice president of Boeing's Global Aerospace Safety Initiative. "Beyond knowing the technical details of an aircraft, pilots are learning to manage and mitigate the most prevalent threats and errors, those real-world threats that we know exist based on pilot feedback, operational data and training observations.

"By partnering with our operators and with global regulatory authorities to strengthen our baseline training, together we are raising the bar on aerospace safety," said Pittman.

"By partnering with our operators and with global regulatory authorities to strengthen our baseline training, together we are raising the bar on aerospace safety."

**LACEY PITTMAN,
VICE PRESIDENT
OF BOEING'S GLOBAL
AEROSPACE SAFETY
INITIATIVE**



TALKING POINTS

(From left) GOL Airlines instructor pilot Denis Blanchini offers real-world training to GOL Airlines pilots Koff and Ribeiro.

PHOTO: TIM REINHART/BOEING

More Show, Less Tell for Pilots



TEAM EFFORT

(From left) Boeing training analyst Rowan Abusad, Vietnam Airlines captains Do Quang Tung and Luong Chinh Binh, Boeing training director Christine Bohl, and Civil Aviation Authority of Vietnam Deputy Director of Flight Training Mai Manh Hung gathered after completing a workshop in Singapore.

PHOTO: BOEING



Data Points: Working With Pilots and Regulators To Build CBTA

When Boeing began to build CBTA methods into its training, its Learning Design team knew the curriculum had to be rooted in facts, data and hard evidence. The team combined industry data on airplane specifications with reporting by pilot unions, airlines, third-party observers and regulatory authorities. Curriculum specialists then designed the courses for delivery across multiple platforms, from mobile, e-learning applications to flight training devices and full-flight simulators.

"As we started to develop the curriculum, we brought in customers and asked for their feedback," said Mike Miller, who manages the Learning Design team. "We partnered with multiple airlines to identify known operation hazards and analyze safety risks, and we found that the flight operations data is really what makes this work."

In 2020, Boeing welcomed Brazil's GOL Linhas Aéreas Inteligentes (GOL Intelligent Airlines) as an early partner in developing the CBTA curriculum. GOL worked through one of the first CBTA small group tryouts with the Learning Design team, and GOL was one of the first operators to have pilots achieve a type rating for the 737 MAX, certifying them to fly the aircraft.

"We partnered with multiple airlines to identify known operation hazards and analyze safety risks, and we found that the flight operations data is really what makes this work."

**MIKE MILLER,
MANAGER OF THE
LEARNING DESIGN TEAM**

More Show, Less Tell for Pilots

“We learned a lot from GOL as we worked with the airline, their pilot union and Brazil’s National Civil Aviation Agency,” said Christine Bohl, who leads Boeing’s efforts to introduce CBTA to operators. The team met with more than 70 customers from 45 countries in 2022 as Boeing expanded the training worldwide.

“GOL offered us extensive safety data analytics and flight operations data, and we were able to specialize our training offerings based on that information.”

The evidence-based training approach is a key strength of the CBTA program. Multiple data sources inform both the curriculum design and training customizations:



■ Airplane

The flight data recorder monitors details such as altitude, airspeed and heading. The cockpit voice recorder captures radio transmissions and sounds in the flight deck, such as the pilots’ voices and engine noises.



■ Pilots

In the U.S., self-reporting of safety events is voluntary and confidential through the Federal Aviation Administration’s Aviation Safety Action Program. As pilots speak up and report issues, analysts study what happened, rather than identify who made a mistake.



■ Observers

This includes anyone who rides in the jump seat and observes the flight crew, including maintainers, trainers, check pilots and peers offering line operations safety assessments.



■ Other Parties

Air traffic controllers, government regulatory authorities, airplane mechanics, dispatchers and others on the ground provide data to support CBTA development. Detailed flight information from Automatic Dependent Surveillance-Broadcast data is another source of information for CBTA.

“Data can tell you a lot, not only about the airplane’s performance, but also the effects of human factors, like how well a crew communicates and balances workload and how pilots make their decisions,” said Chris Broom, vice president of Commercial Training Solutions for Boeing Global Services.



Since March 2022, dozens of operators have expressed interest in adopting the CBTA approach. Boeing has welcomed regulators, operators and pilots to its training campuses for dozens of workshops, webinars and information sessions. Through hundreds of instruction sessions, operators have received the basic materials needed to begin to implement competency-based training right away.

“As the airplane manufacturer, we use all this data not only to advance training, but also to help airlines enhance their operations and to sustain and upgrade the airplanes we make,” said Broom.

“Operators can look to this evidence and reassess their training needs based on current, real-world operational data. If they see repeating reporting trends in a particular region or notice new patterns in an airplane’s operating data, they can work with their regulatory authorities to tailor their training requirements accordingly.”

By analyzing common flight scenarios, patterns start to emerge. For example, there may be typical weather conditions between two cities, or an airport may have a long approach or a particular air traffic control environment.

Although the data can be traced to its unique source — a crew, an airport, an airplane, a region — Bohl said Boeing examines the data holistically, looking for root causes, drawing correlations and identifying the repeating patterns.

“As pilots self-report, we don’t use their information to punish or correct them individually. We use their data in the aggregate to improve operations, to enhance the training, and, ultimately, to make better pilots,” Bohl said.

A Class of Their Own: Enhancing the Training Experience

CBTA changes three things about pilot training — the instructor’s techniques, the student’s learning experience, and the tools and technologies at each training campus, both physical and virtual.

Just a few months after the FAA and the European Union Aviation Safety Agency approved the CBTA curriculum, Boeing began to offer the training around the world.

“If the operators can’t come to us, we go to them or bring them to us,” said Broom.

Since March 2022, dozens of operators have expressed interest in adopting the CBTA approach. Boeing has welcomed regulators, operators and pilots to its training campuses for dozens of workshops, webinars and information sessions. Through hundreds of instruction sessions, operators have received the basic materials needed to begin to implement competency-based training right away.

There are multiple e-learning opportunities too. Cloud-based videos provide some instruction, and a mobile Virtual Procedures Trainer provides visual and audible context for students who need to gain familiarity with select airplanes. Pilots can access the procedures on select electronic devices, which enables a customized, progressive learning experience.

With more than 40 certified CBTA instructors, Miller said it’s the instructors who make the difference.

Competency Builds on Competency

Procedural, technical and human factors competencies shape the CBTA curriculum, training and assessments.

Application of knowledge

Trainee understands airplane systems and identifies and applies standard operating procedures.

Application of procedures

Trainee demonstrates proficiency in flows and checklists for normal operations and manages, monitors and maintains situation awareness.

Flight path management, manual

Trainee flies using basic manual handling skills.

Flight path management, automation

Trainee transitions from manual flying to auto-flight to reduce workload and knows when to return to manual flight if auto-flight is not optimal.

Communication

Trainee exhibits effective communication skills, appropriately selecting what to communicate with whom, listening actively and conveying messages accurately.

Leadership and teamwork

Trainee demonstrates ability to engage others in planning, constructively resolves disagreements, accepts responsibility for decisions and exercises decisive leadership.

Workload management

Trainee shows ability to manage crew workload, managing information and coordinating crew schedules and tasks.

Situation awareness

Trainee demonstrates an understanding of abnormal flight characteristics and shows an ability to mitigate threats and errors in various scenarios.

Problem-solving and decision-making

Trainee exhibits thorough decision-making abilities and demonstrates all competencies and proficiencies required for licensure and qualification.



CAPTAINS SPEAKING

(From left) Bohl, Badr Airlines captains Sulieman Abusalih and Mohamed Ahmed, and Boeing customer training specialist Brian Nyasimi met for a workshop in Istanbul to go over the concepts of competency-based training.

PHOTO: BOEING

**More Show,
Less Tell for Pilots**

“They are trained observers,” said Miller. Instructors recognize when a trainee is not demonstrating competency, perhaps lacking leadership or using poor communication skills, Miller explained. Training can be adjusted, based on existing evidence for that competency.

“These instructors know how to assess pilot trainees consistently, and they know there’s always room for improvement, regardless of the pilot’s level of experience,” Miller said.

**Show Me What You Know:
Shifting From Lecturing to Facilitated Learning**

The move to CBTA means the role of the training instructor has evolved.

“Competency-based training is a huge step forward in how we train future pilots,” said Kieffer, the training center examiner.

“I can go back almost 40 years to when I learned how to fly, and back through the decades when my birth father learned to fly and when his father learned to fly. That’s three generations of pilots who received and conducted training through traditional instructor-led lectures.

“CBTA is definitely a new way of teaching and instructing,” she said. “We are learning, excelling and balancing how to be both a facilitator and an instructor. It doesn’t happen overnight, but it’s exciting to be a part of the evolution.

“As pilots grasp the behaviors that lead to good decision-making, effective communication and efficient workload management, they will develop those behaviors and become more competent, safer pilots,” said Kieffer. **IQ**



“ CBTA is definitely a new way of teaching and instructing. We are learning, excelling and balancing how to be both a facilitator and an instructor. It doesn’t happen overnight, but it’s exciting to be a part of the evolution.”

**ANN KIEFFER,
TRAINING CENTER
EXAMINER**

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Let's Connect:

A digital thread leads to advanced aerospace manufacturing

Smart factories thrive on data and drive quality improvements

BY QUEENA JONES, BOEING WRITER

A much-needed tool is located quickly in a 1.2 million-square-foot factory, as smart tags help manufacturing and fulfillment teams search available or misplaced inventory.

A mechanic uses a wireless device to collect wing measurements without having to climb onto the airplane.

Thanks to a sensor on a worker's vest, an alert sounds to remind an airplane painter to secure their safety harness.



SMART FACTORY

Assembly mechanic Steve Fisher works on the forward fuselage of an MQ-25 in St. Louis.

PHOTO: ERIC SHINDELBOWER / BOEING



“Boeing is embracing multiple advanced manufacturing techniques to strengthen our production systems and deliver on our commitments to product quality and safety.”

SCOTT STOCKER,
VICE PRESIDENT OF MANUFACTURING AND SAFETY,
BOEING COMMERCIAL AIRPLANES,
CHAIR OF THE MANUFACTURING OPERATIONS COUNCIL

TOP-LEVEL SAFETY

For those working at heights, a sensor alerts the user and teammates if a safety harness is not secure or needs adjustment.

PHOTO: BOEING

Production systems and people connect seamlessly with technology to foster a safe work environment and achieve high-quality work, from concept to production to service, in Boeing's smart factories.

“Boeing is embracing multiple advanced manufacturing techniques to strengthen our production systems and deliver on our commitments to product quality and safety,” said Scott Stocker, vice president of Manufacturing and Safety for Boeing Commercial Airplanes and chair of the Manufacturing Operations Council.

To make it possible, digitally enabled devices constantly collect, produce and swap data. Those same devices send the data through various systems and protocols, informing and controlling manufacturing processes.

Just like smart homes, smart factories offer controlled environments, automate equipment maintenance and notify operators when attention is needed — similar to adjusting your home's thermostat while you're away on vacation or getting an alert that it's time to change a water filter.

KEEPING TABLETS

3D part modeling helps engineers, assemblers and maintainers “see inside” every step of the way, including design, manufacturing and maintenance.

PHOTO: BOEING

In the same way, machine sensors send performance data to a dashboard. The operator can then monitor equipment in real time and keep things running smoothly. Indicators may show a low fluid level or notify a technician that a machine requires recalibration. Environmental sensors constantly survey for variations in temperature, humidity, vibration and noise.

At the Boeing Sheffield facility in South Yorkshire, England, a tooling application measures consumption and orders just-in-time replacements, ensuring technicians always have tools on hand for their work, without spares consuming storage space. The site is the first to use an operations management system that, through an intuitive user interface, reduces touch time and complexity for operators and provides live machine performance data to industrial engineering.

“Maintaining constant awareness of the manufacturing environment enables our teams to work safely and efficiently and helps us mitigate downtimes and stabilize the production process,” said Stocker.

One key to a connected factory is known as the industrial Internet of Things, or simply IIoT. The IIoT connects physical things — such as production tools and manufacturing equipment — with various control systems. These systems process and calculate large amounts of data and feed the information back into the production system, providing actionable intelligence in near real time.

At the Boeing Sheffield facility in South Yorkshire, England, a tooling application measures consumption and orders just-in-time replacements, ensuring technicians always have tools on hand for their work, without spares consuming storage space.

DIGITAL MAP

The Sheffield facility in South Yorkshire, England, is Boeing's first factory in Europe. Every corner of the 6,200-square-meter space can be digitally visualized to efficiently monitor the production system and material consumption.

PHOTO: BOEING

“Through IIoT connectivity, we get information we can use,” explained Jonathan Vance, a Boeing Associate Technical Fellow who has worked to integrate embedded and wireless electronic systems at Boeing since 2008.

Engineering, IT and data analytics teams rely on the IIoT platform for the connectivity that enables them to collect real-time data and gain insight into manufacturing processes. Connecting hundreds of pieces of automated manufacturing equipment, IIoT helps inform smarter decisions about equipment use and streamline maintenance activities.

Regarding his experiences integrating wireless systems at dozens of Boeing facilities, Vance said, “Completing the digital thread in a factory setting is easy to say, but hard to do.”

Off-the-shelf technologies like Bluetooth connectivity and radio-frequency identification (RFID) can be especially helpful in Boeing’s large manufacturing centers, where some teammates work at heights or in confined spaces.

For example, Vance developed an application that connects an RFID tag on an airplane livery painter’s safety harness to a digital dashboard on the production floor. If the harness is not secure or becomes disconnected, the embedded tag alerts the individual and teammates to refasten the harness.

More commonly, RFID technologies are used in more than 25 Boeing facilities to monitor inventory or to tag any number of production items, Vance said, including assembly jigs, parts or toolboxes.

“You can pull up a particular building, get a bird’s-eye view of the factory and see exactly where the tagged assets are located,” he said. At Boeing South Carolina, teammates are piloting new uses of RFID tags to track the locations of hand tools across the expansive site where the 787 Dreamliner is built.

In other production areas, Boeing is beginning to use digitally enabled tools to drive efficiency, predictability and stability into multiple manufacturing processes.

In St. Charles, Missouri, mechanics use Bluetooth-enabled, digital torque wrenches to install fasteners on Joint Direct Attack Munition guidance kits. Such digital tools hold a tighter tolerance and require fewer recalibrations, so the person doing the work can be sure the right amount of torque is being applied to each fastener, Vance explained.

The tool automatically records each measurement and sends that data to the production system. “All that happens in the background in real time, so it helps the operator know they completed the job right,” said Vance. “This added capability enables us to use the digital thread to systematically verify the work and also affects closed-loop control in our manufacturing processes.”



PINPOINT PRECISION

Munition mechanic Ron Porter uses a digital torque wrench to secure a fastener on a JDAM guidance kit in St. Charles, Missouri.

PHOTO: BRIAN GARLAND/BOEING



DESERT DEVELOPMENT

The ACFC in Mesa, Arizona, will enable Boeing to scale a platform-agnostic, modular and flexible digital production system across future Defense, Space & Security programs, providing unprecedented speed, agility and cost-efficiency.

IMAGE: BOEING

These loops of data are essential to production quality across Boeing’s advanced manufacturing centers, as data threads connect engineering and manufacturing teams and ensure everyone has the information they need in real time. IT and manufacturing teams are developing a plug-and-play sensor registry, which will scale additional sensors to support the digital threads and digital twins of both Boeing products and production factories.

As Boeing begins to produce composite components for combat aircraft at its new Advanced Composite Fabrication Center (ACFC) in Mesa, Arizona, manufacturing teams there demonstrate how a product’s digital thread affects the entire production system.

“The ACFC capitalizes on the latest in digital engineering — from initial concept and design to the production floor and sustainment — and its capabilities are aligned directly with our customers’ need to design, build and field advanced combat aircraft on dramatically accelerated timelines,” said Steve Nordlund, vice president for Boeing Air Dominance.

Already, Boeing Defense, Space & Security has proved the advantages of digital engineering on three aircraft: the T-7A Red Hawk, the MQ-25 Stingray and the MQ-28 Ghost Bat.

The T-7A, an advanced trainer for the U.S. Air Force, uses model-based engineering and 3D design tools to realize an 80% reduction in assembly hours.

“The ACFC capitalizes on the latest in digital engineering — from initial concept and design to the production floor and sustainment — and its capabilities are aligned directly with our customers’ need to design, build and field advanced combat aircraft on dramatically accelerated timelines.”

**STEVE NORDLUND,
VICE PRESIDENT,
BOEING AIR DOMINANCE**

“We can see the interface of the part before it is built or installed. Doing virtual reviews from the very beginning, we can evaluate the aircraft build and the product and catch any issues before they hit the factory floor.”

**FRANKIE SAGE,
STRUCTURAL ENGINEER**



COMPUTER COMPARISON

Fisher lines up the production MQ-25 with the digital model in St. Louis.

PHOTO: ERIC SHINDELBOWER /BOEING

Similarly, a digital thread flows from design to production to support the Boeing technicians and mechanics in St. Louis as they assemble the MQ-25, the U.S. Navy's unmanned aerial refueler. Production teams access 3D-model-based instructions on tablets and monitors to confirm their work meets engineering specifications exactly. The aircraft is digitally native — meaning it's a clean-sheet design developed entirely with digital engineering.

The MQ-28 is an uncrewed military combat aircraft developed by Boeing Australia alongside the Royal Australian Air Force. With a rapid development timetable of just three years from ideation to first flight, the program leverages advancements in digital engineering and advanced manufacturing.

When it comes to existing aircraft systems that help protect people all over the world, Boeing teams apply digital engineering via 3D part modeling. In Ridley Township, Pennsylvania, for example, engineers, assemblers, suppliers, mechanics and maintainers all work side by side to meet U.S. Army modernization priorities for the Chinook program.

Chris Leva and Frankie Sage, Boeing structural engineers who support the Chinook, are helping development and production teams employ model-based parts from the very beginning. Designers see the physical characteristics of each part in 3D, which often determine how the part will be fabricated and positioned.

“We can see the interface of the part before it is built or installed,” said Sage. Teammates can turn the part on-screen to see a different perspective, enlarge the 3D image to see details and even check how the part fits inside the aircraft.

“Doing virtual reviews from the very beginning, we can evaluate the aircraft build and the product and catch any issues before they hit the factory floor,” said Sage. “We make sure we don't see any issues or problems at the get-go, which helps keep down costs and meet the ultimate goal of first-time quality for our customers.”

This also enables the engineers to make sample parts using additive manufacturing, allowing them to check the fit of the new replacement part on the aircraft before going into production.

“During virtual design reviews, the customer can tell us what parts need to be modified for better maintenance or replaceability, or they can identify known issues with older parts that we can improve now as we update the aircraft,” Leva said. “Maintainers, pilots, crew chiefs and logistics personnel participate in the virtual sessions, where we go over the aircraft from head to tail, down to the fastener level.”

Sage gave an example that “a mechanic may say, ‘you can't put that there because our tools won't reach there,’ or ‘we don't have that tool in the field.’ So, we change our design to accommodate that.”

“Our whole job is to make sure the customer can do their mission with an aircraft that's going to be reliable,” said Leva. **IQ**

Sage Advice: The Family That Works Together Stays Together

Frankie Sage feels the responsibility of his job personally. “My dad works on the Chinook. He's a sheet metal mechanic. So I'm able to actually design parts that he's going to be touching and installing. I'm able to see it through for my family.”

And that's just the start. He also has a brother, a sister, an uncle and a cousin who support the program for Boeing near their hometown in Pennsylvania.

“My family is proud to work on the Chinook. When we get to see what we designed, then see it physically installed and working, it's exciting. Knowing you're creating a good product for the customer, that's satisfying for all of us.”

PHOTOS: GETTY

Trend Analysis: Long-Term Look

Become a master trendspotter – and trendsetter

BY MARNA KAGELE, BOEING ENGINEERING, TEST & TECHNOLOGY

An annual phenomenon occurs without fail – the flurry of top trends that are said to be most significant for businesses, industries and even individuals.

Consulting companies, experts, industry groups and more publish a wide variety of lists that claim to foresee the future. Sometimes the lists conflict. Sometimes they agree. Some are predictable. Others are surprising.

While this yearly exercise is exciting and interesting, it is difficult to determine what the information really implies and what kind of action one should take, if any.

What Kinds of Trends Are We Talking About?

Trends are pieces of information that we can observe in the world today that tell us something about a possible future state.

We are not talking about trendy fads that are the result of short-term hype and will fade out rapidly. Those are useful to some, but for many industries, the time scale is too short to be actionable.

Here we are focusing on today's indicators of tomorrow's potential. There is no guarantee they will endure, but we hope for lasting impact that could:

- **Meet end user needs in a novel way.**
- **Enable a new behavior.**
- **Introduce a fresh business model.**
- **Replace an existing offering.**

When effectively analyzed, this information can surface key uncertainties in an industry, gaps in a business plan and upcoming opportunities for growth.



How Do We Develop Our Trend Radar?

To evaluate if these trends are relevant for you, compile a comprehensive list of your own:

- **Find existing lists.**
Collect from a relevant technical organization, a public database or a consulting agency with a specialty in your field or industry.
- **Search other sources.**
Sift through industry reports, conference proceedings, technology research results, user studies and new market entrants to discover items not on existing lists.
- **Screen your sources.**
Ensure credibility. Check who sponsored the report and be aware of biases.
- **Conduct an internal audit.**
Capitalize on information already collected within your organization through marketing efforts, conference attendance, supplier conversations or other informal networks.
- **Do your own thing.**
Be the trendspotter. During your research, pull out the items that are relevant to your work and then keep looking. From a macro perspective, note elements that are surprising. Look for places where people are acting in a new or unintended way.

These differentiators may not necessarily be ideal solutions, but they are the first signs of change or filling a gap with what is available. Seek input from colleagues or others in your industry to effectively and collectively evaluate what you're seeing.

You may choose to organize your trend list using a known method to add meaning. STEEP is a common business framework that stands for Society, Technology, Environment, Economy and Politics. If legal elements are important for your work, STEEP becomes STEEPLE.

Each of the letters represented in the acronym acts as a real-world guide to ensure you are considering a variety of factors when planning for the future. These frameworks can also organize your thinking and highlight interactions between trends.



What To Do With What You Spot?

With research complete, the next move is analysis. A great first step is to look for commonalities in the lists. Also, spotlight any entries that are only in one place but you still deem significant.



Evaluate your trends to establish which are most and least likely:

- **Predict what kind of impact they will have if they continue on their current trajectory.**
- **Consider which trends might interact with each other to result in an even larger force for consideration.**
- **Ask others to do the same and see where you agree or disagree.**
- **Create a group of the most impactful.**

Compare your plans and strategies with those trends. Would your ideas be impeded or advanced by such changes? Identify areas for growth or where there would be new risk.



BOOST YOUR IQ

Decide your future in six steps.



Expect to have a range of outputs from this work, including immediate actions, things to watch over time and areas where you will need to take a deeper look. The most important trends should be enduring by definition. Look for opportunities to shape future outcomes or create new products and services.

Once you have a list, consider refreshing it annually. Changes will likely be incremental next time as some items are added, some may fade out, and others may simply change in a significant way.

Despite all this work, nobody will be 100% correct. Do all you can to ensure your personal crystal ball is as clear as possible. Prepare for a range of possible outcomes. Then your present-day efforts can result in a not-so-unforeseen future. **IQ**

ABOUT THE AUTHOR

Marna Kagele is a Boeing Technical Fellow in systems engineering and strategic foresight and a real-life rocket scientist.

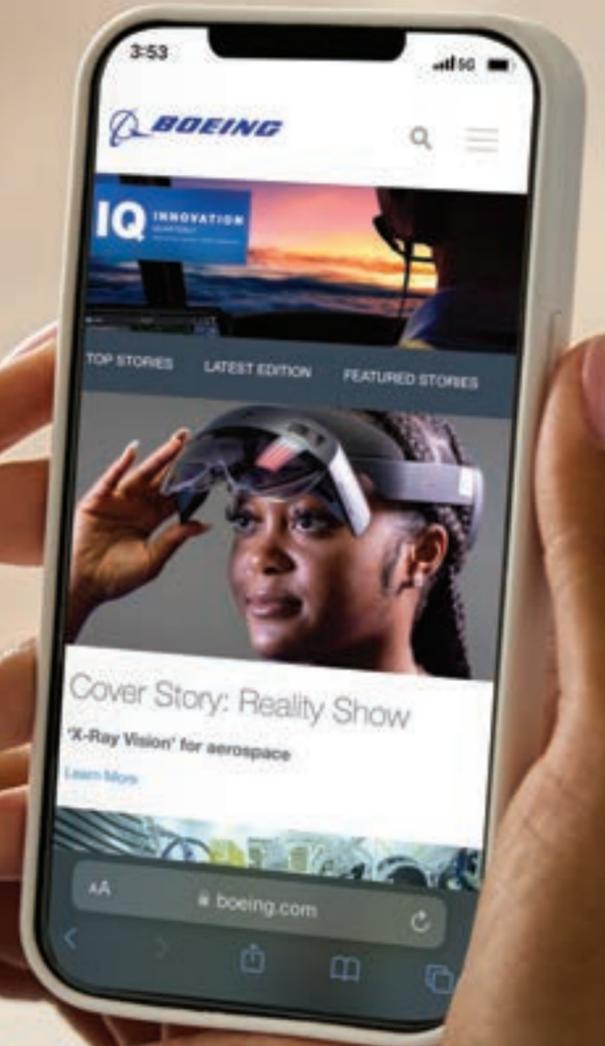
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PHOTO: INSTA_PHOTOS/GETTY

Red-Hot Red Hawk

AIRCRAFT

Boeing T-7A Red Hawk Advanced Trainer

LOCATION

An isolated pad at Boeing's St. Louis Aircraft Delivery Center

TEST

Chained to the flight line, Red Hawk tests its propulsion system and verifies the electromagnetic compatibility of the advanced trainer's digital systems.

FLAME CONE

Stretches 30 feet (9 meters) behind the aft section

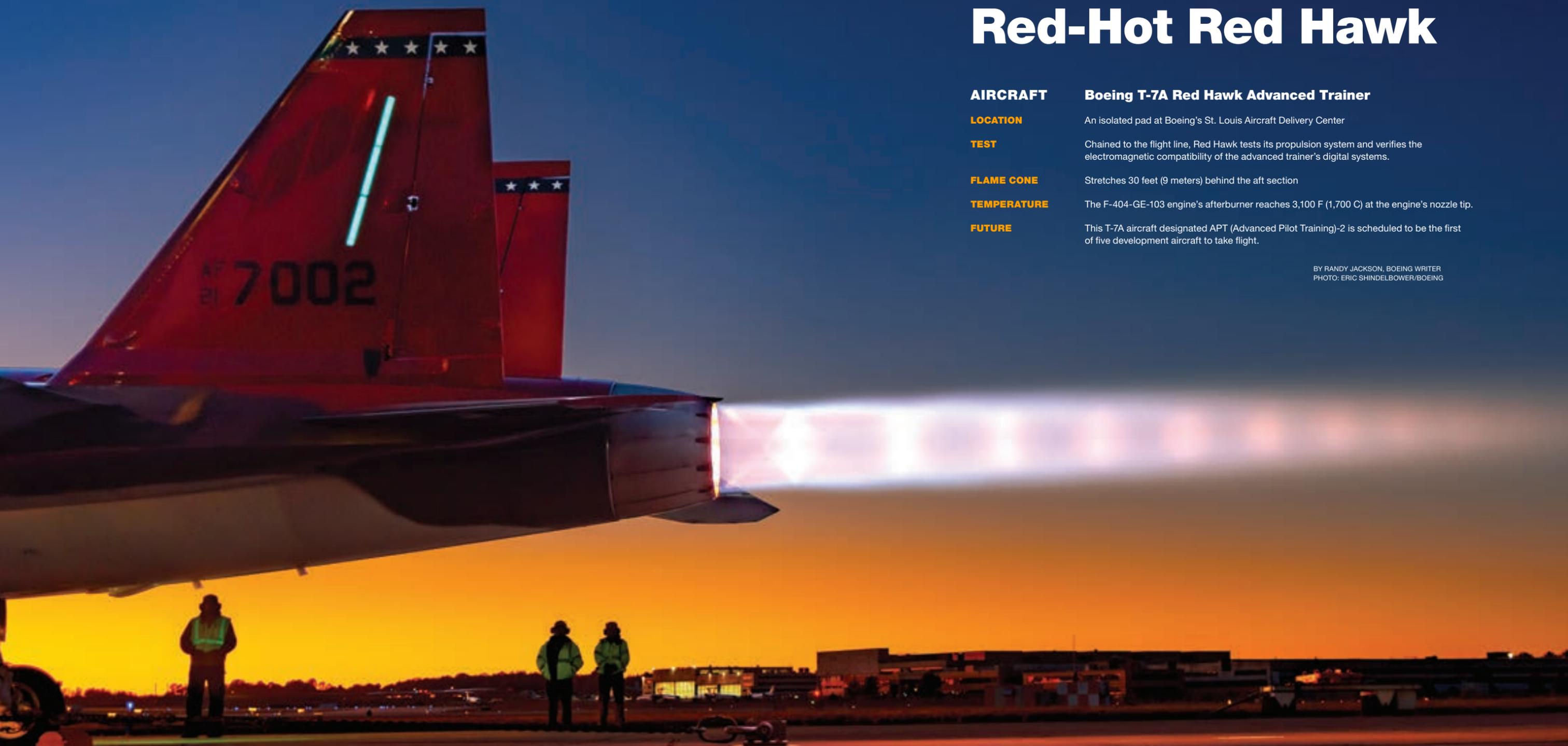
TEMPERATURE

The F-404-GE-103 engine's afterburner reaches 3,100 F (1,700 C) at the engine's nozzle tip.

FUTURE

This T-7A aircraft designated APT (Advanced Pilot Training)-2 is scheduled to be the first of five development aircraft to take flight.

BY RANDY JACKSON, BOEING WRITER
PHOTO: ERIC SHINDELBOWER/BOEING



BOOST YOUR IQ

Video: Meet the team as Red Hawk fires up its engine.

“The images are dramatic, and the sound is deafening, but our test team is laser focused on the data coming from the jet.”

DEREK SCHULTE,
SENIOR TEST MANAGER,
T-7A

“Future U.S. Air Force fighter and bomber pilots must have total confidence in this training system. This test confirms that when future pilots need the power to maneuver and perform their tasks in the cockpit, they'll have it.”

PAUL NIEWALD,
VICE PRESIDENT,
BOEING T-7 PROGRAMS

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