

IQ INNOVATION

QUARTERLY

INNOVATION, INSIGHT, INSIDE AEROSPACE

Wonder Wand

Inside the making of an ultraviolet COVID-19 fighter

Digital Backbone

The Red Hawk trailblazes a design revolution

Smooth Operator

An idea on a napkin saves shoulders with safer sanding

Laser Show

Pesky paint meets its match

LIGHT SAVERS

(From left) Boeing engineers Kevin Callahan, Teresa King and Jamie Childress with the UV wand at Boeing's Concept Center in Everett, Washington.

PLUS:

Tech Talk — to innovate, first communicate

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LET'S TALK

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Resilience
as a requirement

Every person on the planet experienced a disruption in their world in the last year. Each of us changed the way we interact, create, work and live. Resilience is not optional. Our ability to recover, respond and stretch appears on every page of this edition of Innovation Quarterly.

The engineering team that created the ultraviolet wand responded to an urgent need and went to work, sometimes through the night. They take us inside the lab to reveal how their teamwork and ingenuity may transform the way we sanitize the inside of airplanes — maybe inside anywhere.

As efficiency becomes more important than ever, the T-7A Red Hawk lowers costs, saves time and raises quality simultaneously. Stretching the boundaries of digital engineering, the advanced trainer went from the computer screen to the sky in just 36 months.

A similar arc is achieved using lasers to remove paint from aircraft. We spotlight laser ablation and why it's faster, more economical and safer, for operators and the Earth.

We also delve into the concept of TRIZ, a Russian acronym that translates loosely to “Theory of Inventive Problem Solving.” Our engineers explain how this technique approaches a task from a different angle to reveal the solution.

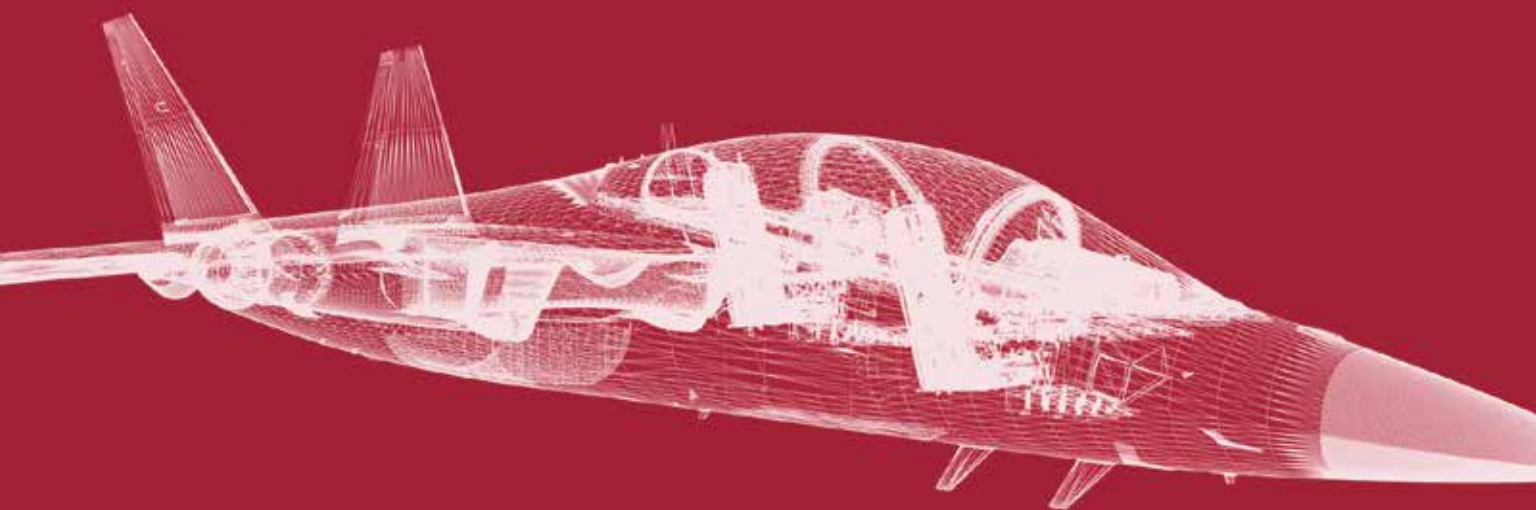
As our archivists find, flexibility in the face of adversity was evident a century ago. A wooden biplane known as the Cloudster attempted one feat but ended up reaching another.

Challenges will arise. We adapt and come back stronger. **IQ**

Greg Hyslop
Chief Engineer

T-7A

Computer screen to
first flight in three years



RED HAWK

Boeing trainer leads the way in digital engineering

BY RANDY JACKSON, BOEING WRITER

The Boeing T-7A Red Hawk advanced trainer is taking an unprecedented digital flight path. Designed, developed and manufactured on a digital foundation, it is the first program acquired as part of the U.S. Air Force digital eSeries initiative. U.S. Secretary of the Air Force Barbara Barrett announced the initiative during remarks at the 2020 Air Force Association Air, Space & Cyber Conference, which was held virtually due to the COVID-19 pandemic.

PHOTO AND GRAPHIC: BOEING

“By lowering development costs, barriers to entry are reduced by establishing digital prototyping — problems are identified and solved quickly and timetables are collapsed,” Barrett said. “The first ‘eSeries’ designator is awarded to an aircraft that was designed, built and tested using digital engineering: the T-7A, the Red Hawk.”

The T-7A Red Hawk trainer was conceived and designed using advanced manufacturing and 3D design techniques and is in the first phase of engineering and manufacturing development flight testing.

DIGITAL PIONEER

The T-7A is the first in the U.S. Air Force's new digital eSeries of aircraft, weapons, satellites and assets — designed and built along a digital thread that embraces advanced manufacturing techniques to improve quality and enhance performance.

PHOTO: STEVE RATKOWSKI

THE AIRCRAFT MOVED FROM COMPUTER SCREEN DESIGN TO FIRST FLIGHT IN JUST 36 MONTHS.



ILLUSTRATION: BOEING

“The U.S. Air Force is setting the tone for how the future of air and space dominance is designed, coded and built,” said Leanne Caret, president and chief executive officer of Boeing Defense, Space & Security. “I’m proud that Boeing’s eT-7A is helping our customers pioneer the digital engineering revolution. Global security threats aren’t slowing down, so we’ve adapted and we’ve e-enabled how we design, test, build and support products for our customers’ needs — moving quickly, taking smart risks and partnering in new ways to get the job done.”

Designed using a digital approach that embraced model-based engineering and 3D tools, the T-7A Red Hawk accounted for an aircraft with a 75% increase in first-time quality, an 80% reduction in assembly hours and a process that cut software development time in half.



T-7 Programs chief engineer G.J. Miller said that following a digital thread ensures a level of truth in sharing among engineers, designers, and production and flight teams.

“By sharing information all along the design, engineering, build and flight test process from a single source, we are able to achieve higher levels of quality than ever before,” said Miller. “When the aircraft is finally assembled, it comes together with precision and less rework.”

The two production-relevant jet trainers — resulting from a competition Boeing won to develop T-X training jets and simulators — have surpassed over 300 successful flights in their robust flight test program and are about to begin Phase 2 high angle of attack testing at Edwards Air Force Base, California.

Dan Draeger, Boeing Test & Evaluation chief tactical aircraft test pilot, said the aircraft continues to impress him with its stability and performance. He said he still remembers the aircraft’s first flight and how different it was from development sorties on other aircraft he’s flown.

“It was amazingly calm in the cockpit,” said the veteran test pilot. “We had already flown the jet in the simulator using the exact same digital software many times rehearsing for the flight, so when it came time for the real thing, we knew what to expect — the jet flew exactly like it was supposed to, no surprises.”

In September 2018, the U.S. Air Force awarded Boeing a \$9.2 billion contract to supply 351 T-7A Red Hawk aircraft and 46 ground-based simulator trainers to replace the Air Education and Training Command’s T-38 training fleet. The first T-7A aircraft are scheduled for delivery to the Air Force in 2023, with initial operating capability the following year. **IQ**



DESIGN EVOLUTION

The T-7A Red Hawk was designed using advanced manufacturing techniques and 3D design elements that improve quality and allow for continuous evolution.

PHOTO: STEVE RATKOWSKI

“WHEN THE AIRCRAFT IS FINALLY ASSEMBLED, IT COMES TOGETHER WITH PRECISION AND LESS REWORK.”

G.J. MILLER , T-7 PROGRAMS CHIEF ENGINEER



IN FLIGHT

A Boeing T-7A Red Hawk streaks over Missouri as part of its engineering and manufacturing development flight testing. The advanced trainer for the U.S. Air Force is designed to evolve for future missions.

PHOTO: KEVIN FLYNN

Boeing's Foresight and Technology Intelligence Community of Practice tracks innovation around the world.

tech

R.A.D.A.R.

Recognizing Advanced Developments and Research



Indestructible Beetle

Irvine, Calif.

The diabolical ironclad beetle's exoskeleton is one of the most crush-resistant structures in the biological world. Researchers at the University of California, Irvine, are demonstrating how engineers can benefit from the exoskeleton's design.



Battle Beam

Nellis Air Force Base, Nev.

During a field test, the Boeing Compact Laser Weapon System successfully defended a force protection convoy against simulated unmanned aerial system threats while mounted on a small utility task vehicle.



Plug-In Plane

London

Aerospace engine manufacturer Rolls-Royce has completed testing of technology to power what it calls the world's fastest all-electric plane.



Liquid Rocket

Hyderabad, India

Liquid oxygen and liquefied natural gas power a cryogenic rocket engine prototype developed by startup Skyroot Aerospace.



Self-Repair Robots

Singapore

Scientists from Nanyang Technological University have developed a way for robots to use artificial intelligence to identify "pain" and repair damage.



Tube Train Test

Uiwang-si, South Korea.

The Korea Railroad Research Institute announced that its hyper-tube train eclipsed the 1,000 kph mark, reaching 1,019 kph (633 mph) in a minitube used for aerodynamic testing.



Autonomous Teamwork

Cloncurry, Australia

Five high-performance surrogate jets operated autonomously in a team at Queensland Flight Test Range. The Boeing flight tests evaluated artificial intelligence algorithms that "teach" the aircraft to understand and collaborate.

L I G H T S A V E R S

THE MAKING OF THE UV WAND

DECK DISINFECT

The UV wand was rigorously evaluated in compact spaces such as a flight deck.

PHOTO: LIZ WOLTER

If they could, pathogens would run and hide at the sight of the purple glow emanating from the Boeing-developed ultraviolet wand. Rapidly yet carefully created by a dedicated team to destroy germs on the inside of airplanes, the UV wand could become standard operating equipment. Teresa King, Jamie Childress and Kevin Callahan were on the front lines of this innovation. They take us inside Boeing's Concept Center to reveal what they did and how they did it.

IQ: Begin at the beginning. Trace the genesis of the UV wand.

Childress: The story is a bit like a rock band that seems to arrive on the scene from nowhere, only for new fans to discover the band has been touring small venues for years. The UV wand was first hatched in my brain way back in 2014 when I first found out 222 nm (nanometer) UV light killed pathogens and is safe for human exposure. Back then the data for both those claims was slim but seemed compelling all the same.

At the time, I was primarily working military projects, so my natural inclination was to apply this technology in that space. I envisioned a “disinfection Swiss Army knife” that could safely sanitize anything from pots and pans to combat wounds.

IQ: How did the idea move to the next level?

Childress: An idea is just an idea until it has a customer. My first customer was not the military. It was Teresa King. As leader of Boeing's Clean Cabin Program, she immediately grasped the value of 222 nm UV for commercial aircraft.

Under Teresa's leadership, we had developed the UV lavatory, which features several clean technologies, including 222 nm UV disinfection. When COVID-19 hit, Teresa informed her management about the wand I was developing.

King: Capitalizing on our UV lav work, we knew a lot about the technology after years of research into 222 nm wavelength. We'd done our homework on the power required to disinfect using this wavelength in the least amount of time possible. And we'd spent hours (internally and externally) testing efficacy, material compatibility and safety of use. The urgency of the pandemic propelled us to a minimum viable product in record time. This is where we turned to the Concept Center, led by Kevin Callahan, to bring it home. And boy, did they deliver.

“I envisioned a ‘disinfection Swiss Army knife’ that could safely sanitize anything from pots and pans to combat wounds.”

JAMIE CHILDRESS



TEAM EFFORT

Hundreds contributed to the effort to conceive, design and build the UV wand. The core UV wand development team gathers at Boeing's Concept Center in Everett, Washington. From top left: Ang "Sam" Sherpa, Teresa King, Yakentim Ibrahim, Doug Brown, Chris Plass, Kevin Callahan, Jamie Childress, Art Brockschmidt and Michael Klein.

PHOTO: MARIAN LOCKHART

IQ: How did the UV lavatory play a role?

King: When our Boeing Research & Technology Tech Fellow Jamie came to us in Product Development with this UV technology back in 2015, it sparked the clean cabin revolution. It was the first time we looked at a solution from a holistic perspective. We later launched the clean cabin self-disinfecting lavatory as a featured suite of products. It was our first Product Development study centered on a UV disinfection system.

Childress: The UV lav was installed on the 2019 ecoDemonstrator 777-200. A critical part of that was a flight-worthy 222 nm power supply designed and built by Art Brockschmidt, a retired Boeing Technical Fellow

and current contractor. Art modified that same power supply in his home workshop for the UV wand. His contribution cannot be overstated. That power supply is practically everything.

It was assumed at the time that the system could be plugged in but would also need batteries for mobility. So Art worked on battery power for the power supply, and I worked on a backpack that could carry it all.

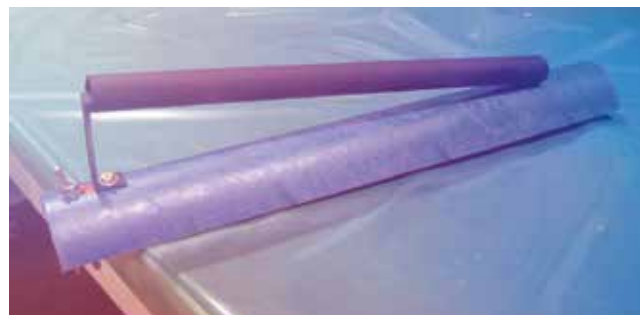
“A critical part of [the UV lav] was a flight-worthy 222 nm power supply. ... That power supply is practically everything.”

JAMIE CHILDRESS

FIRST OF ITS KIND

(Left) Boeing engineer Jamie Childress spray-painted a shipping tube for this first UV wand concept. (Right) A primitive model of the UV wand was crafted out of cardboard, a vacuum hose and duct tape.

PHOTOS: JAMIE CHILDRESS AND TERESA KING



By the end of April 2020, we had preliminary prototype versions with all the key elements of the system: power supply, lamp, cooling system, lamp housing geometry, backpack, extendable handle, ranging LEDs, batteries and charger.

IQ: Sounds like you were inventing in parallel to the emergence of the pandemic?

Childress: At about the same time, I was told there was a critical need for rapid UV disinfection of flight decks.

Callahan: Flight decks are conventionally cleaned using liquid disinfectants. But given the many switches, buttons and dials, it can be a long, intricate process. The urgency of the pandemic required a more efficient approach. Knowing about Jamie's UV wand, I subsequently proposed its use for commercial flight decks.

IQ: What transformed idea into product?

Callahan: The real transformation into a product occurred when the team observed the challenges of existing disinfection methods in sensitive areas such as flight decks. It was the new awareness of this need, paired with Boeing-developed UV technology from Teresa and early concepts like Jamie's, that created the product — one that helps airline customers restore crew confidence in the face of the pandemic.

“The urgency of the pandemic required a more efficient approach.”

KEVIN CALLAHAN

IQ: When did it feel real?

Callahan: I assembled a team to form what became the mobile UV Product Development team. Our charter was to understand what product our airline customers actually wanted. We already had the technology, thanks to Teresa, Jamie, Art and others; the task was to develop the product.

Childress: On Saturday, May 2, 2020, we all met at Boeing's Concept Center in Everett, Washington. It was the first time I had actually seen everyone in person this whole time. Art brought his power supply and battery setup. I brought a wand housing, wand handle, LED light ranging system and a preliminary cooling hose/fan. Kevin and Teresa's team did a brilliant job of taking that tinkertoy pile of preliminary hardware and turning it into something airlines could use.

IQ: Word is, a baby backpack was part of the original design?

King: We had everything from hiking packs to vacuum packs to baby backpacks. Everyone was asked to bring what they had from home and share what they thought might work. I was actually partial to the vacuum backpack at the time. Everyone, of course, couldn't stop making correlations to the Ghostbusters' proton packs.

Callahan: Yes, after Jamie's early backpack prototypes, the development team switched to an infant-carrying backpack, since one of our team members had an old one in his garage. His wife said OK, and the backpack took on a whole new life. There was an incredible number of trips to local hardware and industrial stores. We purchased shop blowers, insecticide applicators, backpacks, vacuum cleaners, power tool batteries, nuts, bolts, sheet metal, rubber hose, activated charcoal (for aquariums), window screen, PVC pipe and plywood.

We first laid out all of the critical components, "Apollo 13" style, that Jamie and Art had already developed and set about integrating those into a product demonstrator. In just six days, we made a fully operational UV wand backpack.

“The usability study conducted with our customers revealed that a new form factor was required; and so was born the Gen 2.0 wheeled bag design.”

KEVIN CALLAHAN

IQ: How did you determine what airlines required?

Callahan: We coordinated with a number of major airlines, both international and domestic, and worked with even more to understand what the product needed to be. We produced and executed a customer engagement process that included research protocol, structured feedback, demonstrations and interviews with objective users (cleaning vendors and airline staff).

ROLL CALL

Incorporating feedback from airlines, the original backpack design evolved into a rollerbag for ease of transport and use.

PHOTO: LIZ WOLTER



WORKSHOP IT

(Left to right) UV team members Kevin Callahan, Jamie Childress and Art Brockschmidt work during the duct tape stage of the UV wand development at Boeing's Concept Center in Everett, Washington.

PHOTO: TERESA KING

IQ: The original UV wand unit included a backpack. Why did you add wheels to make it look more like carry-on luggage?

Callahan: We had to overcome the confirmation bias we all had toward the backpack design. Though we thought it was the right product, airlines told us otherwise. It took careful, objective questioning and engagement with airlines to identify their needs and operational constraints. This is what user research is all about. The usability study conducted with our customers revealed that a new form factor was required; and so was born the Gen 2.0 wheeled bag design.

IQ: How many all-nighters did you pull?

Childress: Since mid-March I've pretty much been in my lab seven days a week, with the occasional exception. However, I have not pulled any all-nighters. Kevin or Teresa would take the trophy on that one.

Callahan: Yak Ibrahim, Ang (Sam) Sherpa and I stayed up 36 hours to build and power up what became the final prototype to get it ready for testing.

King: I had it easy. I only remember one night where I actually worked straight through. (A silver lining to working virtual: I didn't have to drive anywhere, so I barely had to comb my hair.) But there were many long days and nights (I'm a night owl) spent getting organized and sifting through piles of historical data to pull together presentation materials for our new mission. The Concept Center team resolutely worked right through the summer with few breaks. They were unstoppable. I couldn't even force them to take time off. They were determined to get the prototype working. One evening while struggling with a power supply issue, one joked, what are the chances Art, our retired Tech Fellow, would be up at 2 in the morning? Sure enough, he was indeed up and online. Together, they worked through the night, troubleshooting the issue.

IQ: Did you ever think it was impossible?

Callahan: Yes, the night of the all-nighter was one of those times. Everything seemed to be just one step away from working. When we fixed one issue, another would then be identified. It seemed endless. It was the sheer determination of the team to push forward after every setback, understanding how important this was to passengers, airlines and Boeing.

King: If Kevin or the team had doubts, they never shared them with me. I trusted them fully to make this work. We also had great support from key people along the way that made this possible. Everything had to align just perfectly. Thanks to herculean efforts by all team members involved, we did it. We were truly empowered to work across the entire enterprise.

“The Concept Center team resolutely worked right through the summer with few breaks. ... They were determined to get the prototype working.”

TERESA KING

IQ: Have you ever invented anything so rapidly?

Childress: Not in my 33 years at Boeing. Not even close.

Callahan: Invented, yes, developed into a real product, absolutely not! This is far and away the fastest development I've ever seen at Boeing. A process that normally takes two or three years, we accomplished in six months.

King: Our success with the mobile UV wand does play into the myth of the overnight sensation. But like most overnight sensations, it took years of hard work and continued diligence to allow us to more quickly arrive at what most see and recognize, the last step.

IQ: Now that airlines can order the Boeing-developed UV wand (Healthe Inc. and Far UV Technologies will produce and distribute the commercial device), how gratifying is it to see concept become reality?

Childress: Not all research and development efforts actually make it to the real world. This one got there much faster than any other I've ever been involved with.

Callahan: It renews my belief that Boeing has the most amazing talent, excellent leadership and capacity to do great things under the most challenging of circumstances.

REST EASY

Green and orange lights guide operators, like Boeing engineer Kevin Callahan, to the ideal distance for maximum effectiveness against germs.

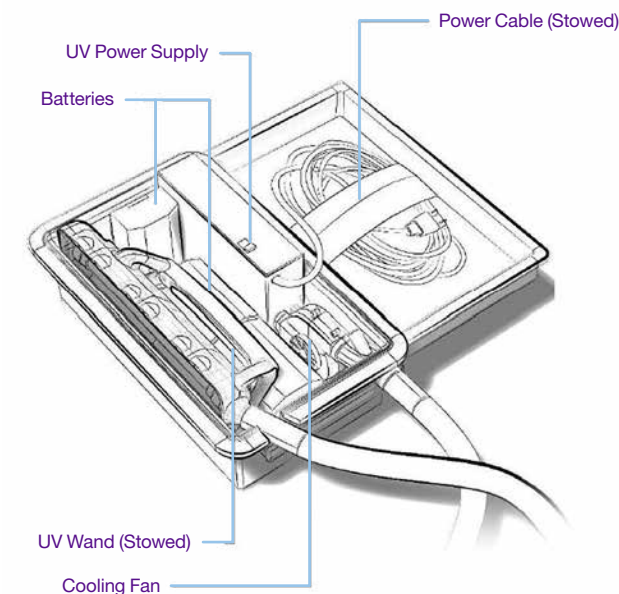
PHOTO: MARIAN LOCKHART

King: I think the most satisfying aspect is finding partners who share our passion about what this technology enables and our drive to help get our passengers, crew and airlines safely back into the air. I can't wait to get back up in the skies again.

IQ: How does this innovation serve the greater good?

Callahan: The Concept Center team took the UV technology and early concepts and created a minimum viable product definition. We validated that definition with airline customers; performed user research; conducted usability testing at Boeing facilities; and, through a rapid development processes, designed and built a near-production prototype used to demonstrate viability to licensees. The real product, however, is restored crew and passenger confidence. The UV wand is simply one of the means to achieve that. Understanding this enabled our success. **IQ**

For links to UV research and UV wand suppliers, find this article at boeing.com/iq.



UNDER THE HOOD

Boeing's latest version of the UV wand system tucks into a case the size of carry-on luggage. Manufacturers may modify components in the future.

GRAPHIC: BOEING

GENERATING SUCCESS

Five generations of the UV wand were shaped by airline evaluation.

PHOTO: MARIAN LOCKHART



Plugging in to the big picture

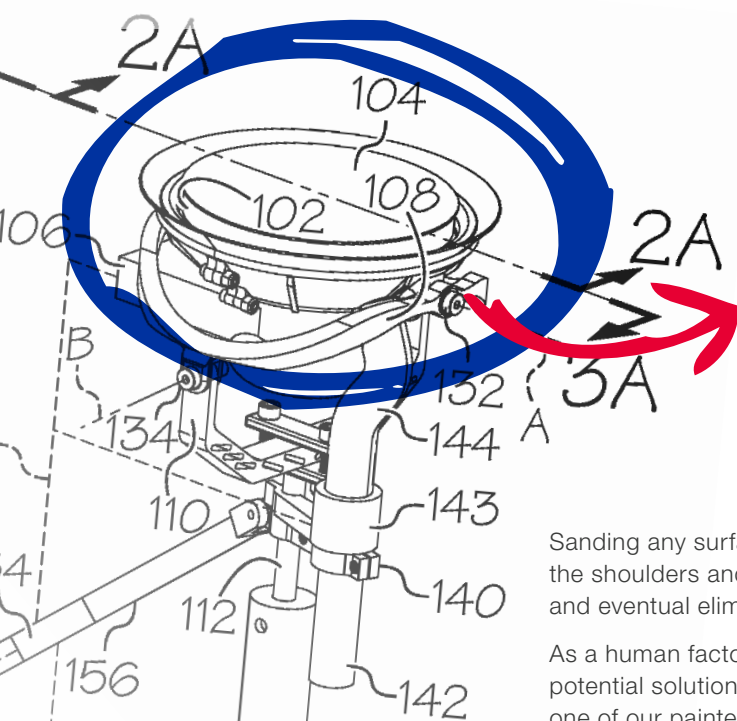
The UV wand is a part of Boeing's Confident Travel Initiative to lead in the global effort to provide passengers and crew a safe, healthy and efficient travel experience. This includes working to minimize air travel health risks amid the COVID-19 pandemic; driving awareness of existing health safeguards, the cabin environment, and cleaning and disinfection processes; and developing and testing new solutions.

We are treating COVID-19 like any threat to the safety of an airplane: assessing the hazard, understanding the environment, and applying proven aerospace engineering practices and data to find solutions.

The risk of contracting COVID-19 during air travel is extremely low compared to typical daily activities. Effective cleaning solutions, passenger responsibility, cabin geometry and the HEPA filter-backed cabin air environment are part of the multilayered approach to protect against COVID-19, helping to ensure the health and safety of every person who steps on board. Going forward, we will continue to evaluate new technologies and techniques that may improve safety in the airplane cabin environment.

How an idea on a napkin became a new Boeing standard

Monopod sander makes sanding more ergonomically safe



Boeing human factors engineer Kadon Kyte's monopod sander solves an ergonomic challenge in the factory. Here's his story of how a napkin sketch led to a patented invention.

Sanding any surface can be ergonomically harmful due to strain on the shoulders and vibrations in the hands. Boeing has made the reduction and eventual elimination of sanding-related ergonomic risk a top priority.

As a human factors engineer, I had the unique experience of investigating potential solutions for this challenge — and even trying them myself. As one of our painters in St. Louis, Mike Kerr, said to me early in my research, "For you to truly understand the challenge we face, you really have to suit up and try it yourself."

One potential concept used industrial exoskeletons. In 2017, I traveled to St. Louis from Charleston, South Carolina, to test various vest-based exoskeleton systems for paint operations. My background is in aviation maintenance, so I was eager to work alongside mechanics to help develop a solution.

After 15 minutes of sanding an aircraft, my shoulders, arms and neck were experiencing discomfort. It was clear that the challenge went well beyond the systems capability and technology maturity level of exoskeletons.

Story continues on Page 23



ABOUT THE AUTHOR

Kadon Kyte (pictured testing an exoskeleton) is a Boeing human factors engineer. He invented the monopod sander to support factory ergonomics.

PHOTO: BOEING

The Ergo Challenge

Aircraft mechanics encounter ergonomic challenges that affect their work every day. Often, ergonomic improvements contribute to increased production rates as well as time and cost savings.

At Boeing, the annual Ergo Challenge has elevated the awareness of ergonomic improvements and their impacts across the enterprise — and inspired more teammates to engage to solve these challenges. The Ergo Challenge helps make local best practices into enterprise solutions.

In recent years, winning improvements have included a modified trailer jack that enables employees to maneuver heavy items; a lightweight, curved ladder that makes curved airplane fuselages more accessible (and eliminates aircraft damage); and a breathable masking tarp that prevents overspray when painting airplanes.

These improvements have increased productivity, reduced waste and saved money. But most importantly, each has reduced the risk of ergonomic injuries for Boeing teammates.

DRAWING INSPIRATION

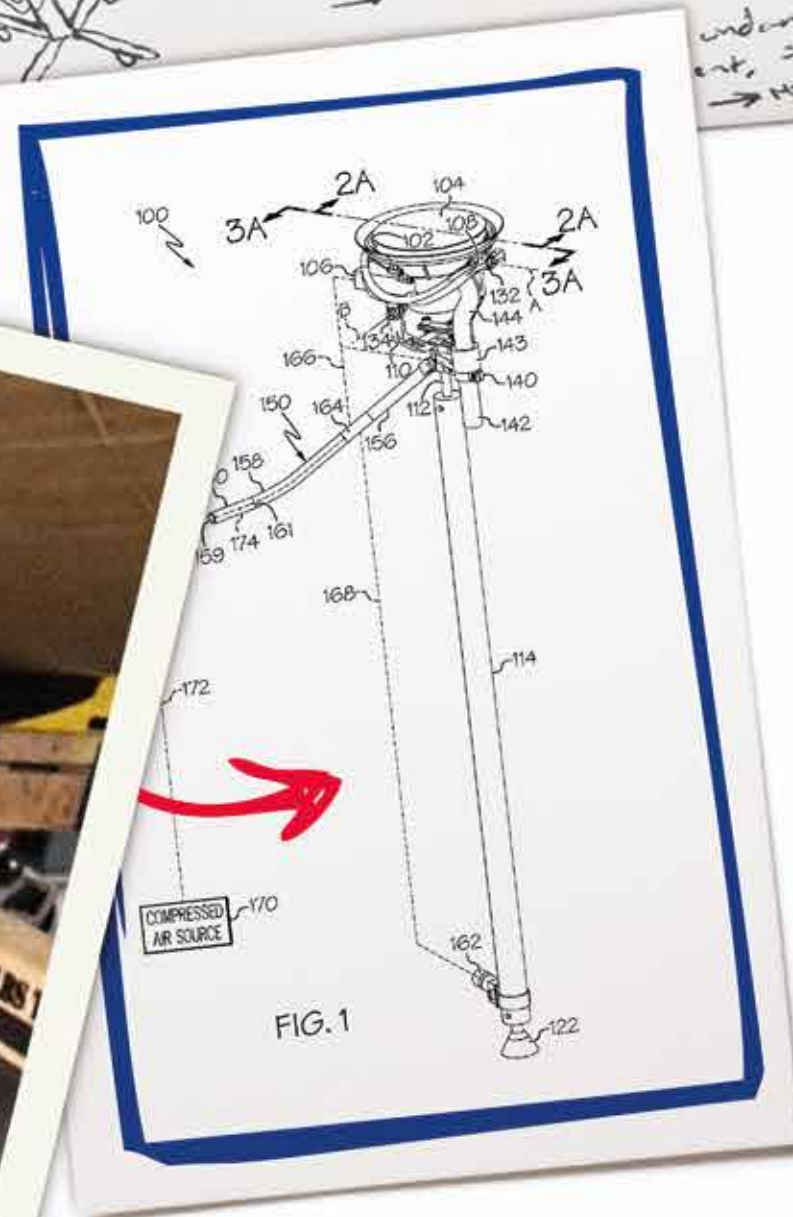
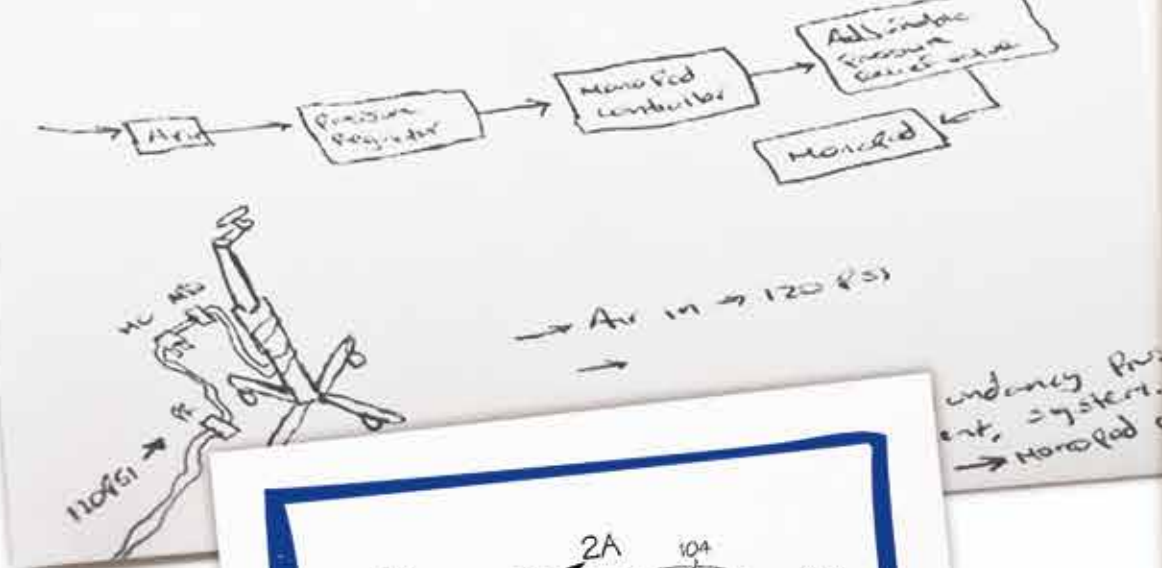
This is what the monopod sander looked like in the early sketch on a napkin.

ILLUSTRATION: KADON KYTE

**SAFER SANDING**

The monopod sander's telescoping handle improves control and minimizes reaching.

PHOTO: BOEING

**PATENT PIC**

This diagram of the monopod sander appears in the device patent.

ILLUSTRATION: U.S. PATENT APPLICATION 20190247972

It is better to engineer out the hazard.

Continued from Page 20

As I mulled the problem on my flight home, a simple but potentially promising concept came to mind: a sanding rotator head coupled to an extendable actuator rod. I sketched it out on that most time-honored of inventor's tools, a napkin.

Back in Charleston, I shared the monopodic sanding device drawing with engineering colleagues Jason Kerestes and Colton Smoot. With their mechanical, robotics and fabrication experience, we had a working prototype in a few days.

As we developed the concept, we also consulted with Lluric Edison, a Boeing ergonomist who specializes in mitigating solutions for high-risk work areas. Edison provided ergonomic risk evaluations of overhead sanding so that we could optimize our solution.

A combination of risk factors makes sanding an airplane strenuous. Much of the job is above the person doing the sanding, and the shoulder and arm support weight overhead while applying constant pressure on the sander and the sanding surface. These same risk factors affect the neck and the primary wrist supporting the sander, as both extend backward at an extreme angle when working overhead.

Vibratory impact is acute for longer durations, and it generally takes a smaller amount of vibratory force to significantly affect the soft tissue and nerves in the wrist and hand.

With that guidance in mind, we designed around the premise that it is better to engineer out the hazard rather than to use risk mitigation such as protective equipment (such as anti-vibration gloves) or administrative controls (such as time-limited sanding).

To address vibratory factors, the tool is coupled to a custom gimbal that keeps it flat against the surface being sanded, so operators don't have to hold the sander in their hands.

Then the gimbal is coupled to a pneumatic actuator that enables painters to set the amount of pressure applied, eliminating strain caused by contact pressure. A telescoping handle keeps the painter's hands close to the body and provides sander and actuator control.

To eliminate risk to the user's neck, the handle is positioned to ensure painters are looking forward instead of upward.

Laboratory tests on simulated aircraft structures proved successful, so within a couple of months, I was en route to St. Louis to test the first working prototype.

After an hour of testing, the painters systematically analyzed the device and identified ways in which it could be improved. The team then made adjustments to ensure a usable product.

We also joined forces with Mary Tobin, a systems engineer who has been leading advanced surface processing efforts focused on eliminating manual sanding within Boeing. She helped us continue testing in a variety of production contexts and implement subsequent sander improvements.

We are now three generations into the monopod sander, continually implementing mechanic feedback from across the Boeing enterprise. We also incorporated site-specific constraints and factors and made modifications easy to implement by providing local teams the design models and drawings.

Boeing's rapid tooling team has applied additive manufacturing to new device iterations. For example, components previously machined with aluminum were changed to 3D-printed plastics, making the system lighter and improving its overall usability.

With the support and insights of Boeing painters, what started as an idea on a napkin has become an ergonomic solution that serves as the new standard for aircraft overhead sanding at Boeing.

But what's been most rewarding to me is something another colleague said: "This is testament to the great work that can be executed by engineers working directly with the folks who do the job every day to make their work safer." **IQ**

A light solution to a gritty issue

Laser paint removal for airplanes is safe, fast and environmentally friendly

BY KADY GREGERSEN, ASSOCIATE TECHNICAL FELLOW,
BOEING RESEARCH & TECHNOLOGY

Laser ablation is a viable method to remove paint from large aerospace components and full aircraft, eliminating hazardous waste, alleviating ergonomic challenges and saving significant time.

An airplane can undergo many changes over its lifetime. Planes need to have their coatings removed about every five years because of fading paint, branding changes and inspections to determine the integrity of the underlying structure.

It is standard for an aircraft to be stripped of its coatings and repainted four or five times within its lifetime.

An increasingly effective method to remove airplane paint involves lasers, specifically a process called laser ablation. Removal by laser ablation occurs when a material absorbs laser light and molecules are excited into the plasma state. This material vaporizes, converting the layer to be removed into volatiles while also converting a small amount of solids in a clean and efficient manner. Laser ablation can replace current methods for removal of paints, sealants and corrosion products.

Laser ablation has several advantages over other removal methods, including less hazardous waste and fewer ergonomic injuries. Compared to chemical stripping and media blasting, laser ablation can decrease hazardous waste by more than 90% (saving thousands of pounds per aircraft). Chemicals used in conventional methods contribute to the waste stream, while laser light remains energy and does not add to physical waste.

Producing less hazardous waste and reducing recurring costs add up to significant savings while helping to protect the environment. The laser ablation process can be used both in manufacturing new parts and servicing existing products. Since laser energy is precisely controlled, the process is safe and effective for both metallic and polymer composite substrates.

It is standard for an aircraft to be stripped of its coatings and repainted four or five times within its lifetime.

LASER PREPPED

A containment carrier holding a painted aluminum spar web is readied for a laser ablation test.

PHOTO:
KADY GREGERSEN



LASER FOCUSED

Laser ablation removed the yellowish-green paint in a tight circle on this aluminum aircraft part.

PHOTO:
KADY GREGERSEN

Also, workplace safety is a high priority at Boeing, and investing in tools with reduced ergonomic impact is a key strategy to protect employees. Laser ablation offers significant improvements in ergonomics when it replaces hand-sanding.

Another factor is speed. Before pursuing lasers for paint removal, Boeing used laser ablation for tool cleaning. That process, now fully implemented in several locations, has led to a 50% cycle-time decrease and 80% labor reduction.

Removing paint from a full airplane can take a week or longer, depending on size; a laser-based process could cut that to three or four days.

Recent advancements are making laser ablation even more attractive. More efficient and higher-power lasers are becoming more affordable, and larger lasers are enabling faster processing speeds.

As an airplane manufacturer and service provider, Boeing is advancing key innovations to better integrate this technology in safe and cost-effective ways. By adapting and combining these technologies with commercial off-the-shelf products, laser ablation can be readily inserted as a fully automated or handheld system. Harmonizing laser ablation with established production processes could require industrial engineering and even floor space redesign for facilities already at capacity. It all adds up to innovation that can reduce the production system's cost and footprint. **IQ**

ABOUT THE AUTHOR

Kady Gregersen is a Boeing Associate Technical Fellow who specializes in paints and coatings for interior and exterior applications.

Removing paint from a full airplane can take a week or longer, depending on size; a laser-based process could cut that to three or four days.



PRECISION DEPAINTING

Illustrating precision accuracy, (from left) laser ablation removes paint in the shape of the Boeing logo.

IMAGES: BOEING

Imagine a world without cars, phones or computers. How about no movies or TV? Fortunately, someone somewhere convinced others to support, invest in and adopt these unproven ideas. They figured out a way to articulate how these innovations would go way beyond fads.

ABOUT THE AUTHOR

Marna Kagele is a Boeing Technical Fellow in systems engineering and strategic foresight.

PHOTO: MARIAN LOCKHART



What's the **BIG** idea?

To innovate, first communicate

In today's significantly more crowded technological landscape, it's crucial to communicate a promising technical innovation clearly and convincingly so it doesn't get left behind simply because of ineffective messaging.

If the audience doesn't understand an idea's significance, they cannot rally behind it. If decision-makers can't envision how your brainchild fits into their portfolio of projects, they won't bring it to the next level. When resources are limited, effective communication is even more important.

Resources for pitching a business idea are plentiful and well worn. But technical communications present their own set of unique challenges. The next time you have the opportunity to promote your technical idea's significance, whether it's part of a broader business pitch or in early stages, employ these strategies to communicate its complete potential.

“This ‘telephone’ has too many shortcomings to be seriously considered as a means of communication.”

**WESTERN UNION
INTERNAL MEMO, 1876**

1 BE CLEAR

So you're ready to deliver a big talk about your technical idea. You need to be clear on what you want to accomplish. Are you generating awareness of your work, searching for collaborators, looking for input on next steps or seeking an investment? These are all valid outcomes, but your talk should be quite different depending on your goal. Ask yourself what you want to leave the meeting with and what you want your audience to take away. Also consider putting yourself in the audience's place and think about what they may want. Ideally, you can meet your own goals and ensure your audience leaves happy too.

Once you've answered these questions, you can refine your talk to meet any time limit, knowing what can be cut and what is essential to ensure everyone's baseline goals are achieved. Be sure to share your goal for this meeting with the audience toward the beginning of your engagement or even before the meeting. This gives them the opportunity to listen with that goal in mind. Should they be listening with the intent to make a decision or the intent to generate a set of additional research questions? Help your audience help you.

You should also have clarity on where you are in the technology development process and how that fits into a larger goal. Are you in early stages, creating a demonstration of a capability for evaluation purposes? Or do you have a technology ready to be implemented or an idea you want to start on? Clarity in your technical progress will guide your message. Knowing the larger goal will shape how you articulate the expected value of your work, the outcomes you foresee and potential impact as well as any significant barriers. Now that you are clear on purpose, let's tailor your talk.

“There is no reason anyone would want a **computer in their home.”**

**KEN OLSON, DIGITAL
EQUIPMENT CORP.
FOUNDER, 1977**

2 KNOW YOUR AUDIENCE

It is always important to know a little something about your audience, but it is critical in the case of technical communication. Determine if you will be speaking with a technical audience. Clarify if they are technically skilled in the area you will be discussing. Based on that knowledge, anticipate any counterarguments or potential questions.

Perhaps the audience will be a mix of technical and nontechnical members. Adjust word choices and level of detail in your explanation depending on their familiarity with the technical content. Research at Ohio State University shows jargon should be avoided, as it “kills people's interest.” Sophisticated, inside terminology alienates audience members, even when explained. If the audience has a mixed skillset, take a little time to consider your language so all can evaluate the idea from a common understanding.

3 CRAFT YOUR MESSAGE

The best way to connect to any audience is to rely on our oldest, most human form of communication: telling a story. And the way you weave your story is pivotal. You must gain the audience's attention at the start. Reveal the pain point you are seeking to eliminate and why it is an obstacle to be overcome. Lead them to wonder, how is anyone ever going to manage without a solution? Then here you come to save the day, providing the answer.

When you share your idea or capability, be sure to include the steps to implementation, which include timing, cost, people and skills needed, as well as technical and nontechnical barriers. Clarify the value your offering brings over other options. You may need to talk to others with different expertise or do some research to put together a solid story.

“The horse is here to stay, but the **automobile** is only a novelty — a fad.”

**MICHIGAN SAVINGS
BANK PRESIDENT, ABOUT
INVESTING IN FORD, 1903**

Be sure to understand the business-related aspects too. A technical idea alone is not enough to warrant support. Include information about the market or business potential for your solution and its impact. Even if you are early in development, there should be a clear connection to a business or research field impact. Address opportunities to extend your solution to other products or industries.

“People will soon get tired of staring at a **plywood box** every night.”

**DARRYL F. ZANUCK,
MOVIE PRODUCER, ABOUT
TELEVISION, 1946**

Finally, circle back to your meeting purpose and verify your messaging is on point. Ensure you included the right information and level of detail for the audience in order to reach your goal.

4 SEEK DIVERSITY

People differ in the ways they connect with technical information. Some are visual or tactile; others connect with spoken words. Consider sharing your idea in multiple ways. Perhaps as you learned about the audience, you gained insight into how they best receive information, and you can target an approach.

If you are still in development, consider building a minimum viable product. It provides something concrete to relate to while also proving your larger vision is feasible. The key is to use minimal resources to demonstrate viability.

In situations where you have more time, you might create a science fiction style vignette that features your idea. This can help others fully understand your proposal in an imagined context that highlights its potential. And take your story for a test drive, gathering feedback from trusted colleagues. There are many tools and methods to consider, and your goal should be to employ multiple pathways to connect your audience with your idea.

5 PRACTICE — A LOT

You've heard it before: Practice, practice, practice. I suggest practicing your talk at least 10 times. It's tempting to stop when you feel like you've memorized the key messages and can masterfully recite the words, but the magic happens in those last few reps, when you become more natural and can add emphasis at just the right moments.

Then you gain the ability to improvise and authentically find your way back to your main points when thrown off topic by an interjected question. This fine-tuning will make all the difference. What if everything veers off-track, as it sometimes does? Not a problem. You practiced. You know your goal and, at a minimum, can always steer back to that. Practice will make you prepared.

After you've had your say, if your idea is not adopted, let it go and move on to the next. Find strength in knowing that, due to your effective communication, you were heard and your idea was evaluated for its merits. Focus on what parts of this activity were successful. There is always an aspect that went well or some constructive learning. It is understandably difficult to let go and embrace the learning, but don't downplay that process. Allow it to propel you to your next brilliant idea. It's out there waiting for you. **IQ**

“The **cinema** is little more than a fad. It's canned drama.”

CHARLIE CHAPLIN, 1916

Tamika Jones
Mechanical Engineer

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RECREATE THE CAUSE

TRIZ: An unconventional engineering approach

When faced with an obstacle, human nature pushes us to avoid or remove what's in our way. But an alternative approach to engineering does neither, at least initially. Known as TRIZ (pronounced "treez"), it intentionally embraces and reproduces the challenge to get a closer look.

When encountering airplane GPS dropout, for example, a TRIZ practitioner does not try to eliminate the issue right away. The first step is to replicate it. That is, assume that the desired output from the GPS is the dropout under the right conditions. To find the right conditions, define the requirements for a field (the means of accomplishing an action), which in this case would interfere with GPS reception. Surprisingly, this change of perspective can open up the team's thinking and, with the aid of TRIZ techniques, identify how resources available in the system create the now-desired complication.

A Russian acronym that translates loosely to "Theory of Inventive Problem Solving," TRIZ attempts to overcome innate mental inertia that pressures us to maintain a set of assumptions and patterns of thought.

Our brains prefer fast and automatic to slow and effortful. TRIZ encourages us to break out of these well-worn tracks.

The basic premise is that someone, somewhere, has already solved our problem or one very similar to it. The method breaks down the issue, generalizes it and finds relevant solutions from principles discovered by the world's best problem-solvers — inventors.

Over the last two decades, Boeing has leveraged TRIZ to:

- Improve designs, such as finding adequate power to meet a fuel offload rate requirement for the KC-767 Tanker.
- Develop inventions, including clamping mechanisms for aircraft interiors, rain-on-the-plane solutions and new actuation technologies.
- Suggest a technology forecasting strategy.
- Remove contradictions that lead to compromise designs.

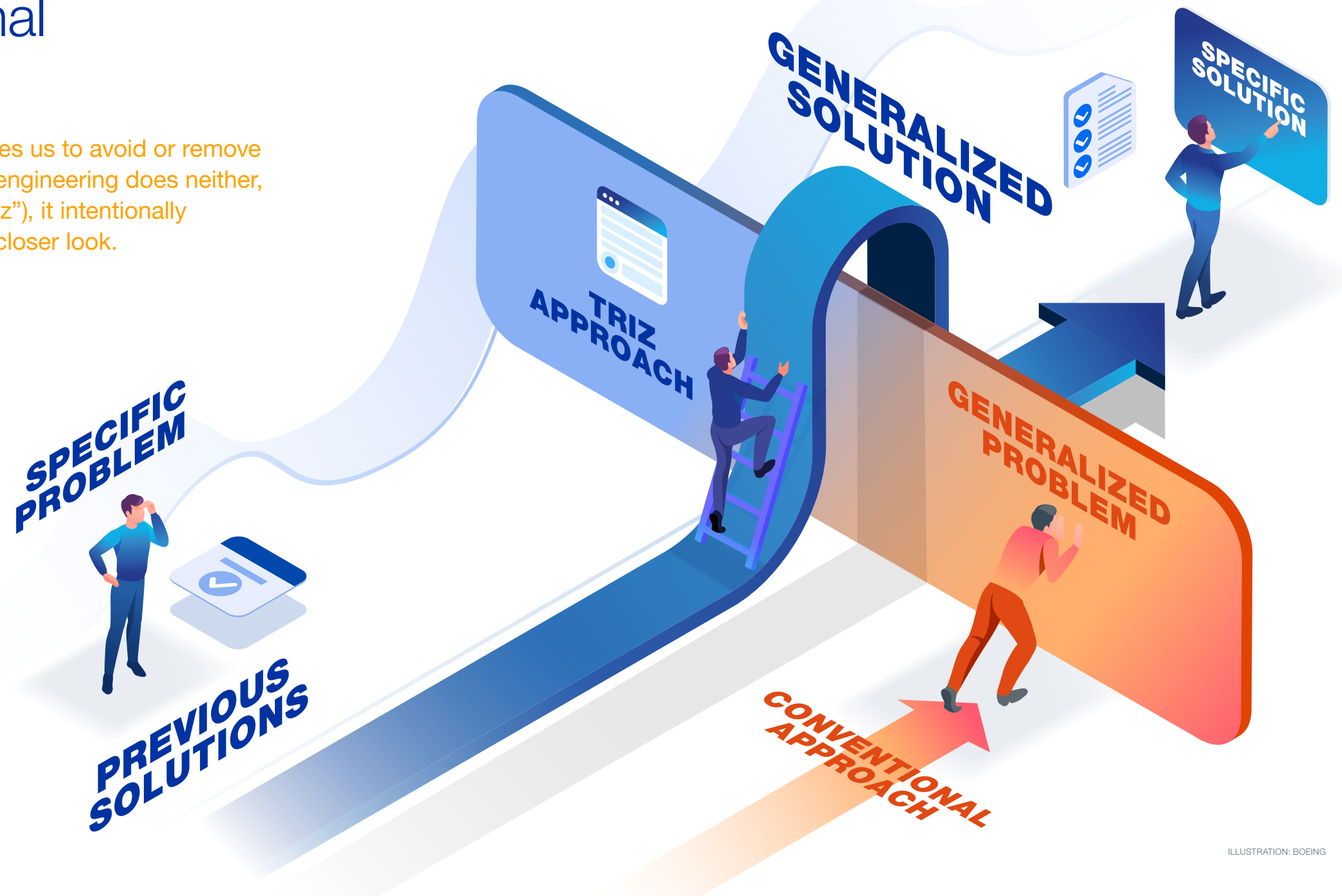


ILLUSTRATION: BOEING

For our GPS example, our team identified key features of the system failure and organized these into a fishbone diagram. However, after close to a year of root cause analysis and lab testing, the cause of an intermittent failure remained unclear.

We decided to conduct a two-hour TRIZ workshop. The roles in the workshop included a TRIZ facilitator, TRIZ scribe, TRIZ expert and workshop participants with technical expertise for the problem domain. During the workshop, a type of TRIZ analysis called Tool-Object-Product was created. In this analysis, a model of the situation is created where a tool acts on an object through a field. The product is the result of the action of the tool on the object.

The strategy used in this workshop was to reveal the cause.

Workshop participants completed some preliminary problem formulation then followed a step-by-step process to create what we were trying to ultimately avoid, as if it were a “desired” product. The desired product in this case study was GPS dropout.

The key activity was to define the requirements that have to be met by the field to obtain that previously undesirable product. This was the point in the workshop where it became clear that there was a signal-to-noise ratio requirement for noise to cause GPS dropout. While this seems obvious in retrospect, the combination of a weak GPS signal with a jamming signal as the cause for GPS dropout had not been formally considered prior to the TRIZ workshop. A weakness for combinatorial causality is a known drawback to fishbone diagrams.

The team next designed and coordinated a laboratory test of the dropout conditions. The approach was to place the GPS antenna in a room shielded from electromagnetic radiation. A signal would be introduced using a GPS simulator so that the intensity of it could be varied. At various levels of GPS signal intensity, interference signals would be introduced to determine the susceptibility of the GPS antenna to interference. Interference would be detected by loss of a GPS fix at the multi-mode receiver, located outside the shield room.

Lab test results showed that an interference signal of sufficient strength in combination with a weak GPS signal does indeed cause GPS dropout. The team used this information to make recommendations on how to use new designs already available to solve this GPS dropout.

We didn't set out to find a fix right away.

TRIZ nudged us to look at the issue from a different angle. And the solution was revealed by creating a model of the problem. **IQ**

BOEING TECHNICAL JOURNAL

The Boeing Technical Journal is a peer-reviewed, proprietary periodical for Boeing subject matter experts to capture and share knowledge. This article is a summary of “Root cause analysis using TRIZ” by Scott Button, Al Nguyen, Robert Hainline and F. Tad Calkins, originally published April 9, 2020.

About the authors:



Scott D. Button, a retired Boeing Associate Technical Fellow and process engineer, is a critical chain project management expert.



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Service and support, day and night

Boeing Design Center is ready at all times to support airlines

BY MIKHAIL BARABOSHIN, BOEING RUSSIA

As their flight prepared to take off from a Middle East airport, the cabin crew of a Boeing-built airplane felt an impact while it taxied on the runway. To be on the safe side, the airplane returned to the gate for a potential incident investigation. However, an external visual inspection did not show any signs of damage to the fuselage, wing or landing gear.

Still, the crew wanted to ensure the sight inspection hadn't missed anything. In stepped the Boeing Design Center (BDC), with teams in Moscow, Russia, and Kyiv, Ukraine, whose service engineers provided an inspection list. They focused on two areas: the hydraulic door-opening mechanisms and the cargo compartment bulkhead wall.

In minutes, the BDC engineers pointed the ground crew to shifted cargo that had dented the wall in the front cargo hold.

BDC engineers then reviewed the dent details and determined the panel could safely and capably carry the designated loads. The flight took off on time.

When operators believe an airplane may be compromised, it is critical that the plane be evaluated and fixed quickly — to minimize flight disruptions for airlines and the flying public.

The BDC often turns canceled flights into safe, timely departures.



Boeing maintains this 24/7 customer support operation to assist anytime, anywhere, especially when potential damage is outside the scope of approved repair limits for the airline. Customer requests submitted from anywhere in the world during European working hours are assigned to a service engineer in Moscow or Kyiv; those during North American business hours are routed to the Boeing customer support team in Seal Beach, California.

The BDC and its 500-member customer support team play a critical role supporting the Boeing global fleet and making sure all repair procedures are executed properly. Implementation of a round-the-clock operation model for engineering support allows airlines to minimize the time any airplane in their fleet is out of service.

When operators submit a service request to Boeing, service engineers are on the front line, identifying the issue and integrating necessary experts from a multiskilled team to expedite the airplane's safe return to service. Customer support unites the service engineer with stress analysts, design engineers, Federation Aviation Administration engineering unit members and subject matter experts in a wide variety of areas.



ULTRASONIC TOOL AND C-SCAN
(From left) The 35RDC is an ultrasonic nondestructive evaluation tool used to find hidden damage in a composite structure.

The ultrasonic C-scan can generate a two-dimensional map of a surface under examination, such as fuselage skin.

PHOTO AND ILLUSTRATION:
MIKHAIL BARABOSHIN, BOEING

The team's first step is to determine a complete damage definition, including detailed photos and measurements. However, visual indication is only good for preliminary evaluation because underlying issues may be undetectable to the naked eye, which is why the results of a nondestructive evaluation (NDE) are vital for Boeing customer support to evaluate and, in turn, substantiate a repair plan to the airline. Receiving an NDE recommendation from Boeing as soon as possible means a more immediate solution.

This efficiency was paramount for a Boeing airline customer in Madrid recently, when an airline reported damage to the cargo door surround. Passengers were already at the gate, and cabin crew regulations only allowed a one-hour delay before the flight would have to be postponed an entire day.

In this case, the BDC's Moscow/Kyiv team was able to determine that there was no damage beyond what was visible to the eye: high-impact damage to the fuselage skin. The BDC coordinated with the customer while the stress team performed the analysis required to show that the airplane met certification requirements without instrumented NDE. The BDC also supplied the customer with proper approval documentation that allowed the airline to get regulators' approval to take off, and the flight was only delayed 30 minutes.

Since its establishment in Moscow in 1998, the BDC has provided many instances of safe and speedy diagnoses for Boeing customer airlines. Today, the BDC is a full-scale operation that creates a competitive advantage for Boeing — and allows teammates around the world peace of mind, knowing our customers are getting expert support day and night. **IQ**

ABOUT THE AUTHOR

Mikhail Baraboshin (pictured opposite) is the engineering team lead for 787 Structures Service Engineering in the Moscow Boeing Design Center.

PHOTO: VYACHESLAV MELESHIN

Airplane modification, home edition

Boeing recently completed its first entirely virtual commercial modification. Due to travel restrictions related to the COVID-19 pandemic, Boeing was unable to provide standard in-person support for a 777 interior issue on an airline customer's airplane at a maintenance, repair and overhaul (MRO) facility in China.

By leveraging the company's global footprint and engineering expertise as the original equipment manufacturer, Boeing set up a 24/7 network to support both the MRO facility completing the work and the airline. Boeing engineers in the United States, Ukraine and Russia used live video conferencing, detailed photographs and computer-aided drawings to work with the airline and the facility to troubleshoot any issues and keep the complex modification on schedule.

UP IN THE CLOUDSTER

Investor David R. Davis inside the record-setting airplane in the Los Angeles area in 1921.

PHOTO: BOEING ARCHIVES

In July 1920, in the back of a Los Angeles barbershop, engineer Donald Douglas and investor David Davis formed the Davis Douglas Co. with one goal in mind: build an airplane that would become the first to fly nonstop across the U.S. The result — a wooden biplane called the Cloudster — first flew Feb. 24, 1921, and attempted the cross-country journey that June.

lifting

Celebrating a century of heavy

From the Cloudster to the Queen, pulling their own weight (and then some)

BY ANNIE FLODIN, BOEING HISTORICAL SERVICES

OPEN WIDE

The 747-8F could carry the weight of 79 Cloudsters.

PHOTO: BOEING

A wooden biplane known as the Cloudster made history by becoming the first airplane to carry a useful load exceeding its own weight.

Departing from California, the single-engine, long-range aircraft made it about one-third of the way but had to land at Fort Bliss, Texas, due to engine issues. Disappointed following the unsuccessful flight, Davis lost interest and left the company. Douglas then formed his own company, The Douglas Co., which became Douglas Aircraft Co. in 1928.

While the Cloudster did not achieve the nonstop, transcontinental flight, it did make history by becoming the first airplane to carry a useful load exceeding its own weight. At just 3,850 pounds itself, the Cloudster transported a load exceeding 5,000 pounds — at the time, the most ever by a single-engine plane.

Despite having been fierce competitors for most of the 20th century, Boeing and Douglas are now part of a shared heritage that spans more than a century of aerospace innovation. In 1967, Douglas merged with McDonnell Aircraft Corp., which in turn merged with Boeing in 1997.

Today, Boeing is proud to honor the Douglas Aircraft legacy by continuing to build on its success. The 747-8 Freighter is the newest and largest variant of the 747, which for decades has been affectionately called the Queen of the Skies. It has a payload of 303,700 pounds, 61 times more than the Cloudster's then record-setting haul of 5,000 pounds. **IQ**

SHINING EXAMPLE

Given it was made mostly of wood, the Cloudster appeared in a 1921 ad for varnish.

PHOTO: BOEING ARCHIVES



Flyover and out

T-Birds soar into history

After 46 years of service, “Red Bird” and “Blue Bird” are heading into retirement. License-built by Canadair in 1954, these variants of the Lockheed T-33 have been used in multiple test support roles, including as the safety chase plane for the first flight of nearly every new and derivative Boeing commercial airplane starting with the 767 in 1981 through today’s 777-9.

During the final flyover of Washington state, engineering test pilot Mark Mitchell snapped the photo from the back seat of Red Bird.

“The image captures the final formation flight of the T-33s over the Puget Sound area before these last two airplanes went into storage,” said Mitchell. “We had just taken off from Seattle’s Boeing Field as a formation, heading northwest toward Victoria, [British Columbia]. You can see Port Townsend in near field, front of wing leading edge. Whidbey Island’s at the top of the tip tank, and Mount Baker is off in the distance.

“The T-Bird is an exceptionally reliable and capable air vehicle. On top of that, they are a unique treat to fly.

“After this shot, we made a right turn for a formation pass along the runway at Paine Field [in Everett], where these planes had done safety/photo chase for most of Boeing airplanes’ first flight events over the past several decades. Then we did a formation slow pass along the runway to give everyone a final look before their last landing at Boeing Field.”

Boeing will keep the aircraft in storage. **IQ**

PHOTOGRAPHER

Engineering test pilot Mark Mitchell

HEIGHT

6,000 feet (1,829 meters)

RED BIRD PILOTS

Randon Stewart (front), Mark Mitchell (back)

BLUE BIRD PILOTS

Norman Howell (front), Barry St. Germain (back)

H-47 Chinook



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