

Frontiers

Worlds above

Boeing Starliner team aims high in preparing 'space taxi' for first flight



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Cover: CST-100 Starliner technician Joel Andriola inspects the first spacecraft test article in the Commercial Crew and Cargo Processing Facility at Kennedy Space Center, in Florida.

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Photo: (Below) The Commercial Crew and Cargo Processing Facility at Kennedy Space Center is home to Boeing's Starliner, which is depicted in this mural, and formerly housed the space shuttle.

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The stories behind the ads in this issue.



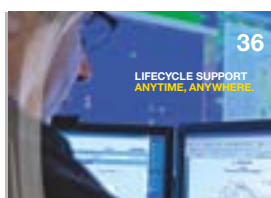
Canada and Boeing share a partnership built on commitment, collaboration and transparency. This ad highlights how Boeing helps build a stronger Canada and appears in Canadian political and news publications.



In this ad, employees showcase their safety gear at work and play as part of October's Safety Promise campaign. Pictured from left: Angela Hall, Samantha Wisner, Jill Bingham, Michele (Mickey) Antonio, Hannah Chung and Kristin Marko.



Celebrating technical excellence and engineering achievement is the theme of this ad as Boeing congratulates winners of the 2016 Special Invention Awards and Technical Replication Awards, which will be presented at a ceremony this month.



Part of the "A Better Way to Fly" campaign, this ad showcases the life-cycle support that Boeing Support and Services provides 24/7. The ads are running in trade publications and online.

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Boeing employees and retirees can access Milestones—the lists of employee service awards, retirements, obituaries and safety achievements—on boeing.com/frontiers by clicking the Milestones button.

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The Canada-Boeing partnership is built upon commitment, transparency and collaboration. It's a partnership that brings over \$1 billion annually to Canada's economy. An economy that would be bolstered by the acquisition of the F/A-18 Super Hornet, building on Boeing's proven Industrial and Technological Benefits initiatives for the CF-18 Hornet, C-17 Globemaster and CH-47 Chinook. Together, we will continue to enhance Canada's global presence.

Discover more at boeing.ca



WORK SAFE. PLAY SAFE.



Safety doesn't take a day off.

Personal protective equipment keeps these Boeing employees safe on the job and on the ice. Be part of the conversation and future campaigns by joining the Go for Zero inSite group.

go4zero.web.boeing.com



One Day at a Time.

Ursula English
 Vice president
 Environment, Health & Safety

PHOTO: GAIL HANUSA | BOEING

Building a safer, cleaner future

True leadership in safety and the environment requires constant improvement

Every day, nearly 160,000 Boeing employees work on some of the most exciting products and services ever created. We imagine, engineer, build and support technology that connects, protects, explores and inspires the world.

At Environment, Health & Safety (EHS), we're focused on two important missions: to create a workplace where every person at Boeing leaves as safe and healthy as when he or she arrived, and to build a better planet by continuously improving the environmental performance of our global operations, products and services.

We have tremendous opportunities ahead of us—and some real challenges.

When it comes to safety, even one injury is too many. The safety of every Boeing employee comes above all else—it's a foundational value to a successful second century. Our Safety Guiding Principles define Boeing's commitment to safety for all employees, but it's up to each of us to put these principles into practice every day:

- We value human life and well-being above all else and take action accordingly.
- All incidents, injuries and workplace illnesses are preventable.
- We are personally accountable for our own and collectively responsible for each other's safety.
- By committing to safety first, we advance our goals for quality, cost and schedule.

Building a robust safety culture depends on having a clear and consistent understanding for safe employee behavior. That is why we established safety standards to protect our teammates across the enterprise, including employees, contractors, suppliers, customers and visitors.

We're seeing success. Employees are actively identifying and reporting "near-miss" incidents, which helps eliminate hazards before accidents or injuries occur—and has contributed to a noteworthy reduction in injuries over the past three years.

We're also making strides in our environmental performance. Aviation accounts for about 2 percent of the world's total man-made carbon dioxide emissions, which is why we continue to collaborate with stakeholders around the globe to create industrywide solutions.

True environmental leadership requires constant improvement and we're working on even more aggressive strategies and targets to meet our goal of being the most environmentally progressive aerospace company. As a company, we continue to improve the environmental efficiency of our products and services. We also are making good progress reducing waste within our operations and manufacturing facilities. This year, ENERGY STAR recognized

Boeing for the sixth consecutive year for our continued leadership in protecting the environment through superior energy efficiency. Our 787 Dreamliner family improves fuel efficiency and reduces emissions by 20 to 25 percent compared with the airplanes it replaces.

We also continue to work closely with regulatory agencies, neighborhoods and conservation organizations on environmental topics and projects. Indeed, last year we were recognized by the National Oceanic and Atmospheric Administration for our work completing the largest wildlife habitat restoration project on Seattle's Duwamish Waterway, restoring a mile of former industrial waterfront to improve Puget Sound salmon runs.

How can you help? Your commitment, fresh ideas and engagement are a key part of how Boeing can improve workplace safety as well as its environmental performance. Keep those suggestions coming; keep looking for better, cleaner and safer ways to do your team's job or design and support our products. Even simple changes in the way we do things at home and work can add up.

Our global EHS team works every day to build something better, cleaner and safer for future generations. Our future is bright! Let's work together to keep it that way. ●



TECHNICAL EXCELLENCE. **ENGINEERING ACHIEVEMENT.**

Congratulations.

Our Special Invention Award and Technical Replication Award 2016 winners.



Special Invention **Awards**

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

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Glenn Caplin

Yi-Feng James Chen

Angelia M. Corbett

Paul Gehlsen

Kim Griffin

Hisashi Inoue

John Jones

Haig F. Krikorian

Douglas Maben

Albert Manfredi

Scott Meier

David Otto

Jayant Patel

James J. Peterka, III

Matthias Schriever

Louie Tran

Technical Replication **Awards**

highlights the most successful projects where cross-enterprise collaboration, learning and replication have driven productivity, growth and program execution.

James D. Badman

Brittany Ballard

Michael Clare

Joshua Crouch

Christine Currie

W. Talion Edwards

Edward Feikert

Ronald Goodman

Sankeerth Goli

Steven Gunther

Thomas Howorth

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Timothy Josten

Mark Leach

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Kevin Sitton

Nicholas Sophy

Steven Strouse

Terry Versheldon

Patrick Walsh

Kim Wood

Perfor

A man with short dark hair and a mustache, wearing red safety glasses and a grey t-shirt with the word 'Fabrication' partially visible, is looking directly at the camera. He is positioned behind a large, green, perforated metal structure that frames him. The background shows a large industrial facility with a high ceiling, structural beams, and various lights.

Photo: Krishnan Kurup, a Boeing Salt Lake Fabrication specialist, inspects a 787 horizontal stabilizer in production at the Airport factory.

performance

in plane site

Boeing's expanding presence in Utah revs up employees, and machines, for business

BY DAN RALEY | PHOTOS BY BOB FERGUSON

Butch and Sundance work side by side in a shiny, new Boeing factory in West Jordan, Utah. They look nothing like the legendary Western characters for whom they are named or the actors who later portrayed the historic duo on film.

They are large, white robots. They each can drill a hole on a 787 horizontal stabilizer, measure it and countersink it, insert a fastener in it, and then torque the fastener. They have reduced three days of work to a single shift and, by diminishing repetitive and strenuous tasks, have helped employees grow in new ways while eliminating the potential for injuries, according to site leaders.

Employees who occupy the West Jordan plant treat the mechanical Butch and Sundance as captivating workplace fixtures.

They created clever Old West logos for them. They named them, relying on geographical familiarity to choose from among 80 sets of employee-submitted suggestions.

"Butch Cassidy was from Utah and Robert Redford [the actor who played the Sundance Kid] lives here," West Jordan factory manager Darren Walker pointed out.

The robots are just two of the more visible elements that make up Boeing Salt Lake—three Fabrication plants that rely heavily on innovation. Another element is a veteran workforce that has been successfully adapting to repeated change over three decades, such as learning new skills to facilitate the production of composite airplane parts.

"Management started out by telling us there wasn't anything we couldn't do," said Chad Simpson, a



Photos: (Left) Randelyn Brady, a manufacturing associate who performs console wiring on the 787, installs overhead panel system lights at the Northport factory, one of two Boeing facilities near the Salt Lake City airport. (Right) Butch and Sundance, robots named by employees, have helped reduce work on a 787 horizontal stabilizer from three days to a single shift at the West Jordan, Utah, factory.

Fabrication specialist and 30-year Boeing Salt Lake employee. “We just jumped in and learned how to do things. We don’t let anybody fail here.”

That determined approach has gone a long way to expanding Boeing’s presence in Utah, Boeing Salt Lake site general manager Larry Coughlin said. As employees have reinvented themselves, the site has grown from one factory to three. In the West Jordan factory, the site’s newest, the Salt Lake team worked closely with people from other Fabrication locations to design and build a production line that uses new technology and advanced automation to improve upon, not simply replicate, what has been done in the past, he said.

It’s all part of the fabric of a resilient aerospace site.

“With its wealth of knowledge, this place knows how to build airplanes,” Coughlin said.

Boeing Salt Lake represents one of 11 Boeing Fabrication sites operating in three countries, with others located in such places as the Seattle area; Portland, Ore.; Helena, Mont.; South Carolina; Melbourne, Australia; and Boeing Winnipeg, in Canada. Each plays

a role in converting bulky metals or sleek composite materials into flight-critical jetliner parts.

In Salt Lake, the three Boeing manufacturing facilities emerge from the shadows of the Wasatch Range, which runs north and south through much of the state and offers these aerospace employees access to world-class ski areas during the winter. The Airport and Northport factories are located within a mile of each other near Salt Lake City International Airport. The West Jordan plant is housed in a converted kitchen cabinet-making warehouse 20 miles (30 kilometers) away. Boeing employs more than 700 people at the three buildings.

The Airport facility, approaching its 30th anniversary, has experienced the most change. Employees produced fuselages and empennages for heritage company McDonnell Douglas MD-80 jetliners there until the airplane program ended. They supplied spare airplane parts until that was discontinued. And they’ve learned how to make carbon-fiber jetliner parts after years of working only with aluminum and other metal machining.

“I don’t think anybody here has been afraid of change,” said Kristen

Bonkoski, Boeing Salt Lake business operations specialist. “It’s one of our guiding principles—we have to embrace change.”

Production lines for 787-9 and 787-10 horizontal stabilizers and a third for the 787 vertical fin operate side by side in the Airport factory. Components are added to the tail structures, which are tested for quality, assembled for fit checks and then disassembled. The site ships out up to 14 sets of horizontal stabilizers each month to factories in North Charleston, S.C., and Everett, Wash.

Kayla Bruner, a two-year assembly specialist who performs finish work on the 787 vertical fin, draws inspiration from her more experienced colleagues. She credits them with being effective role models who set the pace at Boeing Salt Lake.

“Not only do we compete with Airbus, we drive one another to be the best mechanics we can be,” Bruner said. “I know what motivates me: When you’re surrounded by 25-year veterans, that’s what you aspire to be. They make all the tough jobs look easy.”

A regular feature at the Airport plant is the Kaizen Walk, which in Japanese roughly translates to an improvement





moment. Employees gravitate to a factory workstation where a colleague makes a presentation regarding an action he or she developed to increase efficiency.

Blake Johnson, a 27-year employee and join crew team leader, stood beneath a horizontal stabilizer when he spoke to nearly two dozen co-workers and factory leaders and told them about a \$1,162.60 savings he realized by recycling fasteners. He felt compelled to come up with a workplace enhancement, considering it a necessary part of his job.

“We’ve always had the culture here that, basically, if there’s a problem, we’re the solution,” Johnson said. “Everyone takes ownership of the company as a whole. The way to keep the business healthy is continuous improvement.”

Boeing Salt Lake looks for its next generation of employees from those who can develop the necessary skills to work at any of the three site locations. To provide a pipeline

of talent, Boeing partnered with government, academic institutions and other companies to create the Utah Pathways Aerospace Program. Statewide high school students pursue a curriculum geared to airplane manufacturing. Of the 40 students who graduated earlier this year, five recently were hired by Boeing.

The Northport factory, the smallest of the three, is filled with humming machining equipment and multiple assembly lines. White foam panels, resembling small mattresses, hang on their sides from the ceiling to muffle the noise created by so many machines in use all at once. Since 2007, the site’s employees have fabricated and assembled flight-deck structures for every model of Boeing jetliner, collectively shipping out consoles, overhead panels and other parts for more than two dozen flight decks each month.

In this high-energy atmosphere, engineers such as Forrest Newton

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At a glance: **Boeing in Utah**

Across six locations in Utah, Boeing has approximately 1,000 employees who develop and test missile defense systems, support military aircraft customers, and manufacture parts installed in commercial jetliners.

And they do this all within a 50-mile (80-kilometer) radius stretching from Salt Lake City to Ogden, two of the state's largest cities.

Boeing Defense, Space & Security enlists some 200 employees at three sites in and around Ogden. Most of them are directly involved with Strategic Missile & Defense Systems, specifically intercontinental ballistic missiles, or ICBMs.

Fifty engineers and technicians are based at Little Mountain Test Facility, a U.S. Air Force site located on the banks of the Great Salt Lake near Ogden. Their primary responsibility is to test Minuteman III ICBMs in simulations conducted in radiation, electromagnetic, and shock and vibration labs. They provide equipment repairs and upgrades when necessary.

Boeing also supplies engineering support for Minuteman III guidance systems in Ogden. Various support groups focus on Ground-based Midcourse Defense electronics, A-10 Thunderbolt wing replacement, and C-17 Globemaster III, F-15 and Lockheed Martin F-22 aircraft in Layton, which is home to Hill Air Force Base, south of Ogden.

The remainder of the Utah workforce is located at three Boeing Fabrication factories across Salt Lake City, with more than 700 employees collectively producing 787 horizontal stabilizers and vertical fins, as well as flight-deck consoles for all airplane models. ●

Photos: (Far left) Robert Dennis, a Salt Lake Fabrication specialist, inspects the outer surface of a 787 horizontal stabilizer in West Jordan. (Left) Fabrication specialists prepare a 787 horizontal stabilizer composite mold with carbon-fiber material.



Photos: (Above) Assisted by a crane, employees in West Jordan move a 787 horizontal stabilizer. (Below) Mike Thomas, left, and Jacob Cleland guide it into place.



seek ways to increase factory productivity as Boeing's new airplanes come on line. In moving from the 777 to 777X, for example, they've reduced the tools for the flight-deck console from 30 to eight, subassembly parts from 22 to nine, and workbenches from two to one. Other programs might share in this breakthrough, too.

"If there's a good idea that works on the 777X, we say, 'Why don't we do it on the 737? What's the next step?'" Newton said. "There's a lot of synergy."

Boeing Salt Lake's Information Technology specialists fit in this category as well—they helped create

digital software for the factory floor that connects all machine tools to a common network and tracks data on all activities involved. They were part of an innovative Boeing test case that continues to draw plaudits, site leader Coughlin said.

Local employees Steve Wikstrom, Martin Austin and Clarence Whetten teamed with company IT experts and came up with the Common Network Factory Solution, or CNFS. This digital concept has led to significant cost savings and streamlined production, according to site leaders. Previously, when something went wrong with a factory tool, a site monitor had to call in a host of troubleshooters to restore order; now, selective hardware and ready data manage all of this and simplify the process.

"This was a first for Boeing," Whetten pointed out. "Instead of a person monitoring, we input 23 sensors to take readings every day and send out charts and graphs, send out alerts, to do temperature and humidity readings."

The IT specialists received site approval in 2013 to pre-wire the new factory in West Jordan, which relies on automated machines, before it was physically laid out. They came in ahead of schedule and under budget with their digital plans, and continue to look for ways to add to the system.

Employees at the site, which has been operational for nearly two years, build horizontal stabilizers. Aided by automated machines, they form parts on molds the size of flatbed trailers with tape-laying machines. The tape comes in rolls of carbon-fiber composite material that is stored in a freezer at minus 10 degrees Fahrenheit (minus 23 Celsius). They create skin panels and lay them over and under five span-wise spars; the assembly is baked in an 18-by-55-foot (5.5-by-17-meter) autoclave, producing the center section of the 787's horizontal stabilizer, called the multi-spar box.

"Basically, we're making a big composite sandwich," said Joshua Carlsen, a Boeing Salt Lake manufacturing engineer.

Toward the end of the production process, the horizontal stabilizers come into contact with the aforementioned Butch and Sundance. The robots work on tracks in an area that is cordoned off for safety. Employees operate the machines using computers that carry the same Western-themed logos.

As Butch and Sundance stood in a rare idle moment, Fabrication specialist Teresa Bennett worked nearby, putting edge protection on a multi-spar box. This action, she explained, keeps the different layers of carbon fiber from separating.

A 15-year Boeing Salt Lake employee, Bennett shares in the attitude that she and her fellow factory workers are capable of performing any task.

Back at the Northport facility, Michael Goodwin, a 27-year Boeing Salt Lake mechanic, tells how he worked on the MD-11 nose cowl and MD-80 and -90 empennage assemblies when his aerospace career began. He now works in the computer numerical control machining center, programming and milling components for the flight-deck structures.

Goodwin and his fellow factory employees originally weren't trained in metal fabrication. They didn't know how to mill or bend a part. When that need became obvious, Goodwin and others quickly learned a new trade. This resourcefulness led to Boeing Salt Lake employees years ago being dubbed the "Can-Do Crew."

"They've always been able to call on us to get things done," Goodwin said. "We have a very diverse knowledge base and a desire to succeed. Our people are our success story." ●

DANIEL.W.RALEY@BOEING.COM

Starliner role

Boeing Starliner undergoes rigorous testing in run-up to first flight

BY DAN RALEY | PHOTOS BY BOB FERGUSON

Starliner lifts off the ground at Kennedy Space Center. Yet the Boeing-built spacecraft—upper and lower crew module domes detached—is surrounded by a dozen watchful technicians rather than a launch pad. There is no cascading roar, just repetitive beeping from equipment easing things into place.

A crane raises the top half of Starliner's original test article in the air before gently lowering and attaching it to the bottom half inside Boeing's production facility in central Florida, marking a milestone event

ring

A photograph of a man in a plaid shirt and jeans working on a large, complex structure. The structure is covered in a grid of green plastic panels, some of which are open, revealing internal wiring and components. The man is wearing safety glasses and is focused on his work. The background is a bright, industrial setting with various mechanical parts and structures.

Photo: Chris Hess, Boeing systems engineer, prepares the upper crew module dome of the first Starliner test article before it is mated to the lower dome.

for the program.

Crane operator Mike DeCarlo brings the honeycomb-pattern sections together, assisted by fellow Boeing employees operating laser devices and other guided measurement tools. The connection must be level for him to proceed. DeCarlo has to line up everything perfectly so that 216 bolts can be inserted and tightened, and then allowed to settle for three days before getting torqued a second time due to the region's temperature and humidity factors. All of this leads to an ultra-tight fit.

In a nearby factory corner, DeCarlo also is building a Starliner seat pallet, one that can hold up to five people. He has drilled 400 holes and still has two more beams to construct. He is well-suited for this line of work—he previously processed the space shuttles between flights for 25 years and personally knows a few of the astronauts who may guide Starliner to the International Space Station, or ISS.

"I prepared *Endeavour*, *Discovery* and *Atlantis* for their final flights, and bolted *Atlantis* into place at the Kennedy Space Center Visitor Complex," DeCarlo said. "I love this. This has been in my blood since I got out of school. I really want to get us back up there."

Starliner, also known as Crew Space Transportation-100, or CST-100, will make its first unmanned flight a few months prior to its first trip to the space station with astronauts at the controls in 2018.

Five years in the making, the Starliner program has four vehicles in production and even more in testing in the U.S., supported by Boeing employees from coast to coast. The spacecraft are assembled in Boeing's Commercial Crew and Cargo Processing Facility, or C3PF, a former space shuttle hangar and engine shop that has been refurbished. Many of the engineers and technicians involved previously worked on the space shuttle.

Boeing and its legacy companies have built each previous manned American spacecraft. With its reusable capsule, which resembles the cone-like Apollo of the 1960s and '70s, Starliner is expected to open up space travel to a wider range of people, said

John Mulholland, vice president and program manager for Boeing's Commercial Crew effort.

"It's really setting the foundation for accessible travel to space, something the world hasn't seen before," Mulholland said. "Before it was always a government enterprise meant to serve a specific need. NASA has allowed us to service its needs, but also expand to accommodate scientists and tourists—to establish space as a destination."

There is much to be done. In Huntington Beach, Calif., Boeing engineers will drop, shake, push and pull the Starliner test article in a controlled atmosphere to see how it responds. At New Mexico's White Sands Missile Range, a balloon will carry a boilerplate spacecraft more than seven miles into the air and release it, with Starliner deploying its parachutes and airbags to verify its performance during the final minutes of descent. In St. Louis, engineers are building a high-fidelity, fully immersive mission simulator for astronauts that will be transported early next year to Houston for use at NASA's Johnson Space Center. Astronauts and flight directors already are getting to take the Starliner for test drives in the Space Training, Analysis and Review Facility and the Jake Garn Training Facility with Boeing-developed training systems.

Two or more Starliners will be built for actual space travel, with each capable of making up to 10 trips to and from the ISS. Others will be used only for testing. SpaceX's competing Crew Dragon spacecraft, initially geared to carry cargo to the space station, and Starliner share similar compact-sized capsule shapes. The difference is that the Boeing spacecraft will be the first U.S. capsule to return on land rather than in the ocean.

Inside the spotlessly clean C3PF high bay, Starliner crew module domes are mounted on lime green work stands, surrounded by scaffolding and technicians seated at or standing in front of computers. Mechanics install necessary components, a job that has been greatly simplified since the previous space program. The space shuttle needed hundreds of switches and



Photo: In Huntington Beach, Calif., Ashley Williams, left, and Leticia Ibarra of Phantom Works test the CST-100 Starliner autonomous relative navigation system.

dials; Starliner offers just a few dozen.

The Starliner airframe starts life in the Boston area as individual spun-form aluminum upper and lower domes. They're then machined with hundreds of pockets before being shipped to Florida's "Space Coast." After initial assembly, the dome sections are structurally fastened rather than welded as they were for the Apollo spacecraft, providing a lighter and production-friendly vehicle, said Danom Buck, Boeing manufacturing engineering manager. Engineers recently "designed out" even more weight from the new capsule to meet a mass optimization effort, Buck said.

A team of engineers, technicians and mechanics will run Starliner's first assembled vehicle through months of pressurized testing to verify the design and certify components—to ensure the workmanship is solid so that the ensuing

spacecraft can be built effectively.

Team members join the upper and lower domes of the crew module in the high bay; they stack together the capsule and service module used for propulsion in the adjoining low bay. The spacecraft will carry 24 engines and 40 thrusters, enough power to reposition the much larger space station into a higher orbit or move it from the path of speeding space debris, if needed.

Rusty Allen, who previously worked on the space shuttle and the Lockheed Martin Orion deep space capsule, is one of 17 technicians assigned to Starliner manufacturing. His expertise is propulsion. He finds the hardware installation similar from program to program, but says Starliner affords him easier access because of its two-piece crew module configuration, which speeds up the build. While the 25-year mechanic doesn't lack for motivation

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Photo: Technician Joel Andriola works inside the upper crew module dome for Starliner's first test article, which will be transported from Florida to California for stress testing.



The countdown begins

Three weeks before launch, Starliner's journey from Boeing's Commercial Crew and Cargo Processing Facility at Kennedy Space Center will begin. It will take several hours to complete the seven-mile late-night ride on the spacecraft transport vehicle to Space Launch Complex 41 on the northern edge of neighboring Cape Canaveral Air Force Station. Complex 41 is one of more than two dozen launch pads erected across a landscape that is home to 6,500 alligators, 400 species of birds and assorted 300-pound (140-kilogram) wild hogs, according to NASA.

Upon arrival, the Starliner will be lifted by crane into the Vertical Integration Facility, a tall, narrow building, where it will be stacked atop an Atlas V rocket sitting on a Mobile Launch Platform. While there, the fully integrated Boeing spacecraft and United Launch Alliance Atlas V rocket will undergo a series of tests and flight preparations, and the launch team will rehearse the countdown. The day before launch, the Mobile Launch Platform will travel 1,800 feet (550 meters) by rail onto the launch pad, where the rocket will be loaded with propellant and the spacecraft powered up for final pre-launch checkout.

Upright on a launch pad more than a half-century old, Starliner will find itself positioned inside a square of four 360-foot (110-meter) lightning towers, necessary protection on the often stormy Floridian coast. Any environmentally generated electrical currents would be redirected through this grid and into the ground. The spacecraft will stand parallel to the 200-foot (60-meter) Crew Access Tower, the first new astronaut gantry built in more than four decades since the Apollo space program; all others are original structures that have been refurbished.

For the initial crewed flight, a Boeing test pilot and NASA astronaut will board Starliner through the Crew Access Arm, a bridge extending out from the main structure. They will pause at the end in an enclosed area, designated as the White Room, for removal of their portable equipment and a contaminant wipe-down before entering the crew cabin. They will become the first humans propelled off Complex 41, a pad that previously has facilitated only unmanned Titan and Atlas V launches.

Once the launch sequence is set in motion, the Starliner countdown will echo over an outdoor public-address system. The kerosene-fueled rocket and attached solid rocket motors will ignite with a yellowish glare. The ground will tremble. Water will come pouring onto the pad to deaden the sound and ease the vibration, protecting the flight vehicle and systems on the ground. Huge plumes of steam will cascade up and around it as exhaust is redirected away from the pad through a concrete cave called a "flame bucket." Crowds will cheer as Starliner lifts off the ground, carried by an Atlas V rocket generating 1.5 million pounds (6.7 million newtons) of thrust before completing its job and separating nearly 15 minutes into flight.

Following six to eight hours of flight, Starliner will arrive at the International Space Station, which orbits 240 miles (390 kilometers) above Earth. The spacecraft will connect with a new docking adapter rather than the robotic arm that now captures cargo vehicles and pulls them in close. Starliner will remain in space for six months at a time before returning the crew to one of the designated landing sites in the western U.S. Soon after landing, the Starliner will be transported back to Florida where it will be refurbished before repeating this process. ●

on the job, he anticipates he'll become a lot more emotional the closer the spacecraft gets to completion.

"The work can be bolt to bolt and rivet to rivet, but then it's, 'Wow, this is working, this is so cool, I can't wait for it to launch,'" Allen said. "There's a different sense of pride when your vehicle flies."

Starliner is one of the programs credited with re-energizing Kennedy Space Center, which hasn't offered manned spaceflight since the space shuttle program was completed in 2011. American astronauts have had to travel to the ISS aboard Russian Soyuz spacecraft. The idea that the U.S. will transport humans to space again has been a big motivator for Boeing employees currently readying Starliner.

"It's very important to return the

U.S.' ability to launch people to space on an American-built system—it's a major factor," said Joel Andriola, a nine-year Boeing technician. "Our spacecraft has a lot of capabilities."

Starliner will provide a better value to the American taxpayer than the \$81 million per seat that NASA currently pays Russia to fly to the space station on a Soyuz, said Chris Ferguson, Boeing director of crew and missions operations and a former space shuttle commander. Costs roughly are determined by the proven reliability of the space vehicle, the expense of building a new service module each time and the continued upkeep of the crew module, such as replacing the heat shield and parachutes after each flight, he said.

Starliner will be unique for its

ability to operate as a fully automated spacecraft yet switch to manual control if necessary, Ferguson added.

"It's an interesting challenge," he said. "We've found a fine blend of having a vehicle that can be piloted by an astronaut and one very capable of operating on its own. Astronauts can be a backup-minded crowd—they always want to maintain that override capability."

When the time comes to show what it can do, Starliner will leave the factory and travel nearly seven miles (11 kilometers) aboard a transporter to Space Launch Complex 41 at Cape Canaveral Air Station, stopping briefly to be mated to a United Launch Alliance Atlas V rocket at the Vertical Integration Facility.

For nearly two years, United




Photo: Software engineers Dave Chever, left, and Gene Brotherton are responsible for keeping the computer systems operational in the Boeing Mission Control Center at Kennedy Space Center.





Photos: (Above) Starliner's upper crew module dome rests on a work stand before an overhead crane lifts it up and onto the lower dome. (Far right) Technicians install components to the upper dome.

Launch Alliance has prepared the launch pad for Starliner with the erection of a 20-story Crew Access Tower. Sections were manufactured off-site and pieced together, among them the Crew Access Arm and White Room, which together provide a ramp-like structure and preparation room for boarding Starliner. The 44-foot (13-meter) arm, according to ULA, is considered one of the largest built.

"We're creating history here," said Howard Biegler, ULA launch operations project manager, who grew up on the Space Coast and as a child regularly was whisked away in the family station wagon to see the next launch from a prime vantage point.

Biegler understands better than most the significance of what is unfolding, noting that the Atlas rocket

that carried John Glenn, the first U.S. astronaut to orbit Earth in 1962, was launched not far from Complex 41.

"More than 50 years later, we get to do it again—with a new realm of space pioneers," Biegler said.

Three control centers will supervise Starliner launches. The Boeing Mission Control Center at Kennedy Space Center will monitor all spacecraft systems leading up to liftoff and link each of the centers with ground communications, enabling engineers, technicians and astronauts to speak to one another. ULA will manage launch operations from the Atlas Spaceflight Operations Center at nearby Cape Canaveral Air Force Station before handing over flight operations to Boeing and NASA flight directors at the CST-100 and ISS mission control centers in Houston. Boeing initially gives

the "go" for everyone to proceed.

Software engineer Gene Brotherton is among those responsible for keeping the Boeing Mission Control Center computer systems operational for Starliner. Testing currently is ongoing and scripted, and he makes sure everything works properly well in advance of the first launch. Brotherton and others look for any potential issue that might occur. They point out that digital capabilities have come a long way since the orbiters were designed more than 30 years ago.

"This computer has five times the power of the space shuttle's," Brotherton said, regarding one of the 28 new console workstations in the Boeing Mission Control Center.

Near the Starliner production facility, Boeing lead test engineer Derek Otermat occupies a room filled with servers



and data storage. These are powerful machines designed to track all ground operations, connecting the Boeing, ULA and Houston control centers and the spacecraft, and leave no room for error.

Otermat helped design these systems. Now he uses them to focus his attention on vehicle testing and for Starliner meeting stringent qualifications. Either way, he has made a strong commitment to the spacecraft.

“It all comes down to trust and confidence, the trust that the astronauts have in us, that we operate safely,” Otermat said. “This is very important to me. I’ve always been interested in space, in joint ventures in space, and how much is unexplored. My goal is to stay with this program for its life.”

Hallowed grounds that previously sent astronauts to the moon, rovers to Mars

and probes to the outer reaches will roar to life once more when Starliner, widely referred to as a space taxi, lifts off with people on board from the Space Coast, now targeted for 2018, a few months after an unpiloted test flight. Spectators, enticed by a level of excitement that comes only with a human space launch, are expected to crowd surrounding highways and beaches to watch.

At Kennedy Space Center, it is commonplace for everyone who works there to witness each launch, even a competitor’s. The NASA countdown, loudly audible across the grounds, draws employees outside to share in an electric moment that never gets old. Leonie Barden, a Boeing systems engineer, has been the exception—unintentionally.

Barden’s job is to make sure all

necessary documentation is in place when completing Starliner production-floor work and parts procurement. Barden was so busy one afternoon she didn’t realize a launch was underway until suddenly feeling ground tremors and looking up to find she was the only one in the office.

The launch went on without her. That won’t happen with Starliner. She made this vow while standing high above the C3PF factory floor, watching with interest as the domes for the original test capsule were moved into place to be mated.

“When we launch the first vehicle, that’s really going to be a tremendous moment,” Barden said. “I’ll have seen it go from concept to design to flight. I won’t miss that.” ●

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Lion of

With 16 787s in its fleet and more on the way, Ethiopian charts a path for ‘nothing but growth’

BY DAN RALEY

The Douglas C-47 Skytrain was a no-frills airplane, offering canvas seats that folded up to make room for large cargo loads, a cabin configuration that worked well for Allied troops during World War II.

But in April 1946, one of these twin-engine workhorses went from military transport to commercial airliner when it lifted off from Asmara, Ethiopia, and carried passengers 1,120 miles (1,800 kilometers) north to Cairo—establishing what is now known as Ethiopian Airlines and forming a partnership with Boeing and its legacy companies that has lasted for seven decades.

Ethiopian later was one of the first airlines on the African continent to order a Boeing jet, putting a 720B in service in 1960. In fact, a new airport was built in Bole, just outside Ethiopia’s most populous city and

capital, Addis Ababa, to accommodate arrival of the bigger airplane, according to Ethiopian Airlines.

The jetliner delivery followed a well-publicized tour of the United States by Ethiopian Emperor Haile Selassie. One of his stops was Boeing Plant 2, in Seattle. Accompanied by Boeing President William Allen, the African leader in full-dress uniform received a close-up look at the factory, posed for photos and was given a Boeing model airplane as a keepsake, according to news accounts.

The Boeing visit left an impression on the leader, who would return home and make air travel an economic priority for



Africa



Photo: Ethiopian Airlines takes delivery of a new 787 Dreamliner at the Boeing Everett Delivery Center, in Everett, Wash., in July.
PAUL GORDON | BOEING



his developing nation. Upon welcoming the first Boeing 720B to his homeland, Selassie declared in an airport speech, “Let no one underestimate the impact which this revolution in transportation must have over Ethiopia and her people.”

Today, Ethiopian Airlines is the bedrock of African aviation. It has more airplanes, passengers and activity than any of its competitors. It flies more routes throughout the continent than any other domestic airline. It continues to expand internationally. It has doubled its airplane fleet over the past decade.

And it has set an ambitious goal to double its fleet once more by 2025.

“For an airline to be successful, having the latest and technologically advanced fleet is one of the core pillars,” said Tewolde Gebremariam, Ethiopian Airlines chief executive officer. “We are very grateful to The Boeing Company for providing us the most comfortable and leading-edge airplanes for years.”

Boeing continues to play an important role in the evolution

of Africa’s leading airline and efforts to transform Addis Ababa into an international travel hub, said Yonas Yohannes, Ethiopian Airlines manager of maintenance planning and records control.

“Boeing not only manufactures airplanes for us, it gives us the technical skills, the technology, the process,” said Yohannes, a nine-year employee. “Sometimes Boeing is a consultant. It teaches us how to fly each airplane in the fleet. It provides field services both in maintenance and engineering. Boeing has an effect on all parts of our airline innovation system. We’re really happy.”

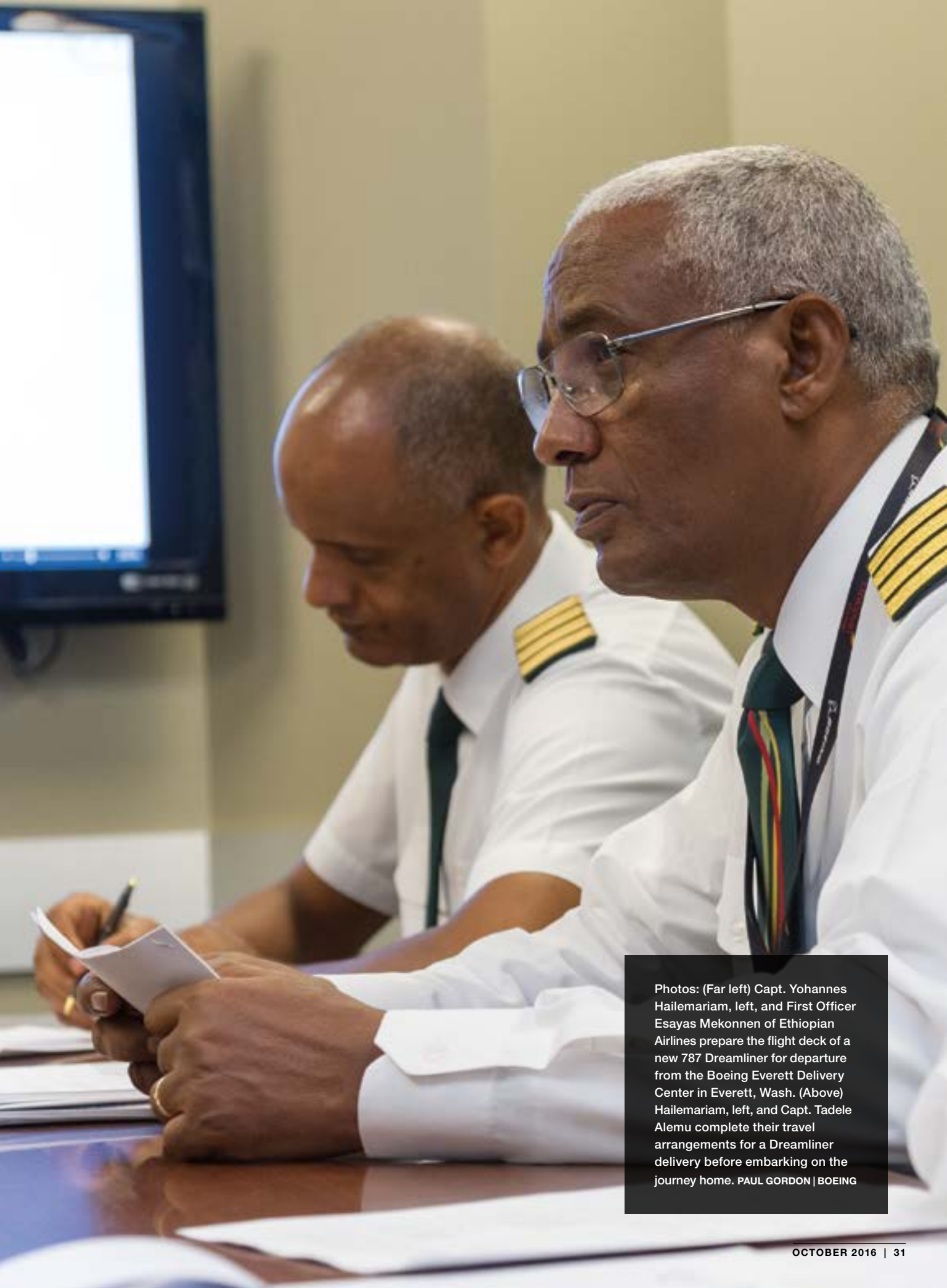
Yohannes’ personal story mirrors the steady progression of Ethiopian Airlines. He saw his first aircraft up close at age 10, when a helicopter landed in his small, rural town, Assela—a moment that prompted most residents to come take a look at a flying machine they hadn’t seen before. This led Yohannes to consider a career in aerospace, ultimately aviation engineering. He didn’t travel on an airplane

until he was 28. Now Yohannes is responsible for regularly crossing the ocean to the U.S. as a resident engineer inspecting 787 Dreamliners for his airline throughout the factory assembly process.

Ethiopian was the first airline in Africa to operate the Dreamliner following the instrumental role that the former Ethiopian prime minister, Meles Zenawi, played in making the 787 a focal part of the airline. In 2005, the airline ordered 10 787s, with the option for five more. It ordered eight more in 2015. According to the airline, the capabilities of this twin-aisle jet enable Ethiopian to fly to 51 cities in Africa and a similar number of worldwide destinations, among them Hong Kong, London, Los Angeles, Paris, São Paulo, Tokyo and Washington, D.C. The airline says it has plans for further route expansion.

The 787 is unique as the country’s flagship airplane, said Surafel Teshome Abebe, an Ethiopian Airlines aircraft inspector.

“It gives a nice picture for the airline—we do most of our advances with the



Photos: (Far left) Capt. Yohannes Hailemariam, left, and First Officer Esayas Mekonnen of Ethiopian Airlines prepare the flight deck of a new 787 Dreamliner for departure from the Boeing Everett Delivery Center in Everett, Wash. (Above) Hailemariam, left, and Capt. Tadele Alemu complete their travel arrangements for a Dreamliner delivery before embarking on the journey home. PAUL GORDON | BOEING



Photo: Ethiopian Emperor Haile Selassie (fourth from left) is greeted by Boeing President William Allen (second from right) and Seattle Mayor Allan Pomeroy (third from right) during Selassie's 1954 tour of Boeing Plant 2 in Seattle. BOEING ARCHIVES



787,” Abebe said. “It’s flying to most African destinations. It’s unique. It gives us great flexibility. The 787 is the main thing for Ethiopian Airlines now.”

To meet this demand, Ethiopian Airlines operates its 787s 12 to 13 hours per day. According to airline personnel, passengers express appreciation for the airplane’s comforts—cabin pressure seems virtually nonexistent compared with other airplanes, as do other operating sensations.

“It is so smooth, sometimes you may not feel it when it’s taking off,” Yohannes said.

In its fleet of 80-plus airplanes, Ethiopian Airlines also operates the 737, 757, 767 and 777, plus 757 and 777 freighters. It has orders for 30 737 MAX 8 airplanes. According to airline personnel, this continued growth has brought expansion plans for the airport in Addis Ababa, which sits 7,000 feet (2,100 meters) above sea level at the center of Ethiopia and is a hub for Africa.

Aviation, too, has become a desired profession across Ethiopia, offering some of the country’s highest paying jobs, added Yohannes, who, like his teammates, takes great pride in his work.

This passion and commitment has helped solidify Ethiopian Airlines as the African leader, said Van Rex Gallard, Boeing vice president of sales for Africa, Latin America and the Caribbean.

“It’s an airline where everyone is aligned and knows that they’re working for personal growth, the success of the airline and the growth of the country,” Gallard said. “You get immersed in the culture—you want to do the best you can to help make this be a great success.”

Ethiopian Airlines employees also find time to team with Boeing on humanitarian efforts that support the African country, Gallard said. Volunteers at both companies are collecting sporting equipment to promote the formation of youth baseball teams in Ethiopia. Previously, Boeing employees donated \$100,000 to Seattle Alliance Outreach, which treats kidney dialysis patients and trains

doctors in Ethiopia. The money was used to stock a new dialysis clinic in Addis Ababa and the supplies were delivered on a new Ethiopian Airlines 777 Freighter.

More than 200 Boeing field service representatives are based in Addis Ababa, facilitating the Ethiopian Airlines effort, according to Tom Addy, Boeing field services team leader. They help with documentation, training and troubleshooting. They work at the airport, near the Ethiopian engineering offices. They share best practices with the airline mechanics, particularly those who service the 787, which has different needs from other airplanes.

Addy arrived in Africa last year following company maintenance assignments in China, France, Mexico, Spain and the U.S. He says he’s never worked with an airline before that’s been on such an upward trend as Ethiopian.

“It won’t lessen, it will increase,” Addy said of future Ethiopian Airlines operations. “The fleet is mostly new. There’s going to be nothing but growth—and I believe mostly [through] Boeing.”

There are cultural obstacles for others trying to enter the marketplace. Airbus recently delivered its first airplane of any kind to Ethiopian Airlines, an A350, but the new twin-aisle jet received attention the European airplane-maker likely didn’t anticipate. There was ready confusion over the brand name.

In Ethiopia, people refer to any jetliner overhead, even a competitor, as “a Boeing,” Yohannes, the airline manager, said.

“One of my friends told me that he ‘saw a Boeing model called an Airbus land today.’ I had to explain the whole thing to him.” ●

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Best in class

One of two T-X aircraft unveiled in St. Louis last month, the all-new jet will represent Boeing in the U.S. Air Force's competition for an advanced pilot training system. Designed with partner Saab, the T-X features one engine, twin tails, stadium seating and an advanced cockpit with embedded training. View a related video at boeing.com/frontiers/videos/october16 or download a poster of this image at boeing.com/frontiers/downloads.
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