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Frontiers

Eye on Mars

Space Launch System employees advance deep space exploration

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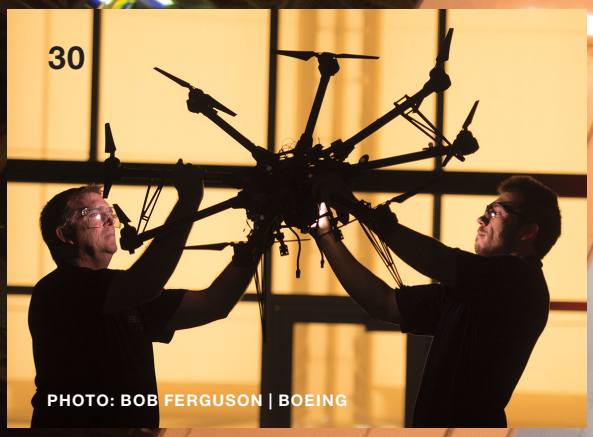

Cover: In Louisiana, Boeing assembles the fuel tanks and the propulsion system for the Space Launch System, which will be the largest rocket ever built and could someday transport humans to Mars. **BOB FERGUSON | BOEING**

Photo: (Right) The floor in the high bay of NASA's Michoud Assembly Facility, in New Orleans, was reinforced to hold the weight of the massive Space Launch System fuel tank and its welding tool. **BOB FERGUSON | BOEING**


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Part of the "A Better Way to Fly" campaign, this 777 ad is from a series showcasing the many ways Boeing airplanes and services enable opportunity and success for customers. The ads are running in trade publications and online.

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INTRODUCING THE FRONTIERS ANNUAL

This issue of *Frontiers* is the last to be printed as a conventional monthly periodical. Starting in 2017, *Frontiers* magazine will become a flagship once-yearly publication that celebrates our "One Boeing" global team.

Continuing the same terrific and inspiring storytelling, design and photography for which *Frontiers* is known, the new edition will deliver it in the commemorative annual style that made the July Centennial issue so powerful and popular, drawing a million page views to the online version alone.

The all-new *Frontiers* will chronicle the year's accomplishments and successes; it will tell the One Boeing story in an even more compelling format that honors our teammates' roles in the company's programs, projects and initiatives; and it will provide insight into the strategies, opportunities and challenges for the year ahead.

The *Frontiers* annual is part of the drive for continuous improvement in Boeing Communications. It's the same reason we continue to introduce new digital channels such as the Boeing Now app for employees' personal mobile devices and the Boeing Instagram site—giving our readers the information they want, when and where they want it.

The inaugural edition will go to press in late 2017 for distribution in early 2018. Boeing Communications and the *Frontiers* staff appreciate your interest and past support, and we look forward to continuing to write and share the Boeing story together.

Tom Downey
Senior Vice President
Communications


BOEING
波音

飞越时代的伙伴

“不要让任何航空业的创新机会与我们擦肩而过”，这是创始人威廉 · 波音对公司的期许，更是百年来我们坚守不渝的信念，与此一脉相承的还有波音与中国同仁的友谊与合作。

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World of growth

Leading in aerospace begins by growing globally

In this Q&A with *Frontiers,* Marc Allen, president of Boeing International, discusses the role of priorities, alignment and agility in driving Boeing's success around the world.

What does it mean to be global?

You could ask 100 people in the organization and get 100 different answers on what it means to be global. It's hard to define, but there are some obvious signposts, including a focus on talent and resources. In a world where our local competition is expanding globally and our global competition is more active locally, we have to ask ourselves: Is our talent global? Do our teams have career pathways to more senior roles?

There's no reason to chase after being "global" for the sake of being global. The reason to build a global platform is because it will make us more competitive so we can be the winners of the aerospace battle for the next century.

Why does becoming a global top performer matter?

It matters because, like any big enterprise, we compete for capital. If Boeing is not able to be an attractive investment, our cost of doing business goes up and our ability to compete goes down. The imperative to drive down cost or find capability advantages is all about continuing to keep us in a leadership position, with top performance.

What's behind the urgency?

It is the nature of business to chase continuous improvement. We live in a different world than we did when we all started working. It is clear that change—in business models, product or technology—is coming faster than ever. Our ability to look back in 20 years and see ourselves as still the best in aerospace depends on our ability to accelerate Boeing initiatives underway.

How do we stay on top of our game?

The Boeing that we are 100 years from now will be different from today's Boeing, just as we are different from the one Bill Boeing founded in the Red Barn in 1916. The increasing pace of technological change and innovation in our industry is real and requires us to adjust. But rather than be disrupted by others, we want to adapt to the changing environment on our own terms.

From a global perspective, managing change takes adaptability and patience. Adaptability speaks for itself. Patience means not running away from partnerships because dark clouds appear. It means maintaining productive company-to-country relationships, even in difficult geopolitical moments. We can give countries a reason to work together rather than to compete, to keep dialogue and commerce open in a wide range of environments.

What is Global 2025?

It's a companywide strategy to improve the competitiveness of Boeing around the world. It's about having cost advantages, capability advantages and market access advantages that come

“If we keep doing just what we do today, we will not achieve our objectives.”

Marc Allen
President
Boeing International

PHOTO BY BOB FERGUSON | BOEING

when we get local and agile in any given environment. They come from operating in different places, with different partners. We need those advantages to stay the best in aerospace and to be an enduring global industrial champion.

How is this international strategy different from what we have done previously?

Part of developing a good strategy is deciding what not to do. Doing everything is doing nothing. Historically, we got comfortable with long lists of “priority” items. One of the principal efforts of Global 2025 has been to take a hard look at the most important countries where additional focus will yield the greatest results. The focus is not static, though. Over time, as investments in priority countries take seed and reach scale, we will swing the spotlight to others.

We are also piloting new ways of operating. The goal is agility and pushing more decision-making to the point of operation. And we are launching new approaches to how we develop and manage global talent. These elements all have to work together to drive our success in the global environment.

How can employees make Global 2025 successful?

You’ll recognize the Global 2025 focus countries that are at the top of the enterprise investment list—none should be a surprise. Understand all the priorities and then make sure your time is aligned to them. That doesn’t mean stop doing the important work you’re doing in other geographic markets. It just means that when you have trade-off decisions to make between markets for your time and resources, follow the priority. Prioritization will drive change. It will also evolve over time.

No matter where you work at Boeing, every employee has a role in our international strategy. The majority of our products and services are going to markets outside the United States. Regardless of your physical location, we can’t be successful without a unified approach. So, everybody needs to understand the role they play and go after it with gusto.

It sounds like employees can expect a lot of change in the coming years?

Yes, this is going to be a time of dynamic change both outside the company—the forces that affect us—and inside the company as we work to be ahead of those forces. But we can change, and we have the right strategy to manage the change, which will allow us to compete.

Just look at what we accomplished in our first century. I’m excited for the future because all of us—all 160,000 of us—are the founders of the next century of Boeing. If we keep doing just what we do today, we will not achieve our objectives. But if we grow ourselves, if we take on the opportunities in front of us with a sense of confidence and a forward-looking orientation, we’ll be the company we aspire to be—and an enduring global industrial champion. ●

Project runway

Engineers 'land it' with software that helps increase pilot situational awareness during approaches

BY ERIC FETTERS-WALP

A modern jetliner like the 737 is full of technology that aids takeoffs and landings, even in less-than-ideal weather conditions.

For pilots, situational awareness in lower-visibility environments is essential—especially during these two critical phases of flight, where factors such as low clouds or fog can obscure runway views, eroding safety margins and resulting in delays for passengers, airlines and airports alike.

Help in seeing the runway is what Boeing's Perspective Runway provides. The recently developed software is part of a vision shared by Steven Fleiger-Holmes, a Flight Crew Operations Integration engineer who helped invent it.

"Regardless of weather or lighting conditions, the pilot sees 'virtual runway' features that are aligned to the actual runway," Fleiger-Holmes said.

Used in conjunction with the instrument landing system approach guidance that pilots already rely on, the system supplements a pilot's situational awareness of the runway environment with real-time visual data.

Patented two years ago, Perspective Runway uses the aircraft's head-up

Photo: In the head-up display inside the 737 MAX engineering simulator, Boeing's Perspective Runway software displays a highly accurate, representative view of the runway to pilots, along with information about remaining runway length, which can be seen regardless of weather-related visibility. **PAUL GORDON | BOEING**

display, or HUD, on the flight deck to point pilots toward the runway even when the airplane is still miles from the airport. Information from a navigation database and airplane sensor data are used to project what Fleiger-Holmes calls a "virtual runway" on the HUD. It adds to information from the glideslope, which guides pilots to the correct altitude as they fly down the approach path.

"Instead of showing you where you are, this shows you where you need to go for landing," said Mark Henderson, a systems engineer with Commercial Airplanes' Flight Crew Operations Integration. "It can be all cloudy outside, and this still gives you a line that points to the runway."

Ed Wilson, chief test pilot for the 737 program, said Perspective Runway is a real help when visibility outside the airplane is diminished. But as more technology is introduced into the flight deck, the trick is to aid pilots without distracting them. Wilson said he and others helped the software's designers make changes toward that goal while it was still in the development stage.

"My team and I worked closely with the engineers to make the display look as close to actual runway markings as possible," he said. "This makes the new symbology blend easily with the real world as you approach the runway."

As a result, the Perspective Runway indicators are relatively simple, developed to closely resemble a pilot's natural cues under visual flight rules, or VFR, conditions, Fleiger-Holmes said.

Perspective Runway underwent extensive testing in the highly realistic "e-cab," or engineering cab laboratory, which was developed for the 737 MAX program to provide simulated flight conditions for engineers, test pilots and airline pilots. Additionally, pilots flight-tested the software on Boeing's 787 ecoDemonstrator airplane in late 2014. Fleiger-Holmes said those tests proved it helped pilots find runway lights and markers in low-visibility conditions.

As the software is operated on more and more commercial flights, Boeing will be able to use that real-world data to assess whether the system can yield further benefits, he added.

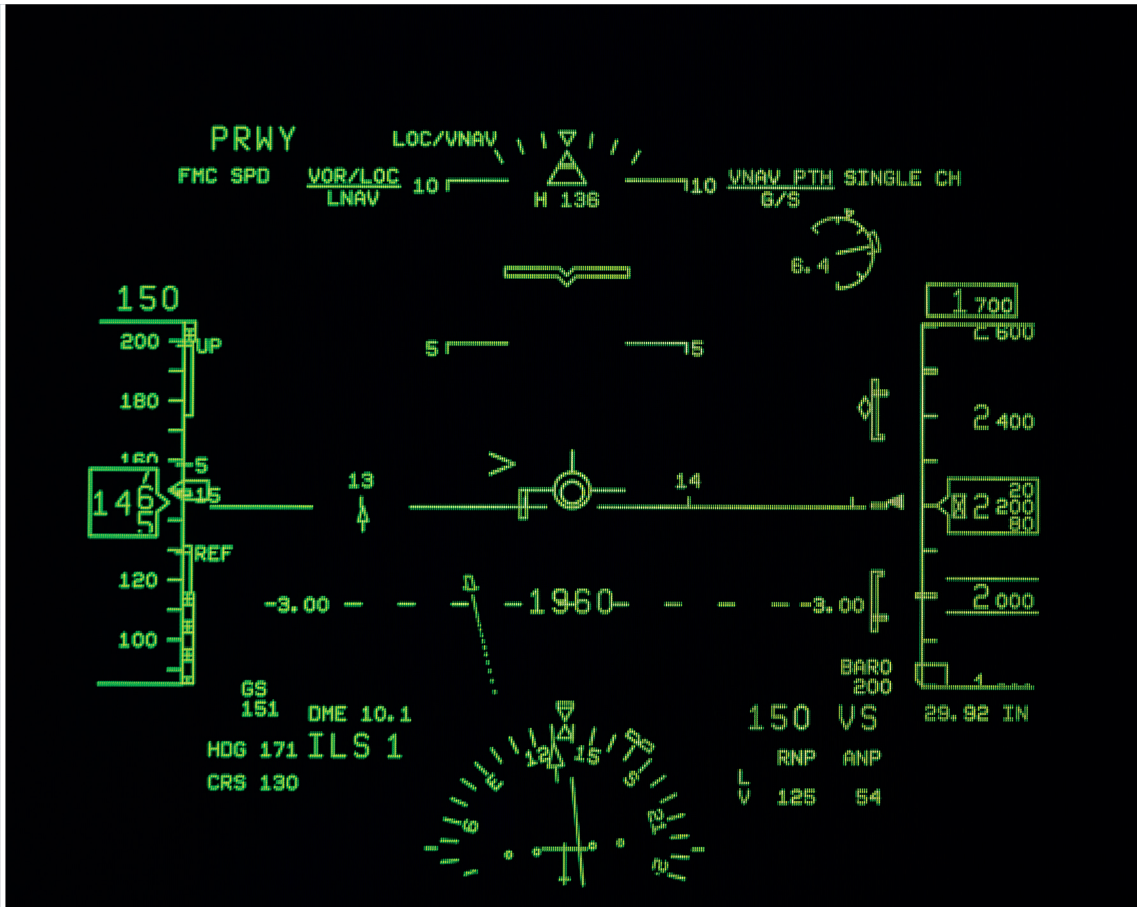
Part of a package of Runway Situational Awareness Tools offered on Boeing's 737 family, Perspective Runway now is certified by the U.S. Federal Aviation Administration for use on the Next-Generation 737, and Boeing offers it as an option for that model and the 737 MAX, said Brian Gilbert, a systems engineer with Flight Deck Crew Operations. Other tools include overrun warning and speed-brake warning functions.

Gilbert said that in addition to new software and technology on the flight deck, flight-crew procedure updates and training aids have been provided to help reduce runway excursions. It's all aimed at making rare runway incidents even less common.

"Boeing continues to investigate additional capabilities," Gilbert said, that are intended to "help pilots make timely, informed decisions that support safe approaches and landings." ●

ERIC.C.FETTERS-WALP@BOEING.COM

Photos: (Clockwise from top right) In the e-cab, test pilot Ed Wilson, left, and Ashley Evans, Aero-Stability & Control engineer, demonstrate how the head-up display and other technology can assist pilots; on a computer, Perspective Runway shows an airplane icon at center and, below that, an arrow pointing the way to a distant runway; Chris Branham, left, Integration engineer, and Mark Henderson, Flight Deck Crew Operations engineer, monitor the simulator's systems.
BOB FERGUSON | BOEING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Monumental journey

Space Launch System employees move closer to completing core stage of world's most powerful rocket

BY DAN RALEY

The massive silver cylinder hovers above the factory floor, held in place by a welding tool that's even larger. At NASA's Michoud Assembly Facility, in New Orleans, the vertical structure offers a mesmerizing sight.

No matter how many times they pass by, most employees say they have to stop and take another look at the Boeing-built liquid hydrogen tank.

At more than 130 feet (40 meters) tall and 27 feet (8 meters) in diameter, the tank represents the biggest piece of NASA's Space Launch System—which, when fully stacked, will be the largest and most powerful rocket ever made. The added fuel and propulsion capacity will enable the spacecraft to transport humans and heavy payloads to the moon, asteroids, Mars and possibly Jupiter and Saturn, Boeing leaders said. Just the sheer magnitude of the rocket on launch day will captivate the general public.

"It'll be like the Empire State Building taking off," said Tom LeBoeuf, Boeing quality engineering manager.

At peak configuration, the Space Launch System will stand 384 feet (117 meters) tall and generate more than 9 million pounds (40 million newtons) of thrust—more than 34 times the power of a 747 jetliner, according to NASA—as it embarks on a most ambitious mission: the journey to Mars.

The Space Launch System is scheduled for an unmanned test flight, known as Exploration Mission I, in 2018 that will boost a payload of 13 CubeSats, or miniature satellites, and the Orion spacecraft, built by Lockheed Martin. The satellites will be used to conduct experiments

to pave the way for deep space exploration, while the Orion will be put in orbit around the moon at a distance where deep space communication and navigation systems can be tested. NASA expects the Space Launch System will send astronauts into deep space for the first time between 2021 and 2023, lofting a Mars touchdown trip as soon as the 2030s. Much of this activity will originate in east New Orleans at Michoud.

"It's the coolest program ever and that's why I'm here," said Karen Branson, Boeing quality senior manager. "It's an all-new dawn. We've spent all of our time in low-Earth orbit—let's find out what's out there."

At the Louisiana rocket factory, which borders a meandering intercoastal waterway that flows into the Mississippi River, Boeing employees prepare the Space Launch System core stage for that profound first step. This portion of the spacecraft consists of stacked liquid hydrogen and liquid oxygen tanks that carry the fuel; an intertank connector; a bottom section that will hold four RS-25 engines, originally made for the space shuttle program and repurposed for the Space Launch System; and a forward skirt at the top that contains the "brains" of the rocket (flight computers, cameras

Photo: Leo Williams, left, Vertical Assembly Center weld manager, and Amanda Gertjejansen, industrial engineer, confer beside a liquid hydrogen tank, the largest section of the Space Launch System, at NASA's Michoud Assembly Facility, in New Orleans.

and avionics) and attaches the core stage to the upper stages, notably the Orion crew module.

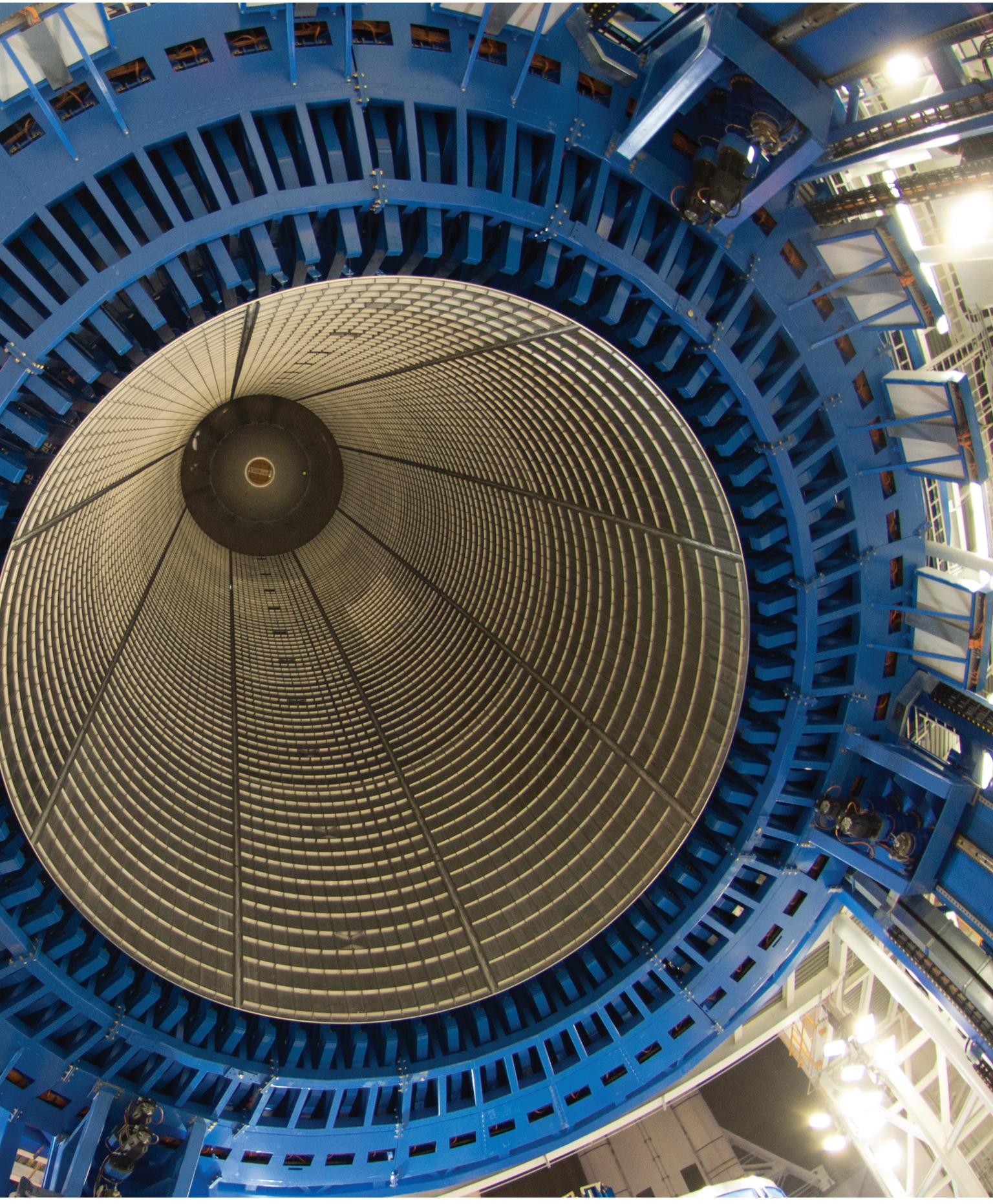
Once assembled, Boeing's core stage will stand 212 feet (65 meters) tall. To produce it, more than 1.7 miles (2.7 kilometers) of welds will be required, using an advanced friction-stir method in which a rapidly rotating pin generates heat that fuses metallic materials.

Fabrication specialist Nick Acosta Mora works in the intertank and thrust beam assembly area. He is one of more than 300 Boeing employees based at Michoud, which is owned by NASA. At his workstation entrance, a plaque describes how 18,500 bolts are needed to fasten these specific parts together. Among his responsibilities, Acosta Mora drills holes into a lime green thrust beam that attaches to fittings for the solid rocket boosters. The idea of supporting deep space exploration keeps him highly motivated while on the job.

"It's easy to get lost in the whole assembly, the nuts and bolts, but it's also kind of wild," Acosta Mora said. "This is going to move humanity forward and I'm pretty happy doing it—who gets to go to work every day and say they build rockets?"

Michoud, an eight-decade-old facility that covers a former sugar plantation, previously produced military airplanes during wartime and manufactured Saturn I, IB and V rockets and space shuttle external tanks. To accommodate the Space Launch System, the ground floor, or high bay, of the Vertical Assembly Center had to be reinforced. Ninety tons (80 metric tons) of concrete, 6 miles (10 kilometers) of rebar and more than 100 steel pilings form a foundation strong enough to support not only the neon blue welding

Photo: The Space Launch System's liquid hydrogen tank, shown from the inside, consists of five huge barrels welded together at Michoud Assembly Facility, in New Orleans.



tool, which stands 170 feet (50 meters) tall and weighs 1,650 tons (1,500 metric tons), but also a fuel tank at the same time.

"It's incredibly satisfying to see this come together in the factory," said Steve Ernst, Boeing propellant tank team lead for the Space Launch System. "They're changing the approach to space travel."

The size of Boeing's liquid hydrogen tank, which consists of five barrels and two domes, made it necessary to introduce heavier equipment and switch from horizontal to vertical welding, said Will Walsten, Fabrication specialist.

"Welding a vertical stack had never been done before," Walsten said. "We never had a welding tool this big, either."

Space Launch System fuel tanks will feed 733,000 gallons (2.7 million liters) of cryogenic propellant to the RS-25 engines at liftoff. The process is similar to draining a family-sized swimming pool every 60 seconds, according to NASA. Boeing's non-reusable core stage will separate and drop into ocean waters within minutes after sending the rocket through Earth's strong gravitational pull, the most difficult part of the journey, and into lunar orbit. The Space Launch System will reach a speed of Mach 23, or 23 times the speed of sound, traveling faster than 17,000 mph (27,300 kilometers per hour)—generating 20 percent more power than the Saturn V rocket that carried astronaut Neil Armstrong to the moon.

"Our team has been working with experts from across Boeing, and with NASA, to deliver the affordable, reliable, evolvable rocket America needs for deep space travel," said John Shannon, Space Launch System vice president and program manager. "We're building flight hardware now, getting ready for first flight, and working on additional capabilities for Mars missions. It's an exciting time to be in the space industry."

In the Michoud high bay, a crane lifts the completed liquid hydrogen tank off the welding tool and onto a horizontal cradle. The tank is moved, in order, to an area where it is washed, another location where it is pressure-tested on hydraulic jacks and yet another where a protective thermal spray is applied to the exterior surface.

The Space Launch System's first liquid hydrogen tank was completed this summer and soon will be barged upriver to Marshall Space Flight Center, in Huntsville, Ala., for structural load testing. Michoud now is manufacturing a second tank geared for spaceflight, one that will be attached to the smaller liquid oxygen tank, the RS-25 engines, and a huge network of lines that connect to fuel, avionics and other electronics before this section of the spacecraft is moved by barge to NASA's Stennis Space Center, in Bay St. Louis, Miss., for an engine test firing.

For the unmanned test flight in two years, Space Launch System sections will be stacked into a final configuration inside the Vertical Assembly Building at Kennedy Space Center, in Florida. A team is erecting a 20-section platform for that purpose. The spacecraft will lift off from Launch Complex 39, Pad B, which previously served as the starting point for Apollo and space shuttle trips into orbit, among more than 50 other launches. A new 355-foot (108-meter) mobile launcher will position the Space Launch System on the pad, which is being refurbished.

"I plan on seeing the first one go up—and many more from that time on," said Leo Williams, Boeing's Vertical Assembly Center weld manager at Michoud. "Everything's a challenge when you have something new and it has never been done before. But this is something that can be done."

To reach Mars, NASA astronauts will need eight months to travel

Photo: Kip Boquet, left, and Nick Acosta Mora, Boeing technicians, drill holes in an intertank section that connects the Space Launch System's fuel tanks.

there, three to six months to stay and explore, and eight months to return. They could be in space for 800 to 1,100 days, dealing with the effects of microgravity and high levels of radiation, NASA said. The astronauts will use 24 tons (22 metric tons) of oxygen to ascend into orbit, their supply replenished by an oxygen-generating machine. These space travelers truly will be on their own at times, facing a 44-minute delay between radio transmissions with Earth and a two-week communications blackout when Earth and Mars are on opposite sides of the sun.

A year ago, Fabrication specialist Jason De Buys was building jetliners in Everett, Wash. He returned to his native New Orleans to work on the Space Launch System. He considered his new role as he drilled holes on an engine beam that would attach an electrical panel: Where an airplane build is systematically laid out, De Buys has had to learn as he goes in assembling a rocket unmatched anywhere. He has found it all new and exciting.

"This mission we're about to go on is unprecedented in humankind," De Buys said. "It's amazing we're all in this together."

Inside a processing cell at the Michoud factory, Jeremy Larson and his team wear white jumpsuits, protective masks and gloves. They cover the floor beneath them with paper. They experiment with different chemicals that will provide insulation protection for the outer surfaces of the fuel tanks and other rocket sections against extreme temperatures at launch.

Larson, Boeing hardware protection program management specialist, pours a liquid substance

into a paper cup—and it combusts into a bubbling, expanding foam he said is warm to the touch. A robot later will spray this material onto a Space Launch System tank riding on tracks inside a nearby building that operates much like a carwash.

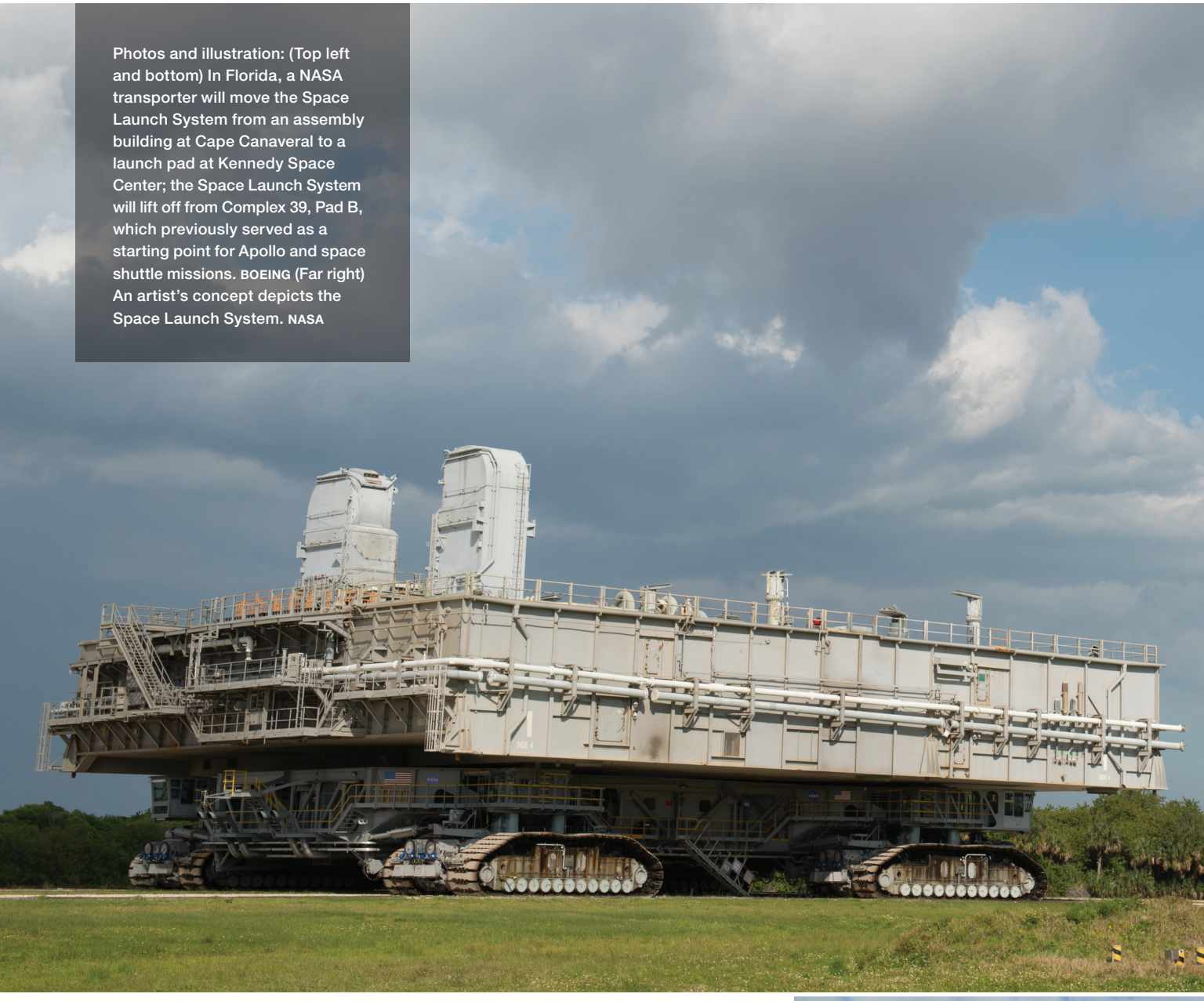
"We've had to come up with a new blend since ET (space shuttle's External Tank) because bigger things are coming, from the barrel to the engines, and we can cover a lot with this," Larson said. "My kids really think I do stuff more special than I do because they think I'm an astronaut. But it could be one of them in one of these first rockets."

Brandon Burroughs would not mind sharing in a capsule moment. As a load analyst intern often working alongside longtime engineers and Fabrication specialists, some with decades of experience, he brings a fresh set of engineering eyes to the Space Launch System. He attends Tuskegee University, in Tuskegee, Ala. He hails from a city historic for its Tuskegee airmen, the first African-American wartime aviators. He would like to add to his college town's aerospace lore by involving the world's largest rocket.

"I want to be a Tuskegee spaceman

Photo: (Far left) A liquid chemical mixture, after it turns into a foam-like material, provides a protective coating for the fuel tanks of the Space Launch System during launch. (Above) Fabrication specialist Courtney White, in safety gear, works on the chemical mix that will insulate the fuel cells.

Photos and illustration: (Top left and bottom) In Florida, a NASA transporter will move the Space Launch System from an assembly building at Cape Canaveral to a launch pad at Kennedy Space Center; the Space Launch System will lift off from Complex 39, Pad B, which previously served as a starting point for Apollo and space shuttle missions. BOEING (Far right) An artist's concept depicts the Space Launch System. NASA



doing what people say can't be done," Burroughs said.

Boeing technician Richard Oramous has worked at the Michoud facility for 40 years. He has seen the factory survive Hurricane Katrina and shift from space program to space program. He assembles Space Launch System domes that cap the fuel tanks at both ends. He operates a production tool and later checks the torque on hundreds of bolts.

He could not be more proud of what he does now, so much that the space mechanic brought his six grandchildren to a Michoud open house and showed them. He took family photos. He has contemplated a Space Launch System future that will involve him—and break aerospace barriers.

"When this launches off the pad, I'll know I'll have done my job," Oramous said. "This is going to be the largest vehicle leaving Earth." ●

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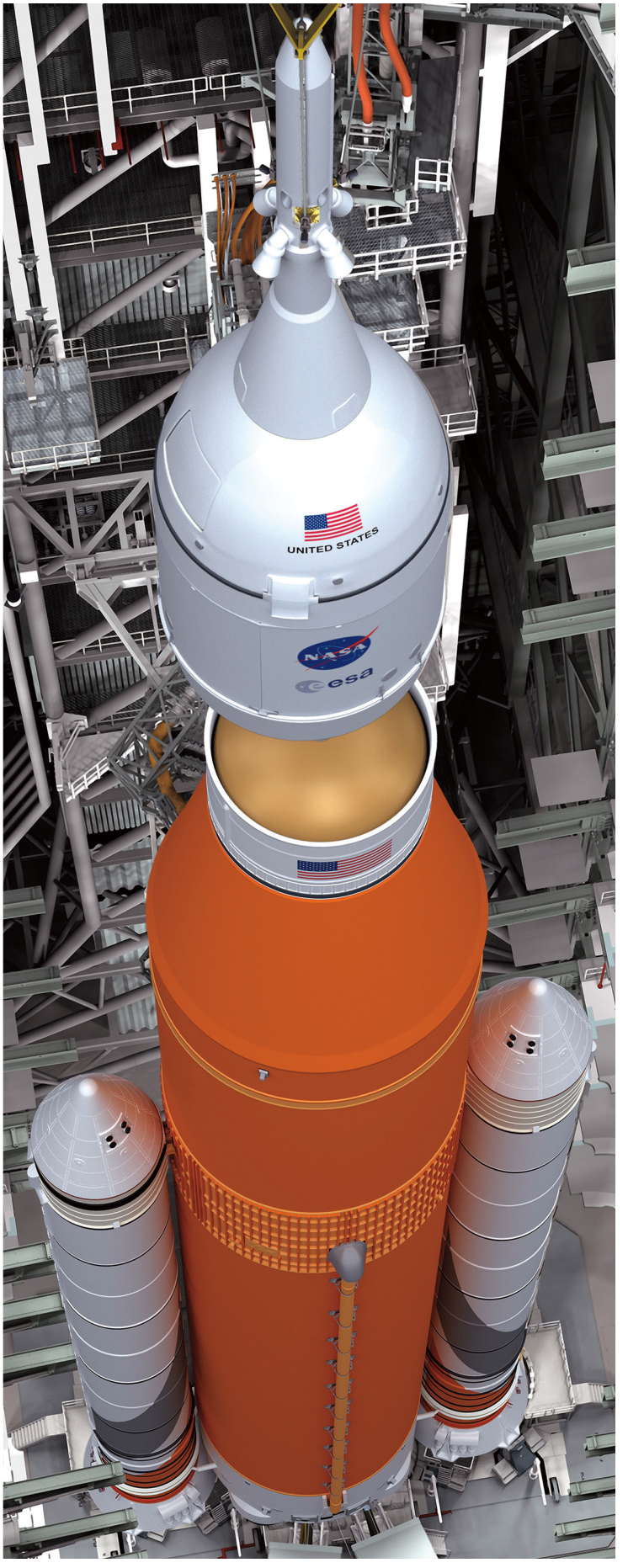
UNITED STATES
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Going the distance

The 787 Dreamliner family has been expanding airlines' reach and making long-haul routes a dream to fly

BY KATE EVERSON

At the Network Operations Center in United Airlines' Chicago headquarters, flight tracker Bill Parker keeps an eye on the skies. But here, the skies are digital. And the airplanes—including Boeing 757s, 767s, 777s and 787 Dreamliners—take the form of dozens of blue and white icons inching across desktop monitors projecting weather patterns, map lines and flight trajectories, as if along a psychedelic web.

Sometimes Parker's wife is on one of those airplanes: She's a flight attendant on the 787 Dreamliner's longest route, San Francisco nonstop to Singapore.

Since adding the 787 to its fleet in September 2012, United Airlines has expanded its well-known advertising slogan, "fly the friendly skies," by flying them farther. In June 2013, it began service from Denver to Tokyo, then added seven other nonstop flights on so-called long, thin routes, which previously required the range and fuel capacity of large jets such as the 747 but didn't have the passenger volume to fill them.

Other airlines such as All Nippon Airways (ANA), Norwegian Air Shuttle and Etihad Airways also have opened new routes. Since the 787 began service with launch customer All Nippon Airways in October 2011, more than 120 new routes have been opened or announced by airlines flying the 787, nearly all of them using the Dreamliner's 242- to 290-passenger capacity and 7,300- to 7,600-mile (13,500- to 14,000-kilometer) range, depending on whether they are flying the 787-8 or 787-9 model. The most recent: British Airways' flight between London and New Orleans, to begin in 2017.

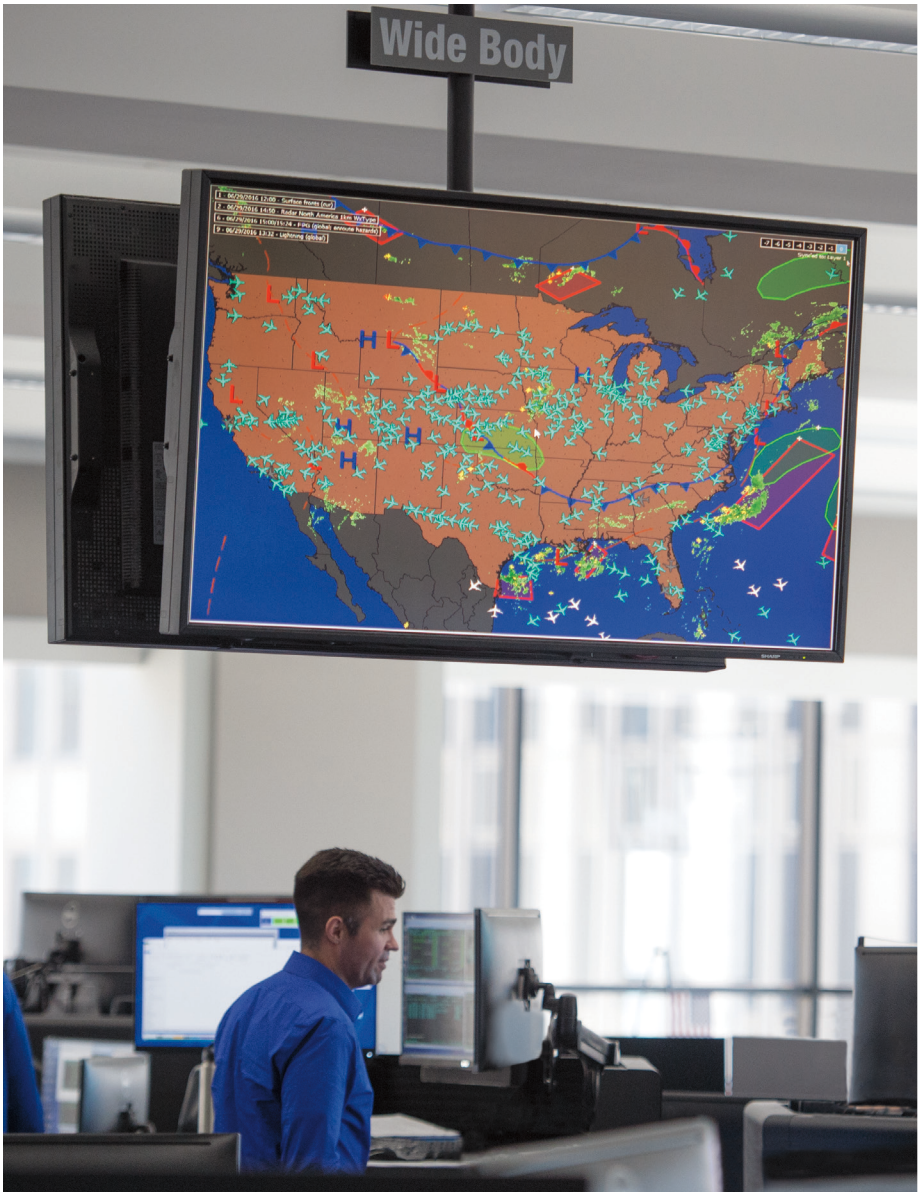
When the 787 family was in development, the Boeing marketing team came up with more than 400 routes the 787 could open up with its unique efficiency, size and range, said Randy

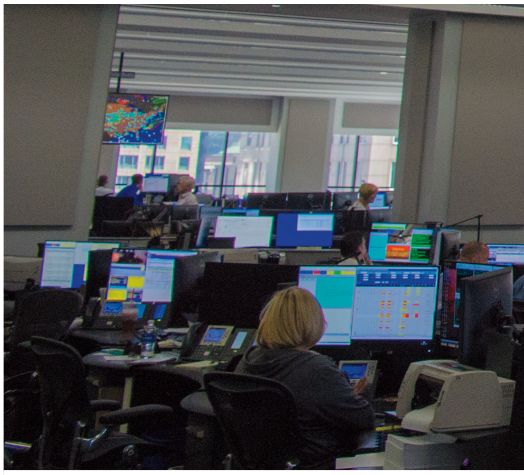
Photo illustration: In 2014, United Airlines received its first 787-9 Dreamliner, which it flew from Los Angeles to Melbourne, Australia—one of the world's longest routes at the time. BOEING

'DREAM' ROUTES BY THE NUMBERS

Among the more than 120 new, nonstop routes that airlines flying the 787 Dreamliner have opened or announced since the airplane's entry into service in October 2011, below are five of the longest.

ROUTE	AIRLINE	RANGE IN NAUTICAL MILES
SAN FRANCISCO–SINGAPORE	UNITED AIRLINES	7,328 (8,433 MILES, OR 13,571 KILOMETERS)
LOS ANGELES–MELBOURNE, AUSTRALIA	UNITED AIRLINES	6,884 (7,922 MILES, OR 12,749 KILOMETERS)
FUZHOU, CHINA–NEW YORK	XIAMEN AIRLINES	6,735 (7,751 MILES, OR 12,473 KILOMETERS)
LOS ANGELES–SYDNEY	UNITED AIRLINES	6,508 (7,489 MILES, OR 12,053 KILOMETERS)
ABU DHABI–BRISBANE, AUSTRALIA	ETIHAD AIRWAYS	6,481 (7,458 MILES, OR 12,003 KILOMETERS)





Tinseth, Boeing Commercial Airplanes vice president of marketing. Boeing customer airlines, however, took that list only as a suggestion and found additional potential. "We had not thought of opportunities like London-Heathrow to Austin, Texas, or in and out of places like San Jose," Tinseth said.

The 787 family's long-range capabilities aren't the only reason airlines use it for extended routes. Ron Baur, United Airlines vice president of Fleet, said some long routes could be performed with the larger 777, but now they can start up with or use the 787, which requires fewer passengers to fly at profitable load factors.

"We love the flexibility the 787 offers so we can match the demand in the market," he said. "If a route proves more popular, we then can use a bigger aircraft to match it."

Baur said size, range and fuel economy are what make the 787 family work for the airline, which now can fly nonstop from its main hubs to secondary cities such as the ones dotting China, where United is the largest U.S. airline offering service.

But there's another benefit that airlines see—and passengers and crew feel. Flights as long as 17 hours, 25 minutes between San Francisco and Singapore—or even nearly 16 hours, as with the second-longest United Dreamliner flight, Los Angeles to Melbourne—can be tiresome on any airplane. Boeing designed the 787 family not only to fly long distances nonstop, thereby reducing connections and travel time for passengers, but also to improve their sense of comfort with an advanced cabin environment based on research.

Inspiration for the 787's passenger-centric design—including increased cabin humidity; larger, dimmable windows; LED dynamic lighting; vaulted ceilings to provide a sense of spaciousness; among other features—originated when Blake Emery, Commercial Airplanes' director of differentiation strategy, and his team talked directly to their customers' customers: passengers.

"We figured out needs that passengers had but couldn't articulate," Emery said, describing how his team engaged

Photos: (Clockwise from far left) At the United Airlines Network Operations Center in Chicago, airline employees (left and right) track the carrier's fleet; United's Ron Baur, left, receives an update; a monitor displays real-time arrival and departure data.
BOB FERGUSON | BOEING

passengers with free association and storytelling exercises that got them to open up about what could improve their flying experiences. Now Emery lists the cabin's advanced design and relaxing environment as one of his favorite aspects of the Dreamliner.

Typically, the structural limitations of aluminum jet airplanes cruising at fuel-conserving high altitudes require carriers to pressurize their cabins to 8,000-foot (2,400-meter) altitudes, and there's almost zero humidity that high. But the Dreamliner's high-strength composite fuselage allows the 787 cabin to be pressurized to a much more comfortable 6,000 feet (1,800 meters), reducing fatigue and altitude-related discomfort. Because corrosion is not a factor with composite materials, increased humidity in the cabin improves the passengers' feeling of well-being during the flight and after landing.

Bob Whittington, 787 vice president and chief engineer, said his favorite part is the Dreamliner's wing, which changes shape in flight, saving fuel and helping reduce bumps from turbulence. But he also sees room for improvement.

"The 787 is changing the face of aviation," he said. "You're right at the edge of technology there, but … I'd like to see us move faster and make it less expensive for operators to change technology in the cabin and flight deck."

United's Baur also said that Boeing should be careful not to recline its seats in victory.

"It's a competitive market—Airbus also builds good airplanes, so it's important that Boeing keeps making small improvements to help reliability and range of the airplane," he said.

"It's got a great foundation, but don't rely on the success of the airplane," Baur added. "Just keep making it better. It's good for United and for keeping up with the competition." ●

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THE GATHERING SWARM

In a lab where multiple unmanned aircraft systems work together, engineers take problem-solving to new heights

BY DAN RALEY | PHOTOS BY BOB FERGUSON

Three unmanned aircraft systems lift off the ground in unison and hold steady. With rotors spinning at high speed, they resemble hummingbirds. They then dart forward and back, and up and down.

A quadcopter and hexcopter follow the lead of the larger octocopter until Boeing software engineer Chris Beauchene, seated off to the side and controlling their movements with a laptop, temporarily halts the demonstration.

"They're going to land for a second—they thought we were done," Beauchene said with a smile.

Here at the Collaborative Autonomous Systems Laboratory, in St. Charles, Mo., flight takes place indoors. The lab represents the latest example of the company's strategy to join smart unmanned systems with people seeking innovative ways to use them. Boeing will test and improve what others build, pushing to become the leader in a rapidly evolving autonomous industry, said Nancy Pendleton, Boeing's System Technology director.

In the middle of the 8,100-square-foot (750-square-meter) building is a high bay outfitted with an infrared motion-tracking system and a dozen overhead projectors. This enables Boeing engineers to cover the floor with virtual mapping and put unmanned aircraft systems through simulated maneuvers. They will ready the machines for activities such as military missions, civil disaster assistance and commercial needs.

"I think we'll see more and more uses of unmanned systems within the environment where we live—the growth and acceptance of them will increase as we move forward," Pendleton said. "The lab allows us to invest in and explore all possibilities."

The Boeing Research & Technology facility was built in response to expanding unmanned aircraft system use, which is evolving in a manner similar to that of the earliest common computers, lab manager Mike Abraham said.

"Computers have gotten very powerful and when you network them, new capabilities emerge," Abraham said. "These aircraft vehicles alone are interesting, but when you put them together to do common things simultaneously, then we're at the cusp of what really could happen."

Inside the lab, the 22-pound (10-kilogram) black octocopter is ready to launch again. It emits a musical sound, a flashing blue light and a beep—alerts that signal various operational modes for the unmanned aircraft system. Once its engines turn over, the copter climbs into the air, followed by others.

Fifteen feet up, the unmanned aircraft systems hover in formation over a map of metropolitan St. Louis that fills up the floor screen. The octocopter carries a sensor that aligns with the "terrain" below, allowing it to move or tilt the map view, revealing stadiums, railways and freeways. The mapping is so detailed that even a pitcher's mound at Busch Stadium, home of the St. Louis Cardinals baseball team, is detectable.

Engineers can display a battlefield,

Photo: Clockwise from foreground, David Huang, Tom Rice and Chris Beauchene prepare to test unmanned aircraft systems in the Collaborative Autonomous Systems Laboratory, in St. Charles, Mo.

commercial building or urban area in order to use multiple unmanned aircraft systems as a problem-solver, said Tom Rice, technology lead for the Collaborative Autonomous Systems Laboratory. The lab's motion capture system covers 80,000 cubic feet (7,400 cubic meters). Protective netting separates the flight area from operators and observers.

"We can make it anything we want it to be," Rice said. "A lot of groups are looking at the lab to see what we can do to help their programs."

The lab team will seek ways to effectively use multiple unmanned vehicles, rather than just one, to perform complex tasks and prove they can operate safely together, Abraham said. Engineers can test with different payloads, adding an engine or a sensor.

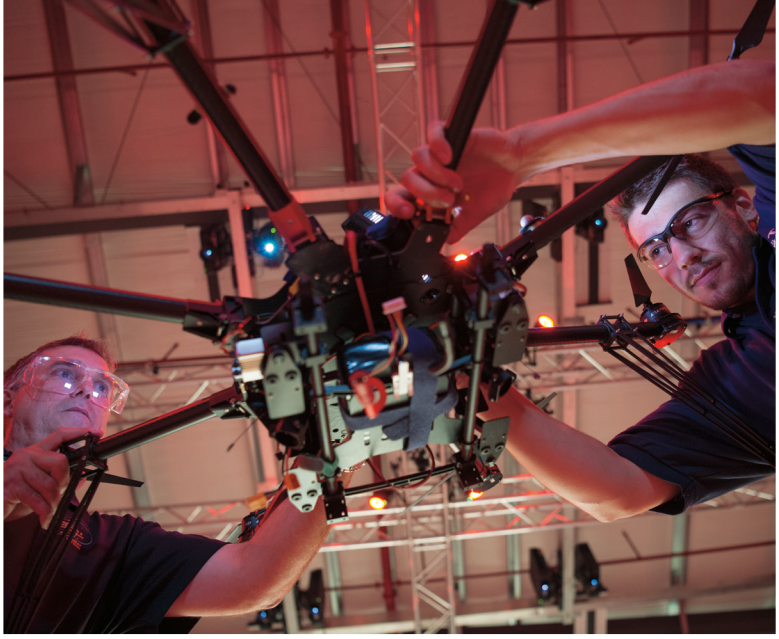
The lab might put an unmanned aircraft system through a simulated event to survey a natural disaster site and offer guidance to a ground robot that will shut off a gas valve. Or it might have two machines enter a mock battle zone to see how one could serve as a decoy while the other collects intelligence for ground forces, effectively reducing risk for a warfighter.

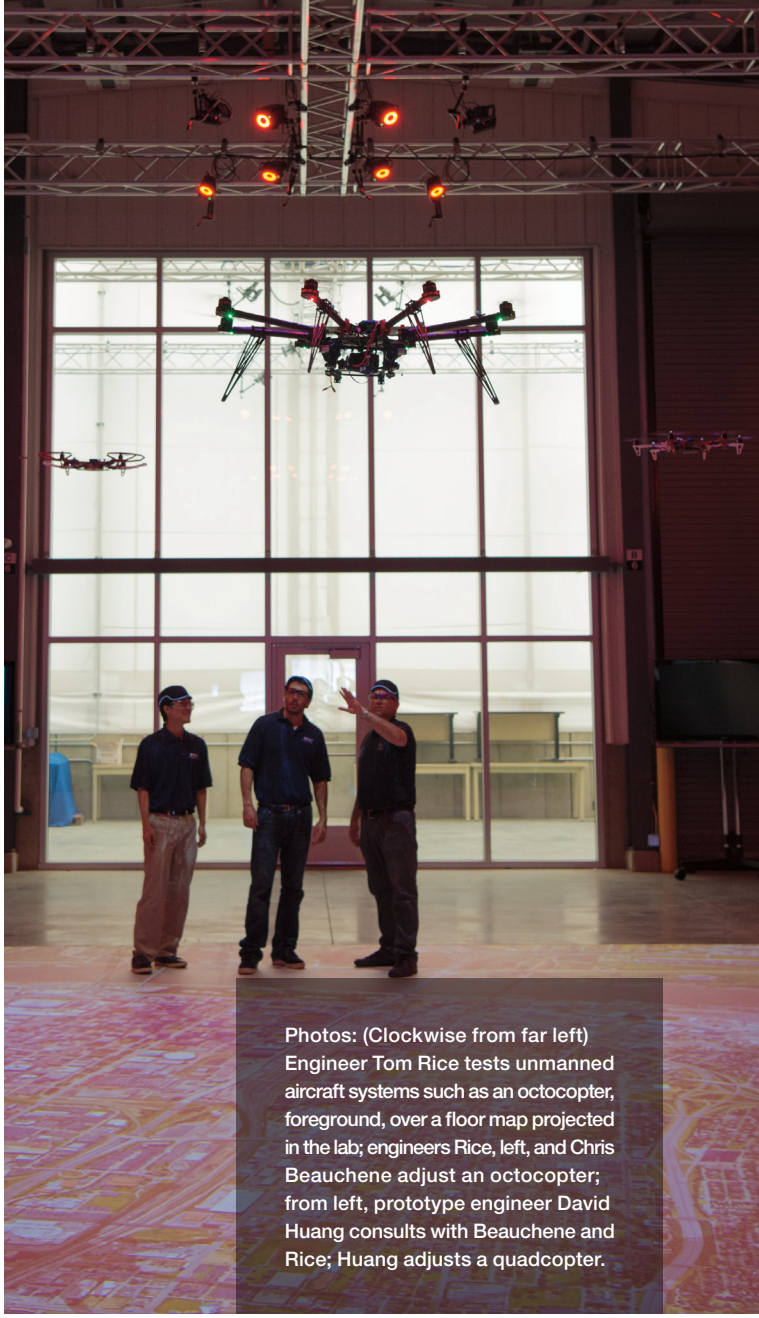
"Think of it as a loyal wingman, as the forward eyes into a fight," Rice said of the vehicle.

Customers can bring their unmanned aircraft systems to the autonomous lab to perform specific tasks and have them evaluated for performance. They can avoid delays that crop up during outdoor testing where equipment repeatedly has to be set up and dismantled because of inclement weather; the lab affords unmanned systems the ability to be tested for long periods of time without interruption, saving significant time and cost, Rice said.

The lab also could be used to help tie together something as intricate as a sea-to-space autonomous network, a concept bridging marine surveillance systems with unmanned aircraft systems, said Egan Greenstein, Boeing director of autonomous maritime systems.

"We have amazing capabilities so few people realize," Greenstein said





Photos: (Clockwise from far left) Engineer Tom Rice tests unmanned aircraft systems such as an octocopter, foreground, over a floor map projected in the lab; engineers Rice, left, and Chris Beauchene adjust an octocopter; from left, prototype engineer David Huang consults with Beauchene and Rice; Huang adjusts a quadcopter.

of the unmanned systems.

David Huang, Boeing prototype engineer, conducts autonomous research in the lab, integrating components into unmanned vehicles. He interacts with systems engineers. Huang is so involved with the technology, he uses it on and off the job.

"I've always been into autonomous systems," Huang said. "In my own time, I work on home autonomous things—voice control, home appliances, lighting, smart home stuff. It's the grand vision of the future."

As various-sized unmanned aircraft systems soar through Boeing's autonomous systems lab, the one thing they share in common is the steady hum of their engines. Once the machines become more mainstream, their operating noise someday will be as recognizable as any other sound to the general public, signifying their widespread acceptance and everyday use, Abraham said.

Over the past year, the Federal Aviation Administration licensed commercial operators of unmanned aircraft systems for the first time, a move that is spurring far more industry participation and innovation. While an unmanned aircraft system is relatively inexpensive to purchase and easy to obtain, the maturation of the technology, networking to perform difficult tasks, and creation of adjoining platforms will bring significant breakthroughs, Abraham said.

The St. Charles facility is poised to share in this evolution, offering Boeing an enterprise resource and encouraging other programs to provide autonomous ideas and products.

"I think you're going to see an explosion of new ideas and concepts, both inside the company and outside," Abraham said. "Every day, people are taking unmanned vehicles and doing something that's not been done before." ●

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Great and small

Soaring over the mountains of the Arizona desert, an AH-6 Little Bird shows off its new technology and capabilities during a demonstration flight last month for a prospective customer. The Boeing-built light attack and reconnaissance helicopter can fly higher and faster, and carry a larger payload, than previous models, according to employees who assemble it in the Mesa factory. The newest version of Little Bird embarked on a first production flight in July and was accepted by its first international customer a month later.

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