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Frontiers

Solar revolution

Spectrolab employees are powering the future—with sunshine

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Cover: Emilia Patino, left, and Lakhvir Sekhon inspect and clean solar space panels at Spectrolab in Sylmar, Calif. **BOB FERGUSON | BOEING**

Photo: Lakhvir Sekhon wires the front of a solar panel used to generate electricity to power a satellite. **BOB FERGUSON | BOEING**

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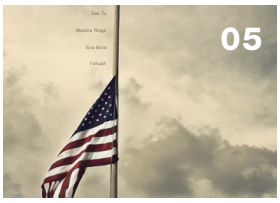
The stories behind the ads in this issue.



With this ad, Boeing shows its appreciation for and gratitude toward the U.S. armed forces. It will run in *The Washington Post* and *The Seattle Times*, as well as regional, trade and military publications, during the U.S. Memorial Day holiday. Boeing will also air a similarly themed commercial on the *Meet the Press* television program.

Part of the "A Better Way to Fly" campaign, this 737 MAX 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.

Frontiers will not be published in June to allow production time for a special 100-page July issue, which commemorates Boeing's centennial. *Frontiers* will return in September. The Milestones section, with employee service awards, retirements and obituaries, will be posted online for June, July and August. Boeing employees and retirees can access Milestones at **http://boeing.com/express** and click on MyBoeing Express > Life and Community > Frontiers magazine > Milestones.

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Investing in innovation

The financial blueprint for building an even bigger, better Boeing

As Boeing marks its first century in business, the company is moving forward on several new programs—including the CST-100 Starliner and 777X—that may well define its next 100 years. What will follow those projects? Will Boeing build a new "middle of the market" airplane that bridges the 737 and 787 families? What about possibilities in the defense and space business? *Frontiers* recently sat down with Greg Smith, Boeing's chief financial officer and executive vice president of Corporate Development & Strategy, to discuss the company's approach to investing in the future.

What role do you see innovation playing in Boeing's second century?

It will play as central a role as it did in our first 100 years. A few months ago, I was fortunate to be able to attend the first flight of the 737 MAX. Standing on the flight line, you could feel the pride and passion of our teammates as the airplane lifted into the air. The commitment of our people to always build something better is what has made our company great. And this innovative spirit will be critical to our second century of aerospace leadership. Though, I would add that innovation is not just about designing a more capable product or service offering. Innovation can also come in the form of a more efficient and flexible production system that allows us to get the product to our customer sooner and at lower costs.

Greg Smith
Chief financial officer, Boeing
Executive vice president, Corporate Development & Strategy
PHOTO: BOB FERGUSON | BOEING

With the increasing focus on affordability, might Boeing pull back on launching new products and services?

Investing in innovation and our people has been and continues to be a top priority for us. Since 2005, we have invested more than $38 billion in research and development. On top of that, we have spent another $18 billion on facility and equipment upgrades so that our teams have the infrastructure to innovate. That adds up to $56 billion over a 10-year period and we're seeing the results in the form of the 787 family, the Starliner and other programs.

What about the plan for future investments?

This year, we plan to invest more than $6 billion in R&D and capital expenditures. And I see us maintaining a similar level for the next few years. These are significant investments to build an even bigger, better Boeing, one that meets our customer needs and positions the company to win in the future. I would point out, though, that dollars alone do not translate to innovative products. We operate in a very competitive marketplace. Our customers want more capability, and they want it faster and at a lower price. New and traditional aerospace manufacturers are adapting to this reality. We have to be smarter and quicker in the way we innovate by focusing on solving our customers' problems, managing development risk, and improving first-time quality and safety as we deliver on our commitments.

Is that the idea behind what you and other Boeing leaders have described as "de-risking this decade"?

Yes. That effort really began several years ago when we decided to go with the 737 MAX rather than gamble with a higher-risk and higher-cost clean-sheet small airplane. With the MAX, we can deliver a jet that is significantly more fuel-efficient than today's 737 and we can get it to the customer sooner. Another way that we have de-risked our innovation is to take a "One Boeing" approach to leveraging our investments and spiraling in new technologies. You see this with the P-8 and KC-46 programs, where we harvested our commercial platforms to provide a proven and affordable solution that our competitors frankly could not offer.

PHOTO: BOB FERGUSON | BOEING

ILLUSTRATION: BOEING

Does this approach signal how Boeing will address the possible "middle of the market" airplane?

We can approach that market in a number of ways. First we have to understand what our customers' needs are today and what they might be two, three decades from now. Then we have to analyze the prices customers are willing to pay, the required development costs and other factors to show the potential return on our investment.

On the defense side of the company, how is Boeing investing in the future?

Well, even during the downturn in domestic defense spending a few years ago, we continued to invest resources in defense and space projects. In fact, we invested more in research and development than any U.S. defense contractor. Recently, our Phantom Works and Network & Space Systems teammates unveiled Echo Voyager, an extra-large unmanned undersea vehicle that begins sea trials this summer. Also this year, we are putting resources into finalizing development of the KC-46A, the Space Launch System and other programs. Going forward, we have our eye on cyber, command and control, and unmanned-type capability, along with investments in extending existing platforms such as our rotorcraft business.

What can employees do to support continued investments in innovation?

Every employee can help, because our blueprint for funding our future depends on all of us delivering on our commitments and doing so more efficiently. When we improve productivity and first-time quality we generate more money to reinvest in research and development, and facility and equipment upgrades. The same is true when we improve the way we manage our inventory, which frees up cash for us to put to work. Finally, we can make our dollars count by taking a One Boeing approach, moving technology and expertise from one program or one site to another. That will help us become more efficient and ultimately get new capability more rapidly into the hands of our customers. ●

Pump up the jam

A U.S. Navy EA-18G Growler prepares to take off last month from the flight deck of the aircraft carrier USS *Dwight D. Eisenhower* while operating in the Atlantic Ocean. The Growler, designed for electronic warfare missions, is built by Boeing in St. Louis alongside the F/A-18 Super Hornet. **PHOTO: U.S. NAVY**

"The P-8 aircraft has transformed how the Defense Department uses its maritime patrol and reconnaissance force … It has proved itself around the world."

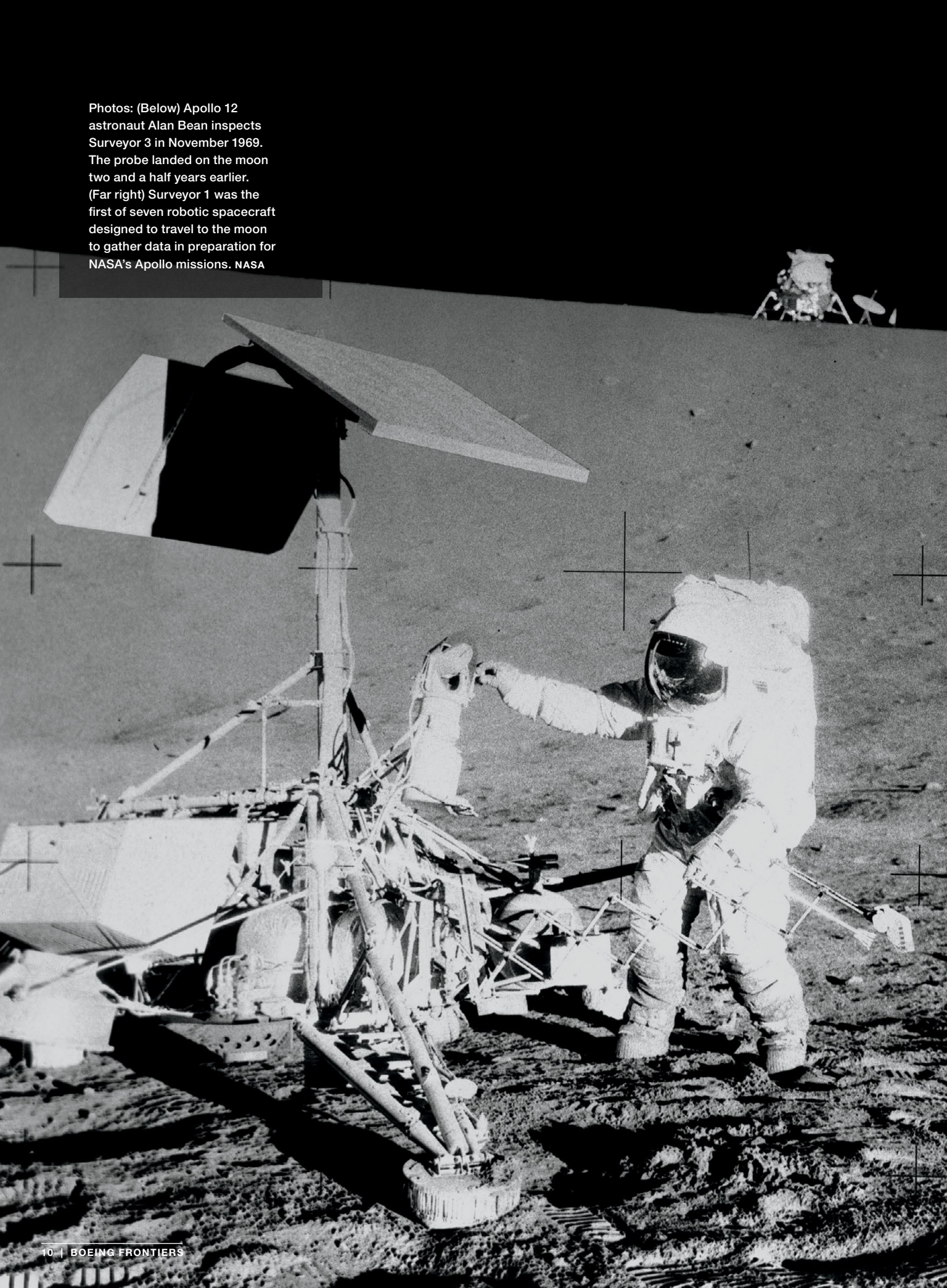
—U.S. Deputy Secretary of Defense Robert Work, after touring the P-8 production line in Renton, Wash. *Boeing News Now*, April 7

"About 100 million new passengers take to the Asian skies every year, adding to the billion that currently travel to, from or within the region."

—From a Reuters story discussing increasing demand for jet travel in Asia, quoting Boeing estimates, April 19

"With red and white TWA colors, the 747 looked like a feather just floating down … That observation was the most beautiful sight one could imagine; seeing an airplane that big floating like a feather."

—Floyd Lukecart, retired, on the first time he saw a 747 as it landed at St. Louis Lambert Field. Read his story and those of others on Boeing's centennial story sharing website at boeing.com/our-stories.



Photos: (Below) Apollo 12 astronaut Alan Bean inspects Surveyor 3 in November 1969. The probe landed on the moon two and a half years earlier. (Far right) Surveyor 1 was the first of seven robotic spacecraft designed to travel to the moon to gather data in preparation for NASA's Apollo missions. NASA

Surveying the future

A half-century ago, development began on a lunar probe that helped astronauts walk on the moon

BY MICHAEL LOMBARDI

When Neil Armstrong made his first step on the surface of the moon, he famously called it "a giant leap for mankind." But getting there required many small and purposeful steps. And some of the most important were taken by lunar probes named Surveyor, made by a Boeing heritage company.

There was little solid data about the lunar surface in 1961, when President Kennedy challenged America to land men on the moon before the end of the decade. What was the lunar soil made of? How much weight could the surface bear? Enough to hold a spacecraft with two astronauts on board? What about the magnetic and thermal properties on the lunar surface?

It was all critical information that would be needed in designing a lunar lander—for astronauts.

Early attempts to gather data about the moon, beginning in 1961 with Project Ranger, were unsuccessful. The first six spacecraft failed. In July 1964, Ranger 7 became the first U.S. probe to return close-up photos of the moon, but by then NASA had started other programs to gather data for the Apollo manned missions that were planned.

NASA had approved a pair of unmanned exploration programs, which included five Lunar Orbiters that were tasked with photographing the moon's surface to aid in selection of suitable landing sites for the Apollo missions, as well as to collect data on the moon's gravitational field, levels of radiation and the density of micrometeorites in the vicinity of the moon.

The second program was known as Surveyor, with the primary mission to validate the technology for soft landings on the moon. Surveyor would also provide data to determine whether the Apollo lunar lander design was compatible with the actual conditions that would be encountered on the lunar surface and, in general, to add to the scientific knowledge about the moon.

Hughes Space and Communications, North American Aviation and McDonnell Aircraft competed for the Surveyor project. All are now Boeing heritage companies. In January 1961, NASA accepted the design proposed by Hughes.

Hughes was contracted to build seven Surveyors, and on May 1966—50 years ago this month—Surveyor 1 was launched to the moon. Unfortunately, it would not be the first soft landing on the moon. Four months earlier, the Soviet Union achieved that objective with Luna 9. But for six weeks, including a two-week-long shutdown for the lunar night, Surveyor 1 transmitted 11,237 high-resolution pictures back to Earth.

Surveyor 2 was lost because an engine failed to fire; Surveyor 3 bounced twice before coming to rest 103 feet (31 meters) from the initial landing site. But it still managed to send back 6,300 pictures—many were of its mechanical scoop used to dig 7 inches (18 centimeters) into the lunar soil.

Surveyor 4 was lost; Surveyor 5 irradiated the lunar soil so that its composition could be analyzed.

Surveyor 6 engines were fired for 2.5 seconds and the spacecraft moved 8 feet (2.4 meters) away from its landing site to get a stereoscopic view of the lunar surface and a viewing of the area disturbed by the original landing.

With the successful conclusion of the Surveyor 6 mission, the program had accomplished all of its goals for the Apollo program.

Unlike the previous Surveyor missions that landed in the barren maria, or dark and flat regions, of the moon, Surveyor 7 was sent to the rim of the crater Tycho in the lunar highlands, where it examined an area filled with debris created by the formation of the crater and obtained very different types of lunar samples than the previous Surveyors.

All seven spacecraft are still on the moon. In 1969, Apollo 12 landed within a quarter-mile (402 meters) of Surveyor 3 and astronauts Pete Conrad and Alan Bean retrieved parts of it, including the camera, to determine the effects of long exposure to the lunar environment. The camera is on display at the Smithsonian National Air and Space Museum in Washington, D.C. ●

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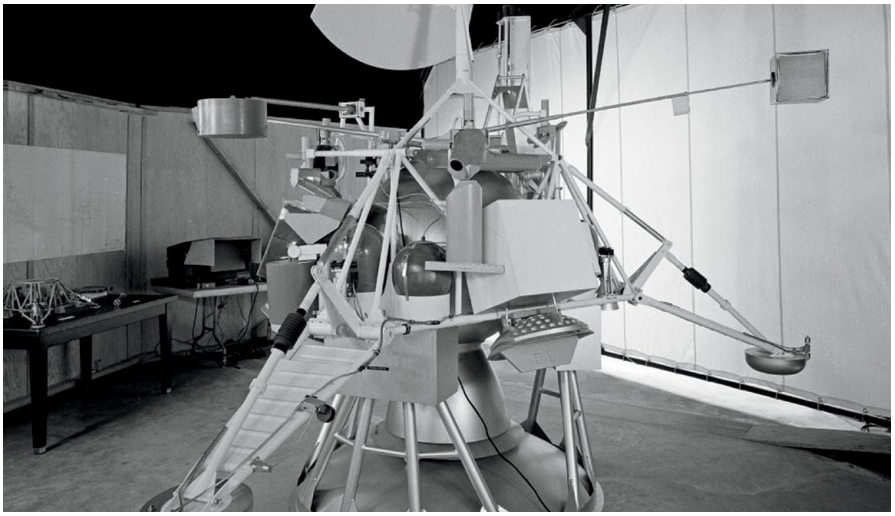


Testing to

Flight testing for the new 737 MAX is going well as pilots and engineers push the test aircraft to the limits

Photo: Flight testing of the 737 MAX, which began in January, will involve four airplanes.
PAUL WEATHERMAN | BOEING

the MAX

BY DAN RALEY

A 737 MAX, the second to come off the assembly line and designated 1A002, is parked in a hangar at Seattle's Boeing Field between test flights. People gather around the new airplane, performing maintenance. A lone engineer seated on board checks flight data, nearly hidden by the 14 banks of computer equipment mounted on metal stands that surround her.

Two nitrogen tanks are strapped to the floor in the back, used for engine instrumentation tests. A circular device, which resembles a giant fishing reel, holds rolled-up line that trails a sensor and plastic cone in and out of the vertical stabilizer to measure airspeed.

By the fall, this particular MAX and three others will have endured hundreds of test flights—from Washington state to Bolivia—that involve everything from midair stalls to high-speed braking. The airplanes will have been pushed to their aerodynamic limits in every manner, ensuring the airworthiness of the latest 737 series model to satisfy Federal Aviation Administration certification and Boeing engineering standards, according to Boeing test pilots and flight-test engineers involved in the flight-test program.

The first MAX aircraft, 1A001, flew for the first time in January, taking off from Renton Field in Washington, adjacent to the factory where employees assemble the 737 airplanes.

On March 4, test airplane 1A002 also lifted off from Renton Field on its initial flight. As a new airplane, it had to take off to the north over water, with a fireboat below for safety requirements. James Hanley, one of the two Boeing test pilots on board, said he experienced an adrenaline rush as the jetliner accelerated down the runway, knowing that airplane's engines had never been airborne before.

Flight tests, he explained, are meant to push a new airplane all the way to its


737
N8701Q

Photo: Against a Seattle backdrop the 737 MAX conducts a test flight. The process will take the new airplane from Washington state to Bolivia before it is certified by the Federal Aviation Administration.
PAUL WEATHERMAN | BOEING

design and performance limits and see how it reacts, a challenge that Boeing pilots readily accept.

"You're taking the airplane past where we let commercial pilots go," Hanley said. "Our goal is to get an airplane that's safe and reliable."

Since February, the first two 737 MAX airplanes have averaged around 20 test flights a month, initially traveling from Seattle to Mullan Pass in Montana's Rocky Mountains and back, according to flight-test engineers. Using this route avoids most commercial airline traffic in the region. And Moses Lake, Wash., at the halfway point, can be used for refueling or ground testing.

For more difficult flights, the MAX flight-test aircraft work in concert with the telemetry room at Boeing Field. The control center provides instantaneous data and enables higher-risk testing such as flutter, or flight instability, according to Mike Torres, a flight-test engineer with Boeing Test & Evaluation. Dozens of engineers monitor different parts of the airplane, grouped in the areas they represent, such as propulsion or structural dynamics, he explained.

Display screens fill a third-floor space that has frosted windows. Engineers and others see the airplane only through movement on a real-time map or by fluctuating charts and graphs that report hydraulic or engine pressure. Everyone in the room is required to wear a headset. "It allows us to be safer," Torres said. "We can look at number changes. Now we're always setting limits (rather than estimating)."

Shannon Timke, test director with Boeing Test & Evaluation, sits in the back row of the telemetry room during the flight testing. She provides a central voice. People communicate with her and she, in turn, speaks directly to the pilots. Distractions are kept to a minimum.

"The pilots are flying the airplane and that's a lot to do; we try to reduce the workload," Timke said. "It's a pretty sterile environment. We try to treat it like a flight deck."

An emergency button located at each table in the telemetry room will flash a red light and sound an alarm if necessary, if data indicate a problem, and pilots then are told to stop the flight maneuver, Torres said. The first two MAX test airplanes are heavily instrumented inside the passenger cabin in order to perform aerodynamic work. The third, also filled with instrumentation, is referred to as the systems airplane, testing autopilot and other mechanisms. The fourth jet comes with a fully installed passenger interior, similar to what is found on board a commercial airliner.

Flight tests also are conducted at sites in California, including at Edwards Air Force Base, to utilize longer runways. Brake testing often is done in Roswell, N.M., because the composition of the runway provides a better friction measurement. Noise testing is performed in isolated Glasgow, Mont. One of the MAX test aircraft is scheduled to fly to Farnborough, England, for the international air show in July to see how it performs in long flights over water.

Keith Leverkuhn, vice president and general manager for the MAX program, said flight testing has gone very well and there have been very few "squawks," or problem write-ups, on the test airplanes currently flying. Manufacturing is on track, with the first production MAX making its way through final assembly, he noted. Although it's still early in testing, the MAX LEAP-1B engines are performing even better than the program had anticipated, Leverkuhn added.

The engines require three markedly different test sites—sea level in Florida, intermediate altitude (5,000 to 6,000 feet, or about 1,500 to 1,800 meters) in Colorado and high-altitude (14,000 feet, or 4,300 meters) in Bolivia—with pilots putting the engines through strenuous exercises in each one, according to flight-test engineers.

More difficult maneuvers are dives, stalls, flutter, zero-gravity push-overs and anything conducted close to a runway, said Craig Bomben, chief test pilot and vice president of flight-test operations. Plenty of precautions are taken.

"If it's a higher-risk test point, we make sure we have crews that have previously flown those types of maneuvers," Bomben said. "We'll practice in the

simulator if they're difficult."

Each of the early MAX test flights is trailed by a chase plane, a former T-33 or T-38 military jet trainer, which carries a flight-test photographer and pilot. They wear parachutes and occupy ejection seats. The photographer is responsible for documenting each flight with photographs, video or high-speed video.

It's no easy job trying to capture images at jet speed or through a reflective jet canopy, said John Parker, Boeing photography and video team leader.

"You can't throw just any photographer into a chase plane; he or she needs to know what's going on," Parker said. "It's not for the faint of heart. You have to be prepared for anything to happen—they're testing for the unknown."

MAX flight testing so far has been noteworthy for its efficiency, according to David Loffing, engineering integration chief engineer for the 737 MAX. Planning that began four years ago has significantly reduced the hours needed to push the airplane through the process, he said. Instrumentation was installed and calibrated in the factory, a big timesaver. Test data have been gathered for multiple groups rather than gathered at multiple times.

The number of hours spent testing the MAX has dropped nearly in half from the Next-Generation 737 flight-test program in 1997, Loffing said. Program-to-program teamwork has been the key, preventing unforeseen delays and uninterrupted testing, he said.

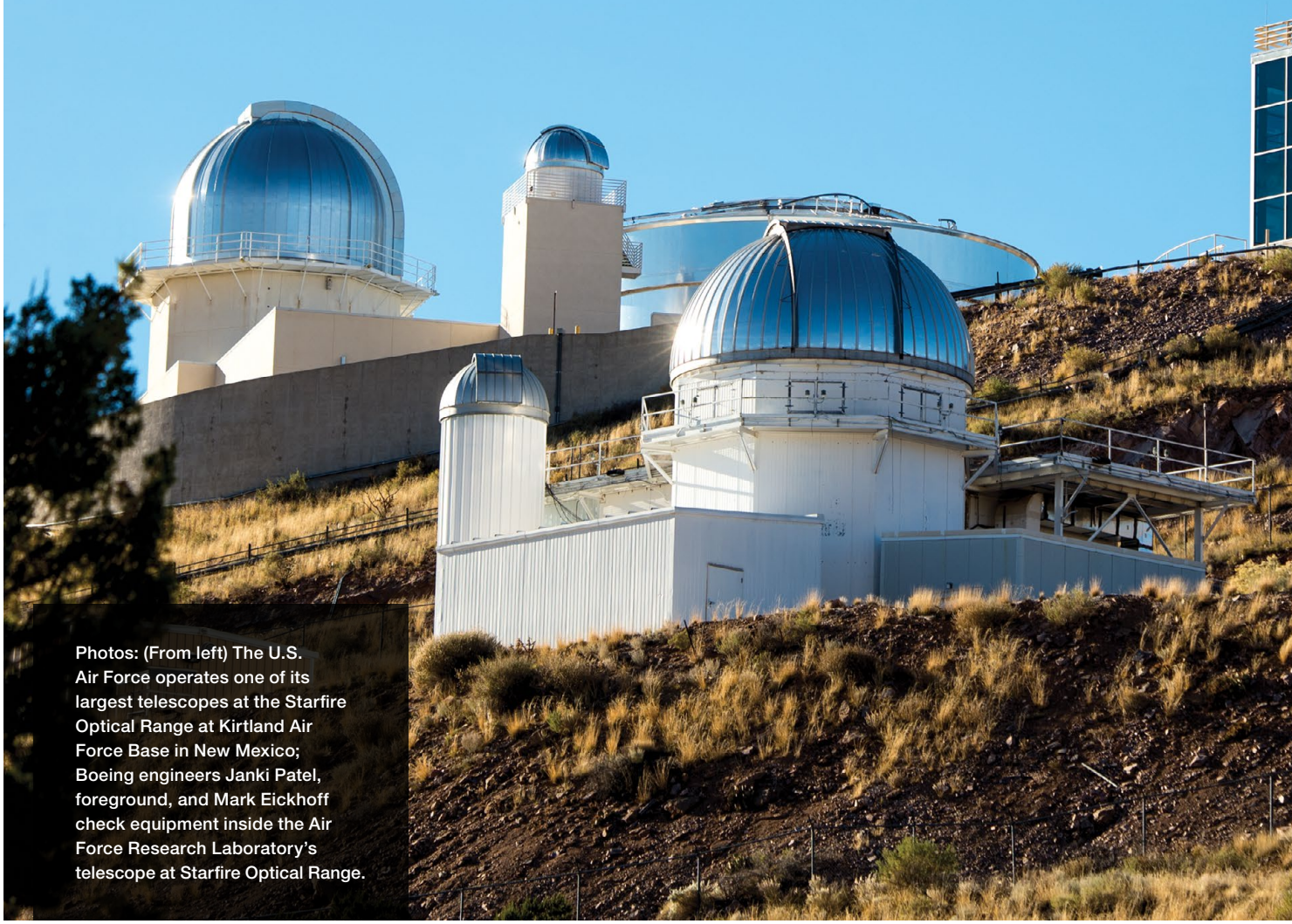
"It's been the engineering team working really tight with our factory operations," Loffing said. "When the flight-test airplanes started coming through the factory, we were there, asking, 'What are the issues and how can we help?' As a result, we got a very clean airplane out of it." ●

DANIEL.W.RALEY@BOEING.COM

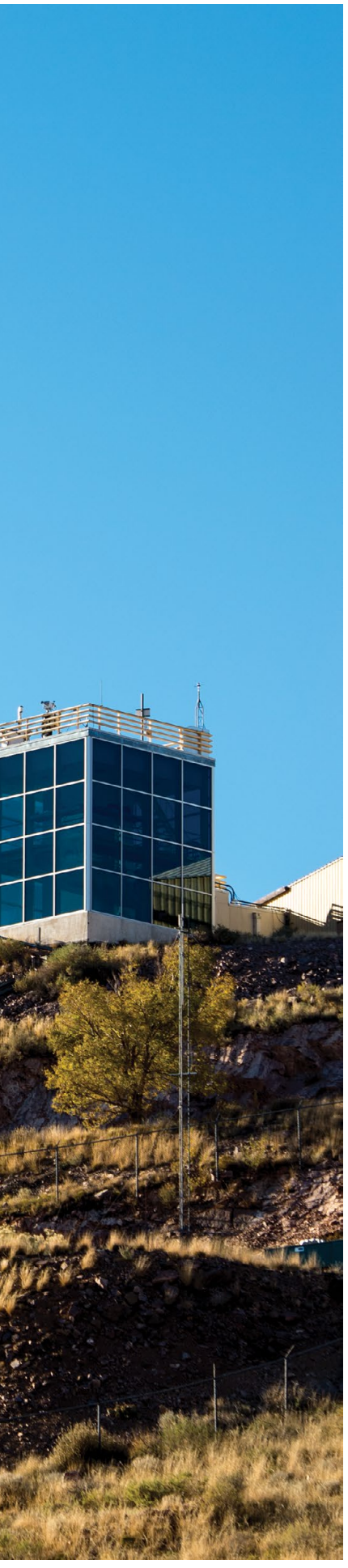
Photo: Takeoff and landing performance of the 737 MAX will get a thorough examination during flight testing. **MATTHEW THOMPSON | BOEING**

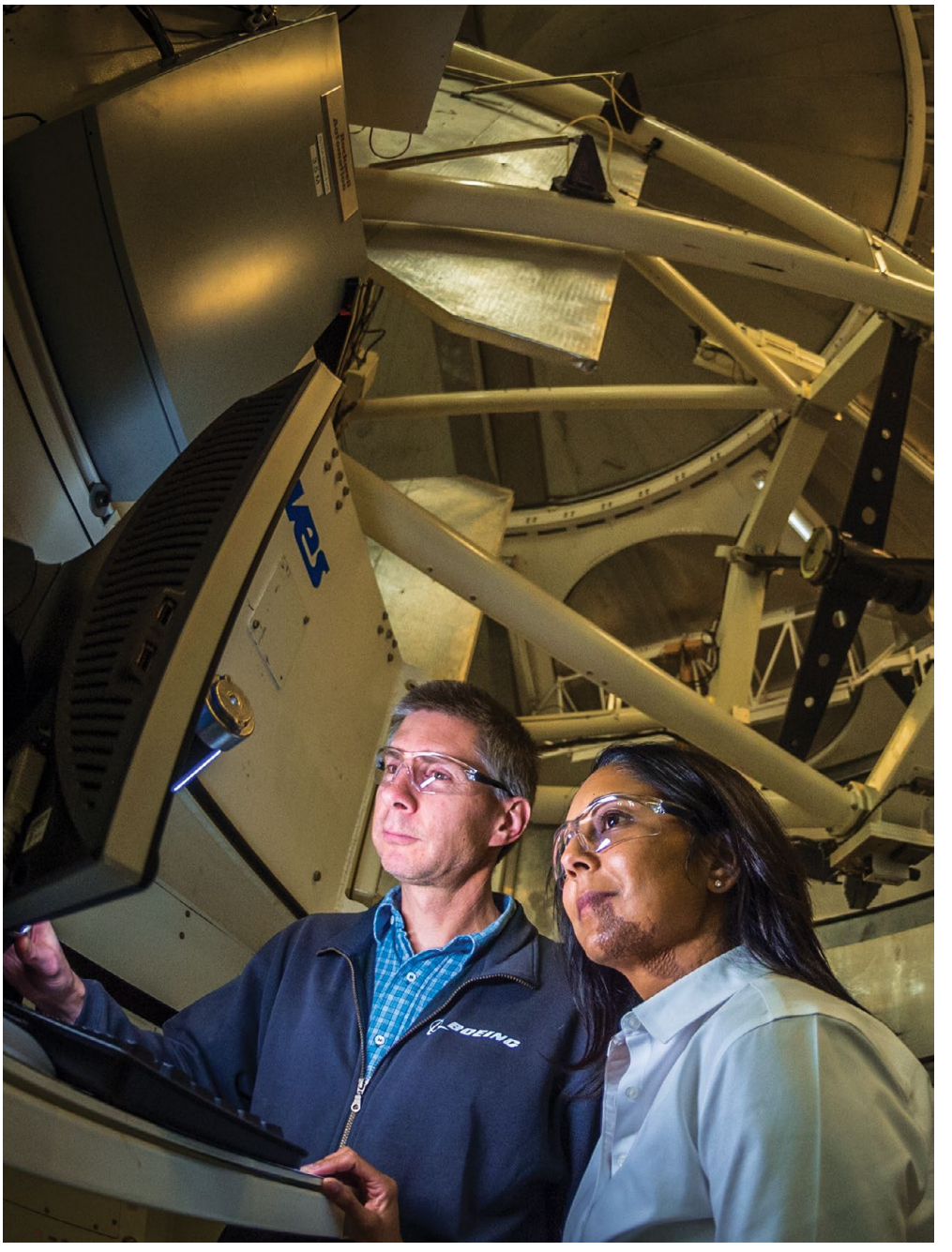
Star light, star bright

In the high desert of New Mexico, technology moves at light speed



Photos: (From left) The U.S. Air Force operates one of its largest telescopes at the Starfire Optical Range at Kirtland Air Force Base in New Mexico; Boeing engineers Janki Patel, foreground, and Mark Eickhoff check equipment inside the Air Force Research Laboratory's telescope at Starfire Optical Range.





BY DAN RALEY | PHOTOS BY BOB FERGUSON

The Starfire Optical Range sits nestled in the high desert of New Mexico, its shiny collection of domes distinguishing it from the barren landscape. Kirtland Air Force Base boundaries offer plenty of privacy, as do seemingly endless stretches of sand and sagebrush.

At the center of the hillside observatory is a powerful black and white telescope that comes into view once the largest dome collapses and rotates out of sight and heavy metal doors open on an inner protective shell.

Boeing supports the U.S. Air Force engineers and scientists who experiment here with lasers in conjunction with the 3.5-meter (11.4-foot) telescope to better monitor man-made objects in orbit, much of it space debris. As satellites get smaller and the number of space objects increases dramatically, research in imaging and identification of the space objects is paramount.

The Air Force conducts research in laser guide star adaptive optics, beam control and space object identification. A laser guide star is an “artificial star”

used to correct for atmospheric turbulence, enabling high-resolution imaging through the telescope. The laser guide star is created by focusing a laser in the atmosphere and using the return light to sense and correct the turbulence that would otherwise preclude the high-resolution imaging, said Harold Schall, Boeing Laser & Electro-Optical Systems chief engineer and a Senior Technical Fellow.

"You get a sample of light that goes off a series of mirrors and into an optics room where all the magic happens," Schall said.

Starfire Optical Range is just part of the high-tech community surrounding Boeing in and around Albuquerque. While a number of contractors work with Air Force personnel and military at the observatory—perched south of New Mexico's largest city at 6,200 feet (1,880 meters) above sea level, not far from where the Sandia and Manzano mountains intersect—another 85 people are assigned to the Boeing Albuquerque site, occupying a sprawling white building that houses 13 different labs, all of which is located on the northern edge of town at 5,500 feet (1,670 meters) altitude.

This elevated, southwestern region of the United States offers a melting pot of scientists and engineers with advanced degrees and industry credentials, a populace that has been in place since the onset of World War II.

They fill up laboratories and research facilities for different organizations throughout the area, continually looking for ways to enhance modern civilization, space navigation and military technologies used to protect freedom. Boeing has a significant presence.

"It's a great place for productivity," said David DeYoung, Laser & Electro-Optical Systems director, Boeing Albuquerque, of the desert's advantages. "It has the dry climate, high elevation and available test ranges."

Sandia National Laboratory and the Air Force Research Laboratory, which develop war-fighting capabilities and technologies, are located inside the 57,000-acre (23,000-hectare) Kirtland Air Force Base.

Los Alamos National Laboratory, where the first atomic bomb was created and which remains one of the world's largest scientific institutions, is 100 miles (160 kilometers) north. White Sands Missile Range, the largest American military installation anywhere, is 150 miles (240 kilometers) south.

Alamogordo, the first nuclear weapons test site, and Holloman Air Force Base, which has been home to some of the U.S. military's most advanced aircraft, are 200 miles (320 kilometers) to the southeast.

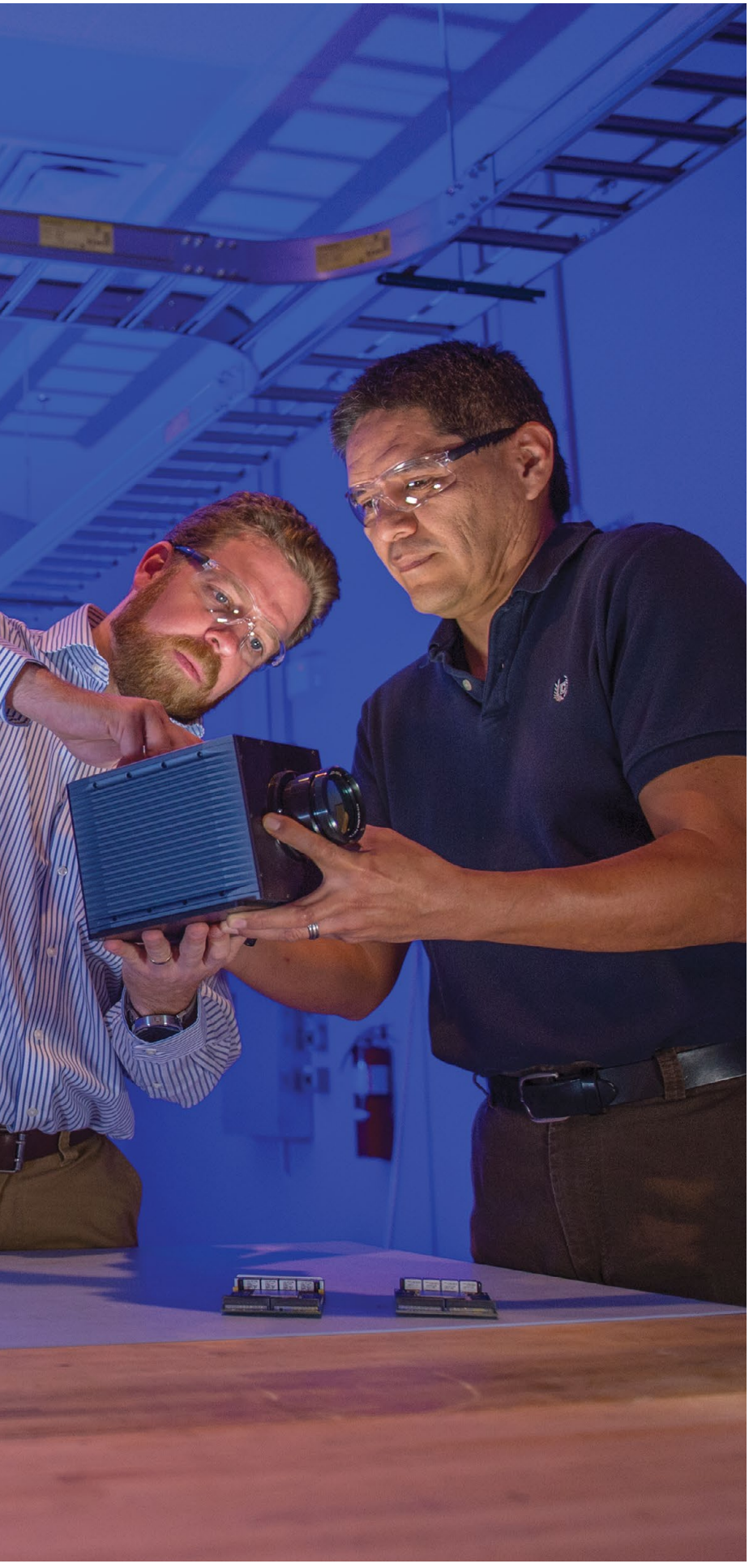
With so many resources close at hand, project crossover that involves Boeing and its desert neighbors is a regular occurrence, according to Mario Alleva, Boeing Embedded Systems manager.

"It's a very tightknit community of technology in New Mexico," Alleva said. "You work with people for decades. I've worked with people at the Air Force Research Lab since I was 18. I still coordinate with them."

At Starfire Optical Range, a red warning sign flashes outside the doorway to the telescope whenever a laser is in use. A floor below, SOR employees occupy a control room and operate camera and adaptive optics systems. Clocks are set to Greenwich Mean Time, the benchmark for

Photos: (From top) Boeing Chief Engineer Harold Schall, foreground, and engineer Mark Eickhoff examine data captured by the laser guide star system; Boeing engineer Chloe Malveaux develops Image Auto Tracker software for the Apache Longbow Crew Trainer.

Photo: From back left, program leader Juan Ceniceros and engineers Jeremy Manning, Matt Beckmann and Harrison Danny develop cameras, lasers and processors in Albuquerque, N.M., that will help dock Boeing's CST-100 Starliner to the International Space Station.



global connectivity.

A test director is in charge. A safety officer is on duty. A spotter stands outside and watches overhead for approaching airplanes. Boeing employees bring a strong sense of purpose to the observatory and its advanced research.

"People here feel a real ownership in the site," said Josh Kann, a Boeing senior physicist and Associate Technical Fellow. "It's extremely interesting work. It's extremely challenging work. These are cutting-edge programs. You definitely understand there's a need for this kind of technology."

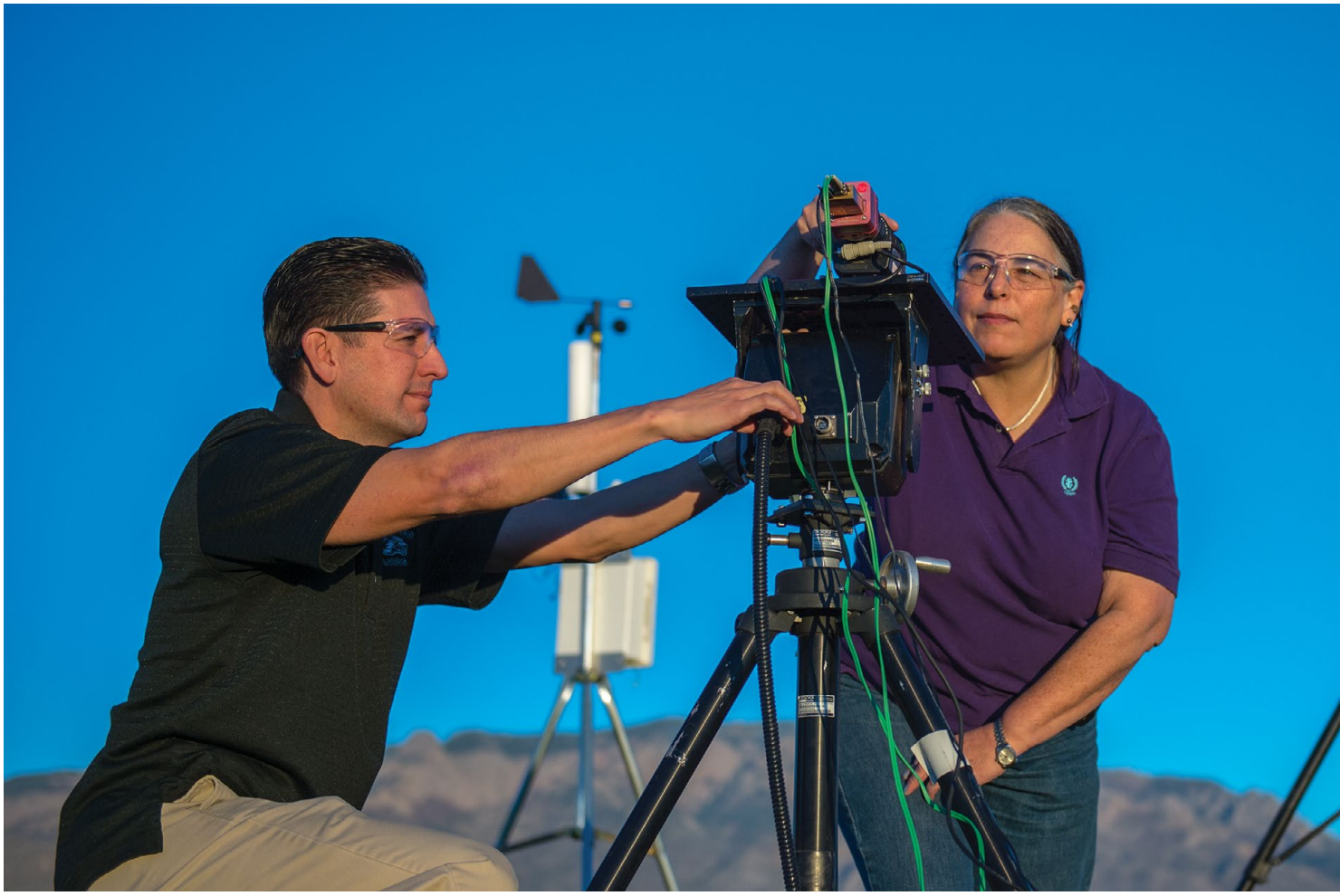
In this rugged landscape, they are not always alone when in pursuit of their high-tech breakthroughs. Boeing employees often work late at night at the observatory and are encouraged to carry flashlights when getting in and out of their vehicles during the warmer seasons—otherwise they might not spot the rattlesnakes which show up from time to time on the asphalt parking areas.

"You need a flashlight for safety, just to get to your car, to see where it is when you're working at night, and there are snakes up there," Schall said. "It's not like they're swarming all over the place, but you have to be careful not to step on one."

Twenty-five miles away, Boeing Albuquerque has a much more urban feel to its workplace. The block-long building anchors the middle of a commercial strip mall, surrounded by hotels, restaurants and medical clinics. What goes on inside, however, is hardly everyday activity.

Prototypes of satellites and weapon concepts are on display in various hallways. Current laser and sensor projects get full attention behind closed doors, where clean rooms, or debris-free areas, are cordoned off in labs by dangling plastic ribbons. Lasers require clean optics. The need for precision here can't be overstated.

In the middle of a pristine lab, Isaac Neal, guidance navigation control engineer, and Barry Crow, electrical design engineer, make adjustments to a boxlike structure mounted on a three-legged stand. Two large lenses



protrude from the front end. Multiple wires connect to the back.

While it hardly looks threatening in appearance, Boeing's Compact Laser Weapon System represents the latest response to the increasing use of unmanned airborne systems in warfare situations. Developed for the U.S. Army Special Forces, the laser weapon can disable or bring down an enemy unmanned aircraft by destroying its camera, engine or aerodynamics. It shoots a silent, light-speed beam at a target, including from long range, and brings down unmanned aircraft in seconds.

"Small UAS (unmanned airborne systems) are a priority for us—our adversaries have them and bad actors within our borders have them," DeYoung said. "You can buy them with a high-definition camera at an electronics store for $1,200. The legacy we want is to get laser advances to our product, and get the product in the hands of the warfighter."

The Compact Laser Weapon System can be more easily transported across a battlefield and used than comparable weaponry, the engineers say. Just two people are needed to pick it up and load it onto a military vehicle. Setup time requires 10 minutes.

Added troop and civilian safety is a big motivator for these Boeing Albuquerque engineers to complete this project that is about two years in the making.

"If we can have just one more American soldier, airman or Marine come home safe, if we can lessen the civilian casualties by being more lethal, I think we've done our job," Crow said.

With customer feedback in hand, mechanical engineers Kurt Sorenson and Bryan Crespin apply upgrades to the Compact Laser Weapon System. The chief outside request: Build the equipment even more rugged in order to deal with different types of terrain and weather, plus troops packing it up in a hurry to exit a combat zone.

Users welcome controls that operate similar to those on a video-game console. They also appreciate the element of surprise the laser weapon guarantees, which is a strong selling point for the military.

"Even a kilometer or two away, it's stealthy," Crespin said. "People just don't know where it's coming from."

Elsewhere at Boeing Albuquerque, a team of engineers led by Juan Ceniceros, a former NASA employee, builds cameras and sensors for the Vision-based, Electro-Optical Sensor Tracking Assembly, or VESTA. This is part of the transportation technology that will guide Boeing's Crew Space Transportation vehicle, known as the CST-100 Starliner, in navigation and docking at the International Space Station.

"Not a lot of people can say, 'I build something that will help transport crew into space,'" Ceniceros said. "We push boundaries here. We do stuff that hasn't been done before. To be part of historic first events, it's a badge of honor."

Photos: (From left) Ahead of a laser system test, Boeing engineers Bryan Crespin, left, and Teresa Neudecker check atmospheric conditions in Albuquerque; mechanical engineer Kurt Sorenson ensures the Compact Laser Weapon System is ready for rugged terrain.

The engineers keep images of the astronauts who were selected to train to fly the first Starliner flight test posted on an office wall, reminding them of the human element involved in their work. They continue to refine two cameras and a processor that will work with lasers to track everything from the International Space Station to stars and algorithms for the Starliner, America's newest space capsule.

The crowning moment for the engineers will be watching the broadcast of the first Starliner flight that docks with the space station with a crew on board.

"Of the things that will be shown on TV, we will be responsible for them, and it's really cool to think about it," said Matt Beckmann, Boeing Albuquerque chief engineer for VESTA. "I've tried to explain to friends and family what I do, but it's not easy. They don't understand laser stuff."

Bruce Stribling, Boeing Laser & Electro-Optical Systems engineer and Technical Fellow, who previously worked at the Air Force Research Laboratory in Maui, Hawaii, heads up another Boeing team that is preparing space situational awareness and advanced tracking technology, which is similar in purpose to what Starfire Optical Range is testing, yet different in approach. Stribling and lead engineer Steve Hanes work on a complicated optical assembly atop an elevated table that holds a wide assortment of intricate parts.

They share a great sense of responsibility—their project carries national security implications.

"Building a strong light processor is the secret sauce," Stribling said. "That's how we detect real targets in space."

Mark Skinner, Boeing Albuquerque senior scientist, moves in a different direction when it comes to Boeing tracking options. He pursues commercial customers for available space-awareness data, proposing that every new commercial satellite have access to this protection.

Geosynchronous orbit is getting crowded, putting expensive assets at risk. Whereas space was once the exclusive domain of a handful of countries, more are developing technology and mulling space

Photo: As the sun sets in Albuquerque, Boeing engineers Tony Easley and Mark Kozemchak complete a pre-mission safety check before testing the gimbal of a sensitive optical system.

exploration, Skinner said.

Government agencies worldwide want safeguards for their space assets in what remains an unregulated environment, Skinner said. Boeing offers the interrelated use of radio frequencies, satellite dishes and telescopes to address this matter, sharing with the commercial sector existing technology that already supports military interests.

"We're convinced that the customer is ready to do things that matter in a cost-effective way," Skinner said. "It's an international kind of thing; we're working closely with people in Europe. It's a role Boeing can step into quickly."

Engineers and scientists feel a sense of urgency to test out their tracking systems and weapon concepts. The next step is to put these systems to use, enhancing national security and defense missions among other pressing needs, Boeing Albuquerque leaders say.

Maybe then, according to DeYoung, the lingering perception that lasers are somehow geared only for a futuristic world, that these narrow, colorful bands of light remain an untapped resource still years from making a difference, will diffuse.

"One of the comments attributed to laser weapons drives me crazy—that they're weapons of the future and they always will be," DeYoung said. "Lasers are available today. We're trying to break that paradigm, that mindset. It's now." ●

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Photo: Nuart Righetti monitors thin film deposition equipment used in the production of solar cells at Spectrolab.

BY DAN RALEY | PHOTOS BY BOB FERGUSON

Inside a cluster of tan buildings at the base of California's San Gabriel Mountains—and thousands of miles below most of the products it manufactures—Spectrolab's scientists, engineers, technicians and a one-armed robot form the world's largest producer of space solar cells and solar panels.

A wholly owned Boeing subsidiary, Spectrolab has provided electric power to more than 600 satellites and delivered more than 4 million solar cells for communications, science and defense needs. It is responsible for the solar panels that sustain the International Space Station and the planet-finder Kepler Solar Array, and for the electric power to the Mars rover Opportunity, which is still exploring that planet 12 years

Working on sunshine

Spectrolab employees are producing some far-out solar cells

after landing. Relying on Spectrolab solar cells, NASA's Juno space probe earlier this year reached a record 492 million miles (792 million kilometers) from the sun—the longest distance ever from the sun by a spacecraft using solar power. Its final destination is Jupiter.

Spectrolab is so ingrained in space it even captures the imagination of the people who work in its factory in Sylmar, Calif., which is northeast of Los Angeles. That includes Rina Bardfield, panel design and test engineering section leader. Her love for the TV series *Star Trek* led her into her profession. Spectrolab keeps her there.

"It's all science-fiction stuff, but it's what we do; it's a leaping point for sure," Bardfield said. "I get a little choked up when I stop to think about it—we do pretty cool stuff."

Spectrolab, founded in 1956 by recently deceased philanthropist and entrepreneur Alfred Mann, has three main product lines: solar cells, solar simulators and lighting. One business has led to another. The need to test the cells brought the simulators, which, in turn, created the illumination products. Today, Spectrolab provides

Photo: Tan Bui prepares substrate for solar cell bonding in the panel manufacturing area at Spectrolab.

80 percent of the helicopter-mounted searchlights used by U.S. law enforcement, according to the company.

A solar cell is a device used to convert sunlight into electricity. The cells are the building blocks that form photovoltaic modules, or solar panels. The International Space Station has 275,000 solar cells that generate up to 120 kilowatts, or about what it takes to power more than 100 households in the United States, the largest amount of power of any space vehicle in orbit.

"There is the opportunity for evolution, and at the same time revolution, to change people's lives for the better," said Tony Mueller, Spectrolab president, of the solar cell. "You have to be on your 'A game' every single day because you know it has to work."

At Spectrolab, solar cells are created in a chemical reactor, which looks like a 3-foot-diameter (1-meter) stainless steel tank. The process takes 90 minutes. At high temperatures, gases, metals and other materials form crystal layers on germanium wafers. In a fabrication laboratory, solar cells are cut from the wafers, the layers forming triple-junction structures, with each layer capable of receiving a different color of light. "We grow different kinds of crystal to absorb different parts of the solar spectrum," explained Jeff Krogen, senior director for photovoltaic metal organic vapor phase epitaxy, which describes the growth process.

Solar panels are sized to fit the needs of the space vehicle, which mostly involve communications satellites. Spectrolab shipped out over 200 solar panels in 2015, many of them going to international customers. The panels come with a 25-year reliability life. Spectrolab's most recent solar cell technology has a greater than 30 percent efficiency rate for turning each watt of sunlight into electricity—double what it was two decades earlier, according to the company.

In the factory high bay area, technicians work on rectangular orange and black panels, soldering or snipping wires, applying liquid adhesive and tape, and cleaning debris particles off the surface. Panels are mounted on stands and are flipped over with the turn of a wheel.

The work is so precise that Beth Chiodetti, a Spectrolab technician for 37 years, wears headgear replete with magnifying glasses and yet uses a separate hand-held magnifying glass, all to check solar panel connections. The goal for her and her colleagues is to build the solar panel right the first time in the factory, Chiodetti said. There is no room for error later on.

"The mantra of launching something into space is this: Once it's gone, you don't get it back," pointed out Chris Fetzer, chief engineer, epitaxy products.

The cells must be perfectly mated on the panels to be properly exposed to the sun. The panels have robust glass covers and are tested for electrostatic discharge, one of the largest causes of failure during testing.

Richard Smith, a 15-year Spectrolab technician, keeps track of everything he does on a color-coded paper taped to the panel. He makes sure all wires are soldered to tabs. He calls out a warning to others as he flips a panel over.

"I'm very proud of the work that we do," he said. "My name is on some of the stuff that's on the Mars Orbiter and the Kepler satellite."

Depending on size, panels are completed in four and a half to six months. They need to be tested on- and off-site. They leave the factory packaged in a variety of containers, everything from metal crates to wooden boxes, wrapped in foam and shock mattresses.

Spectrolab continues to look for ways to make panel production less time-consuming and more economical. That might involve finding new methods or applications to shave days or even weeks off the process. The 300-person Spectrolab team is highly skilled and experienced, said Jim Hanley, senior director, solar panel operations.

"We're around the periphery of space power," Hanley said, standing in a room filled with 36 solar panels. "Nothing gets done here without it being done right."

Separate solar cells are either shipped directly to the customer after testing or assembled into CICs, which stands for Covered Interconnected Cells. Spectrolab uses a robot to

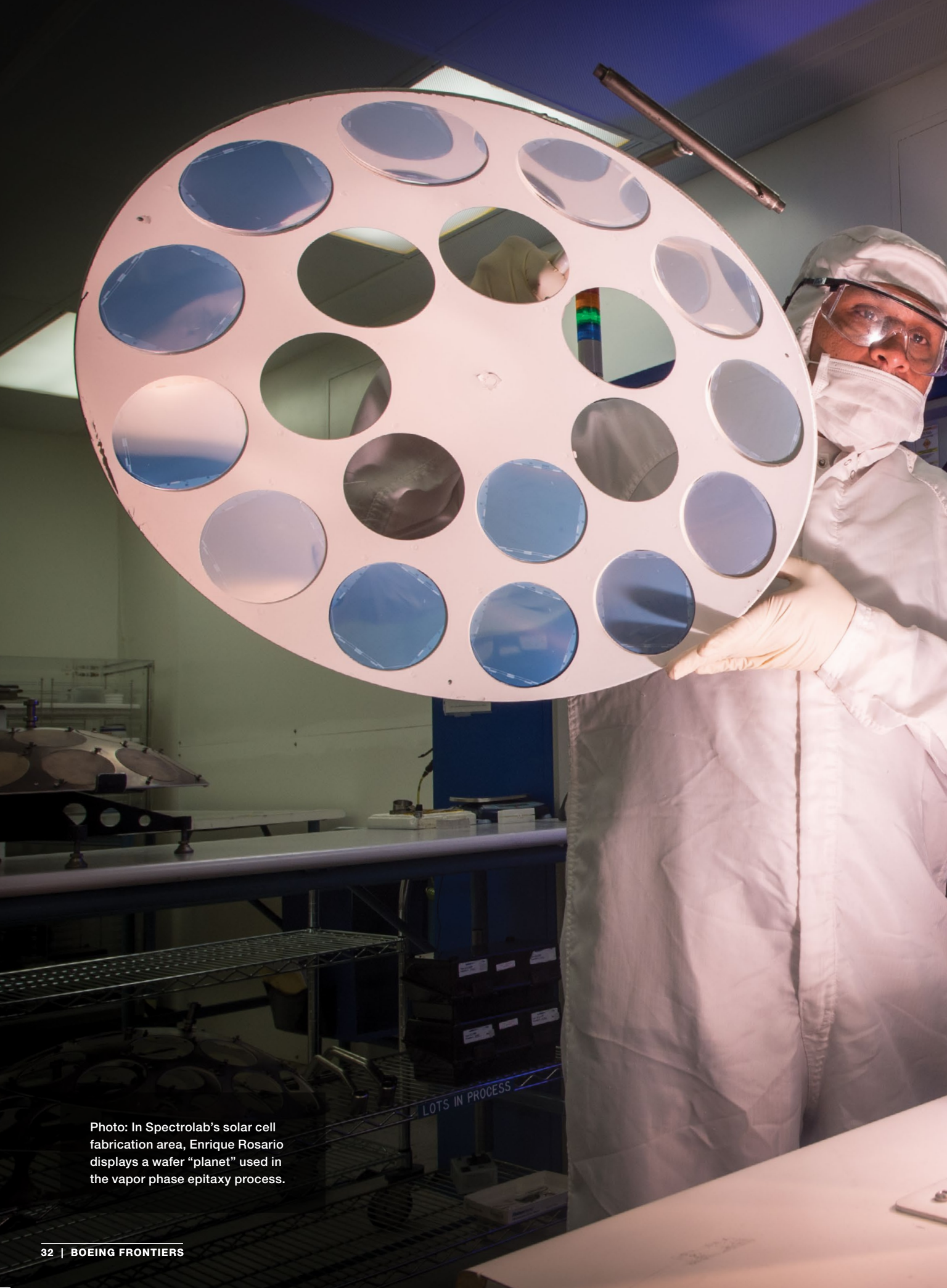
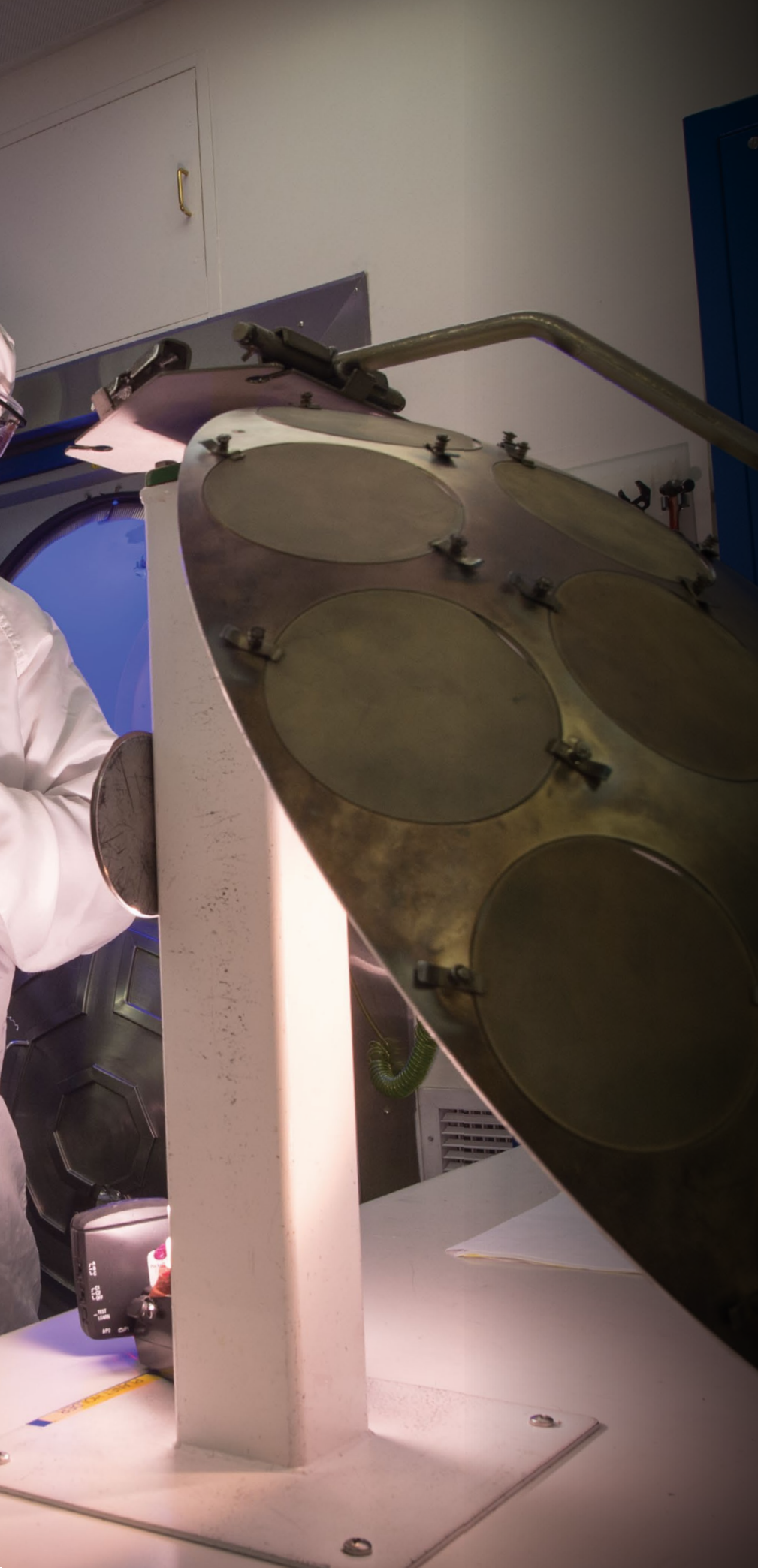


Photo: In Spectrolab's solar cell fabrication area, Enrique Rosario displays a wafer "planet" used in the vapor phase epitaxy process.



perform the latter chore.

Twenty hours a day inside a large glass case, the half-body robot methodically picks up a cell, welds and mounts it to space-grade glass, attaches a diode (which is an electrical component) to the back, and places the CIC in an area for human inspection.

"We call it Susie," said Jose Gonzalez, an assembler, of the one-armed space auto welder.

Spectrolab's lighting business is housed in a building adjacent to its solar technologies. The company has been selling helicopter searchlights since the Los Angeles Police Department first used one in 1968, and has spun off solar technologies ever since, said Luis Castro, business development manager, illumination and sensor products.

While Spectrolab eventually wants to illuminate everything on a Boeing aircraft, from cabin lighting to landing lights, it also is developing Spectroscan, a form of Lidar, which stands for light detection and ranging, Castro said. Spectroscan is a radar-like camera with 3-D imaging. In the future, it is hoped the camera will enable autonomous tasks in the simplest form, helping map cargo loading on an aircraft, scanning runways for foreign object debris—even guiding driver-less cars, according to Castro. "It will change the way many things can be done," he said.

In July, Spectrolab will reflect on its 60 years of operation while Boeing celebrates its centennial. For the two companies, it will be a month of milestones. Each will reflect on past accomplishments and look hard at the future, noted Mueller, Spectrolab president.

For Spectrolab, a Boeing subsidiary since 2000, it will continue to focus on core satellite and deep-space exploration markets while also diversifying its business with illumination and sensor products, Mueller said. "We're in a business where there's going to be a continual evolution of technology, he said. "We must always be mindful of what our customers need and when they need it. We can't rest on our legacy." ●

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Little GIANT

Given its pedigree, Little Bird looks to have a big future

BY ERIC FETTERS-WALP

Boeing's newest attack helicopter is known by its nickname and smaller size compared with the AH-64 Apache—but those attributes don't define the AH-6 "Little Bird."

The light attack and reconnaissance helicopter has a pedigreed background. U.S. Special Forces have used a variant of the AH-6 model for years, and the model's heritage can be traced back to a helicopter first developed in the 1960s.

The Little Birds that Boeing is building now may look similar to their predecessors, but today's version is substantially more capable. The AH-6 flies higher, goes faster, and carries more payload, said Josie Woody, AH-6 program manager.

"There's a significant payload capacity, and it can be used as a light-attack aircraft, for reconnaissance, search and rescue," Woody said. "It was built for the mission, with a lot of technology, flexibility and affordability."

Todd Brown, chief test pilot for the AH-6 program, said the helicopter boasts the highest power-to-weight ratio in its class, making it well-suited for a variety of uses, from direct combat actions to security and escort flights.

"It's very agile. It has a very powerful engine, so it's very maneuverable and quick," Brown said. That helps when providing close-range support for ground troops and operating in crowded urban settings. The AH-6 also performs well in hot and high-altitude locations, according to program officials.

Those demonstrated capabilities already have attracted customers, and a production line is up and running at Boeing's rotorcraft assembly factory in Mesa, Ariz. The first production AH-6, one of 24 ordered by a Middle Eastern ally, is expected to fly soon.

David Renteria, Final Assembly manager for the AH-6 program, has plenty of experience building the Apache helicopter. He said lessons he and others learned from assembling the AH-64E model have been invaluable on the new Little Bird line.

"We're learning on a daily basis," Renteria said. "This is a totally different build process, but we can implement best practices and Lean initiatives learned on the Apache line and apply them to this new production line."

The production line team, which is running two shifts at present, recruited talent from the Apache line and took other steps to start strong. "They have done everything possible to make it

Photo: The AH-6 Little Bird helicopter has completed developmental flight testing and is now in production at Boeing's rotorcraft factory in Mesa, Ariz. BOEING

Photos: (From left) The AH-6 airframe, seen on the Mesa production line, is designed to protect the cockpit crew in combat and other missions; employees work on the AH-6 production line. BOB FERGUSON | BOEING

successful," Woody said.

With a rounded cockpit, smaller frame and T-shaped tail stabilizer, the AH-6's differences from the larger Apache are evident at first glance. But the two models share many common systems, especially evident in the weapons management and cockpit control systems. "They look almost identical in the cockpit," Brown said.

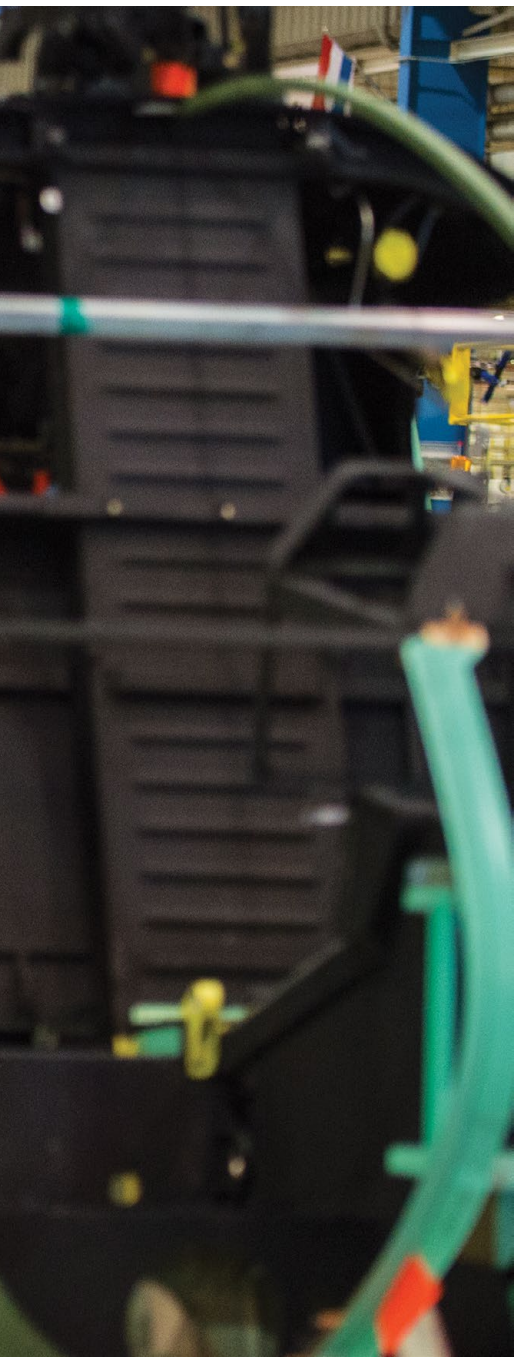
That commonality is a benefit for military forces that already fly the Apache and have pilots familiar with its cockpit systems. And smaller militaries aren't in the position to procure the Apache can still benefit from the AH-64's advanced technology for weapons management, obstacle avoidance and other systems in a smaller, less expensive rotorcraft, Woody said.

The helicopter is able to carry Hellfire missiles, laser-guided rockets and guns of several calibers, aided by sensors and targeting systems that are tied into the pilot and co-pilot's cockpit controls.

The AH-6 has a range of 179 nautical miles (206 miles, or 331 kilometers) and a maximum cruise speed of 125 knots (144 mph, or 232 kilometers per hour), as well as the ability to fly well at extremely low, "nap-of-the-earth" altitudes to avoid detection.

In addition to the existing launch order, Woody said the helicopter has attracted interest from militaries in Europe, Latin America and the Asia Pacific region. As the first production models start flying, she and others in the program expect more potential customers will order the aircraft.

With developmental flight-testing of the Little Bird complete and production



underway, the test pilots in Mesa are preparing training for the first customer pilots. Renteria said he can't wait to see that first production model of the AH-6 Little Bird take its initial flight. For now, he's enjoying the challenge of a new production line after a couple of decades with the Apache program.

"I get to start a new program and see it through its infancy," he said. "And to see the first ones on the production line, that's a different feeling… it's exciting." ●

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Photo: The 400th Next-Generation 737-800 jetliner to join Ryanair's fleet passes over a mountainous region of Greenland on its nonstop flight home to Dublin from Seattle.
BOB FERGUSON | BOEING

Special delivery

Take a ride on Ryanair's 400th Boeing 737 as it is delivered from Boeing to Dublin

BY DAN RALEY

A Ryanair 737-800 jetliner touched down in the late afternoon at Dublin Airport early last month, culminating a journey that proved more remarkable than it was routine.

The flight represented a milestone moment—the Irish airline, a steady customer since 1999, was taking home its 400th Boeing 737-800.

The Ryanair jetliner ended up in Europe just 33 days after it first entered Boeing's Renton, Wash., factory, right on schedule and once more demonstrating the rapid movement of the 737 production line.

The 400th 737-800 traveled nonstop from continent to continent, usually something only the bigger jets do. On this trip, the milestone airplane covered 4,300 nautical miles (4,950 miles, or 7,960 kilometers) in 9 hours, 24 minutes, passing just below the Arctic Circle and over sparsely populated northern Canada, Greenland and Iceland at 41,000 feet (12,500 meters). At times it was out of radar range, requiring the pilots to communicate their position the old-fashioned way—at designated points over high-frequency radio.

Other than the pilots, the only passengers were a photographer and writer for *Boeing Frontiers* magazine.

Ryanair pilot Brendan Davis holds

the distinction of flying the first Boeing 737-800 delivery airplane back to Ireland in 1999 and now the 400th. He's been on dozens of these flights. The novelty has worn off, but the significance of the latest milestone was not lost on him.

"It's a big deal," Davis said. "It's all good with this airplane."

Once the 400th was on the ground in Ireland, there was no time for further celebration. Just as Boeing remains on a fast track to build airplanes, Ryanair is in a big hurry to use them. After the jet was towed into a Dublin hangar, the pilots were barely out of their seats when a half-dozen Ryanair technicians boarded and began installing equipment that would allow the airplane to be put into service in as little as 24 hours.

Michael O'Leary, Ryanair chief executive officer, said he prefers the 737 to be his flagship airplane because of its reliability. By 2024, the Irish airline plans to have more than 500 737-800s and 737 MAX airplanes in its all-Boeing fleet, according to O'Leary.

The Dublin-based carrier has ordered 100 with options on an added 100 737 MAX 200s, a variant that can accommodate up to 200 seats.

How the 737 airplanes come together so quickly on the assembly line—42 per month now, 57 monthly by 2019—remains a manufacturing marvel even to the people who fly them.

"It's amazing how little time it takes to build them," said Ryanair pilot Mark Logan, who shared the milestone flight with Davis. "It was nice to do the 400th; it was nice to bring that one back."

The 400th plane was in factory production for just 10 workdays, in a Renton paint hangar for three days, and in preflight testing, flight testing and Federal Aviation Administration certification at Seattle's Boeing Field for the remaining two and a half weeks.

Early on the morning of Feb. 29, the process began when the Ryanair jetliner entered the Renton factory somewhat anonymously, as they all do—as a bare fuselage delivered by train from Wichita, Kan., covered in a green coating that protects against corrosion. Lifted by crane to an upper bay, the airplane was indistinguishable from any other nearby 737 shell except for a four-digit number stenciled in multiple places on the exterior: 5843. This represented its place in the lineage of the Next-Generation jetliners, which encompasses all 737-600 to -900 models.

The Ryanair fuselage was mounted on tracks and pulled through the upper production line for the next three days while it quickly began to take airplane shape. Different crews performed different jobs. Insulation blankets, hydraulics and miles of electrical wires were among the items installed.

One assembler and mechanic had to lie on his back on a movable yellow mat in a tight space in order to reach up and attach wiring directly below the flight deck. He said it was amazing to think that someone would be seated in

the overhead space in just a few weeks, operating the airplane.

On March 4, the airplane was lowered by crane to the factory floor and placed on three sets of lifts, ready for the wing installation. Winglets carried the Ryanair name, the first tangible confirmation of the airplane customer. The wings were moved into position at 5 a.m. The work was radio- and digitally controlled.

"The wings are guided in by computer," Rich Vossler, a 38-year mechanic, explained. "A laser shoots targets and measures all the points. We work on it every day and we don't realize all the stuff we do to make this happen."

At 6 a.m., a half-dozen mechanics outfitted in protective eyewear, white surgical masks and blue jumpsuits stood side by side. They simultaneously drilled holes in an upward and furious motion. Metal chips flew and drill-gun mist formed.

Fasteners were inserted as soon as the holes were ready. One wing installation took an hour. These factory workers could have passed for emergency-room surgeons for the way they scurried about this patient.

"It's probably the most important part of the factory—it's the heartbeat," said Tony Naylor, a wing-to-body join mechanic. "It has to be precise. We're airplane doctors."

On March 9, the jetliner moved to the third floor position from the huge factory door. Engine installation was next. Most of the seven-man crew came dressed in blue Boeing T-shirts, wearing what they called their "Ryanair" colors to salute the moment.

Among them was Al Lind, a 28-year engine join mechanic and one of the more experienced guys at this juncture of the production line.

"People ask me what I do for a living: I tell them I hang engines," Lind said. "I've done over 5,000."

When it came time to do their job, Lind and the others pulled on surgical gloves. Engines mounted on wheeled platforms were moved into position near the wing with a remote control. Once everything was lined up, two mechanics guided the engines and attached them using four large bolts and four small bolts, lubricating each one before installing.

The mechanics applied three stages of torque, loudly calling out numbers as functional test inspector Tom Boyle, a 28-year Boeing employee, closely monitored the work, in some instances using a flashlight.

Each engine went up in a half-hour. Everything ran smoothly, with the mechanics deftly exchanging tools with others when needed, much like someone trading surgical instruments. Indeed, like airplane doctors.

"I could hold out a tool without looking and somebody would take it," said Sean Patrick Keenan, a nine-year engine mechanic. "It's a total team effort."

T-shirts aside, the production line crew was no stranger to Ryanair jetliners. Justin Kimball, a fuel cell sealer, has worked on more airplanes

Photos: (From far left) On the production line Renton, Wash., mechanic Michael Emsley tightens bolts during main landing gear installation for the 400th 737-800 delivered to Ryanair; wings are moved into place, ready for installation, on the jetliner's fourth day in the factory.
MARIAN LOCKHART | BOEING

Photos: (From left) Ryanair delivery manager Joe Ryan, left, and Boeing customer engineer Maryam Assary inspect the interior of the Irish airline's 400th 737-800; the Ryanair jetliner awaits delivery at Seattle's Boeing Field, with Mount Rainier in the background, before its nearly 10-hour flight to Ireland.
BOB FERGUSON | BOEING

headed to the Irish airline than any other in his year at Boeing.

"This plane is going to be in the sky, holding people, so you have to put 110 percent into it," Kimball said. "It's kind of amazing to think my planes are flying."

Factory assembly of the Ryanair jetliner finished two days later. The plane was parked outside until it could be painted in the airline's colors, with the Ryanair name in big, blue letters and its logos of an interspersed harp and angel in different colors.

Ryanair routinely brings its pilots to Seattle on six-week rotations to test and accept the new jets and eventually fly them home on the delivery runs. Fabian Schone, a 10-year Ryanair pilot based in Italy, flew the 400th and pronounced it fit for service. He steered it along the ocean coast, performed takeoffs and landings at Paine Field in Everett, Wash., and never strayed farther than 80 miles (130 kilometers) from the Seattle area.

"To me, the 737 is a perfect airplane," Schone said. "It's very reliable with all the modern automatics necessary for a safe operation but still a pilot's plane, which you can fly manually very well."

On March 31, Ryanair's 400th jet gently lifted off from Boeing Field for its overnight flight to Ireland following a casual dinner that involved Boeing and Ryanair employees eating with the pilots and everyone posing for group photos with a commemorative banner outside the airplane.

Joe Ryan, Ryanair's Seattle-based delivery manager, was among them. He's witnessed his share of airplanes changing hands. He anticipates he'll see quite a few more.

"When I started here two years ago we had the 350th delivery and we were getting two planes a month," he pointed out. "It's eight now." ●

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BY ASHLEY JOHNSON

U.S. Navy Cmdr. Brian Sinclair feels like he grew up with the Harpoon missile strapped to his wing.

He started his naval aviation career flying an S-3 Viking anti-submarine warfare aircraft armed with the Harpoon, the all-weather anti-ship missile system developed by Boeing heritage company McDonnell Douglas. Back in 2000, Sinclair said, he became familiar with the Harpoon 1C variant—it would zero in on the first target it saw.

That all has changed with the new Harpoon Block II Plus, which adds a data link, GPS guidance and updated aircraft interface, providing the U.S. Navy with a rapid-capability enhancement. The network-enabled variant can receive and transmit communication while in flight, allowing it to change course to strike a different target, even a moving target, according to Boeing.

Those in-flight target updates, Sinclair said, turn Harpoon into "a more precise surgical tool. I see it as a very accurate, very flexible weapon that will actually redefine the war-at-sea tactics for the Navy."

In November 2015, Boeing and the Navy flight-tested the new version. After launching the Harpoon from an F/A-18, the crew input new coordinates to redirect the missile to hit a moving target. It did.

After watching the flight test, Boeing Guidance and Control Technical Lead Engineer Bill Sanders said he was in awe of the performance. "It was spectacular," he said. "When we got down to the end of this test we realized, 'oh, my goodness, we just checked off this, this, this, this, this, this in one fell swoop.'"

The Harpoon program has consistently adapted to match evolving threats over decades, according to Boeing. The newest Harpoon is being integrated on Boeing's new P-8A Poseidon maritime patrol aircraft, and there are plans for developing an extended-range option to double the reach of the weapon.

The Harpoon is built by Boeing employees in St. Charles, Mo. "The Harpoon program tells a great story of partnership and iterative innovation," said Beth Kluba, vice president of Boeing Weapons & Missile Systems, part of Defense, Space & Security. "It's a global strike asset that continues to advance and outpace today's threats through some very impressive and very affordable upgrades."

Previous versions of the missile can be retrofitted with the latest technology and new capabilities.

Harpoon is deployed by 29 international customers on more than 600 ships, 180 submarines, 12 types of aircraft and several land-based launch vehicles.

Jim Brooks, director of cruise missile systems weapon programs for Global Strike Weapons & Missile Systems, pointed to quality and reliability being hallmarks of the missile. Each updated version has demonstrated more than 90 percent reliability in fleet exercises, according to Brooks.

Target acquired

Latest version of the Harpoon missile has advanced networking capabilities and can be redirected in flight

"It's a very reliable and capable weapon system, and it's due to the dedication of those people out in the factory and depot who are making it happen with their engagement and attention to detail," Brooks said of the St. Charles production facility.

Sanders also credited the program's success to the dedication of generations of Harpoon employees.

"We're literally standing on the shoulders of giants," he said. "The thing that I think that we're most proud of … is that we've taken the existing system and we've integrated this new capability in a way that retained so many of the proven capabilities and methods while also addressing today's threat." ●

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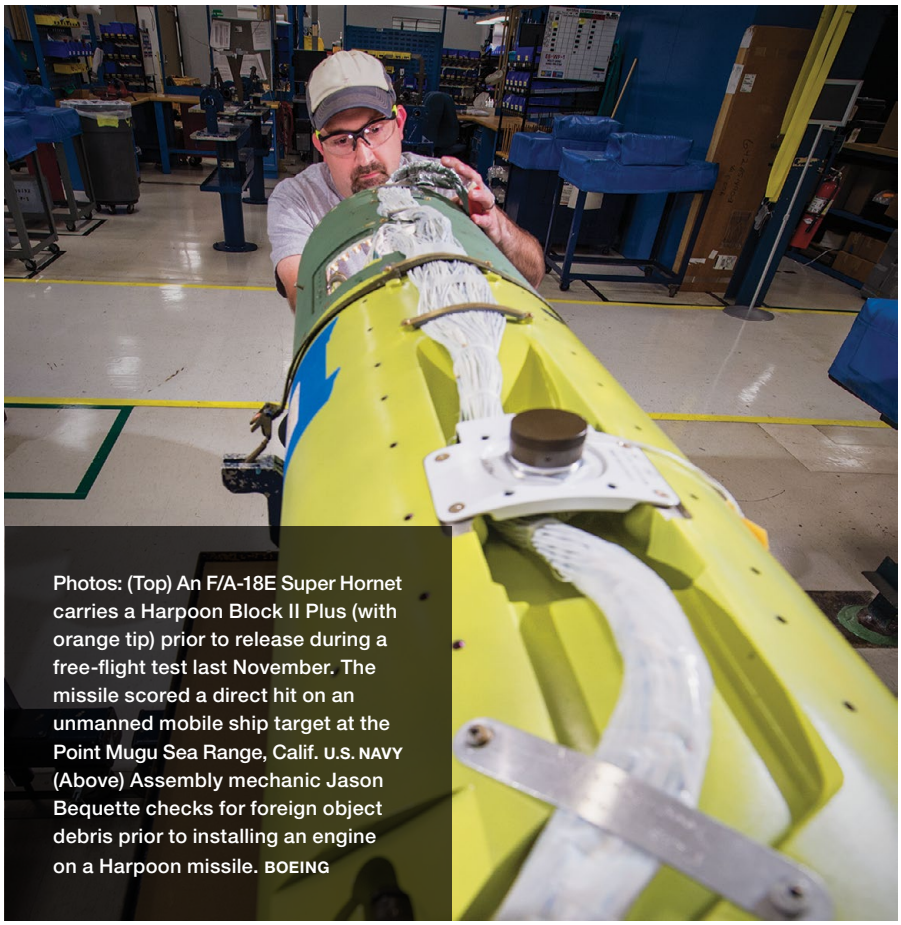


Photos: (Top) An F/A-18E Super Hornet carries a Harpoon Block II Plus (with orange tip) prior to release during a free-flight test last November. The missile scored a direct hit on an unmanned mobile ship target at the Point Mugu Sea Range, Calif. U.S. NAVY (Above) Assembly mechanic Jason Bequette checks for foreign object debris prior to installing an engine on a Harpoon missile. BOEING

Leading edge

Among his many accomplishments, Frank Shrontz oversaw launch of the 777 program

BY DAN RALEY

As Boeing approaches the start of its second century in July 2016, *Frontiers* visits with some of the men and women who have helped make Boeing a global leader in aerospace.

Frank Shrontz initially planned to skip college. He was content to stay home and work in the family's sporting goods store in Boise, Idaho.

However, his father convinced him otherwise—that he needed to see what the rest of the world had to offer, that there was more to it than bicycle sales and lawnmower repairs.

Shrontz was found to have great business acumen after receiving an education as credentialed and comprehensive as any: He earned a law degree from the University of Idaho and a master's degree from the Harvard Business School. Later, he was a Sloan Fellow at the Stanford Graduate School of Business Administration.

That this all could have gone unrealized by the future chairman and chief executive officer of The Boeing Company was due in part to the Idaho native's modest nature. Shrontz was grateful for getting a nudge in the right direction.

"I can't say I had grand plans as a kid to head up an aerospace company, but it developed and I'm glad it did," he said.

Shrontz became the sixth Boeing CEO in 1986 and served in that capacity for a decade. Mike Lombardi, Boeing senior historian and archivist, said Shrontz provided strong business discipline as the company expanded globally. He oversaw the launch of the 777, encouraged a greater emphasis on production quality and efficiency, and was largely responsible for Boeing's first ranking among the top 10 of the Fortune 500's most admired companies.

As Boeing prepares to celebrate its centennial, Shrontz is among the many men and women who have made milestone contributions to Boeing or its heritage companies. Lombardi said Shrontz is considered one of Boeing's most respected and influential leaders.

"He completely redid the business of Boeing and redid the culture in several ways—in particular, he led great change," Lombardi said. "He was a man of tremendous ethics and flawless character, and it had a big impact on our airline and government customers. He made the company a leader with a bigger focus on quality. It's still reflected in every airplane we build today."

Following a stint in the U.S. Army as an artillery officer, Shrontz received his Harvard MBA and joined Boeing in 1958. He chose the airplane-maker over Eli Lilly & Co., an Indianapolis-based pharmaceutical firm that employed him as a summer intern. Shrontz said he was intrigued by the aerospace business and wanted to return to the northwest U.S.

He assisted in Boeing contract negotiations. And he caught the attention of commercial airplanes leader Bruce Connelly and then–Boeing chairman and CEO T. Wilson, who mentored and promoted Shrontz. Wilson nominated Shrontz for a Pentagon job, which turned into a four-year congressional appointment as assistant secretary for the U.S. Air Force and assistant secretary of defense.

Returning to Boeing in January 1977, as corporate vice president of Contract Administration and Planning, Shrontz subsequently held a series of top leadership positions.

From September 1978 until May 1982, he was vice president and general manager of the division for 707, 727 and 737 jetliners, and in April 1984 he became president of the commercial airplanes organization. Less than a year later, in February, he was named president of The Boeing Company, and served as chairman and chief executive officer from April 1986 until April 1996.

Shrontz preferred a leadership style different from his more autonomous Boeing predecessors, surrounding himself with a management staff that he roundly encouraged to make its own decisions, according to Lombardi. He was known for stressing an

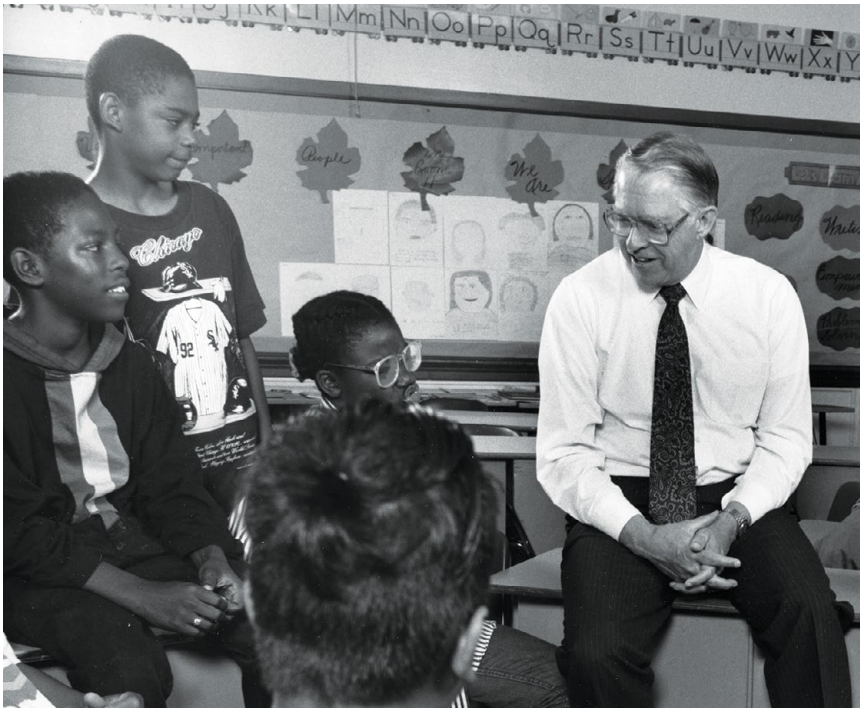
Photos: (Above) Frank Shrontz retired as chairman and chief executive officer 20 years ago. **MARIAN LOCKHART | BOEING** (Below) Shrontz, urged to attend college by his father, in turn encouraged students to follow their dreams. **BOEING ARCHIVES**

ethical approach at every turn.

"I'm convinced it's up to a company to be ethical in every way," Shrontz said. "When it's not, it has all sorts of problems; the customers have questions whether they can trust you and the employees are dissatisfied. I also think integrity is important for the career of a senior executive. My father had something to do with my ethical preoccupation. He was very ethical in every way."

It was Shrontz who set in motion the development of what would become the highly successful 777, Boeing's first airplane designed entirely on computers. Significantly, it also marked the first time the company integrated the design-build process.

John Roundhill, who led commercial



Product Development at the time, recalled that Boeing engineers were initially considering various options to stretch the 767, rather than developing an all-new airplane.

In the fall of 1988, Roundhill and other commercial managers attended an executive meeting to review plans for the jetliner program to follow the 767. Shrontz was the Boeing chairman then, and during the meeting Shrontz asked why they were not considering an all-new airplane, Roundhill recalled.

"That was the turning point," Roundhill said of what became the 777, a program officially launched in 1990.

As important as the 777 program was, Shrontz said his greatest satisfaction was with the 737 programs.

"I had a keen interest in the 737 program from its inception until I retired," he said.

"I always thought it was a great airplane, but there was a time when people wanted to let it go. It was not as competitive at first, but the more we worked on it, the more we got it competitive. I kind of took it on as my own interest and actually ran the production division at one time. We got the program on solid footing. In hindsight, the decisions were right."

The 737 was developed in the 1960s. First flight was in April 1967. Boeing launched development of the Next-Generation 737 in the 1990s, when Shrontz was chairman and CEO.

Today, Boeing employees are producing more than 40 737s a month at the Renton, Wash., factory. Rates are scheduled to go even higher. From a shaky start, with orders coming for only one or two airplanes at a time, more 737s have been delivered over the years than any other commercial jetliner. Another version, the even more fuel-efficient 737 MAX, is now in flight test. (See story, Page 12.)

Shrontz welcomes the 737's accelerated production rates. He's amazed Boeing can roll out as many airplanes as it does in a singular facility. He said he always found great pleasure in watching an airplane come off the assembly line.

Twenty years after stepping down as Boeing chairman and CEO, Shrontz lives in Seattle. He travels occasionally and serves on nonprofit company boards. He watches Boeing leaders operate from afar, and while acknowledging the competitive challenges facing the aviation world, he thinks the company is in a good place.

"I have no regrets except one or two minor ones, like the short-term purchase of de Havilland of Canada," Shrontz said of his time leading all of Boeing. "I had a good career. The company was good to me."

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Photo: Frank Shrontz, far right, greeted test pilots John Cashman, foreground left, and Ken Higgins after the first flight of the new 777, on June 12, 1994. BOEING ARCHIVES

Photo: Air Europa's first 787-8 awaits delivery at the Boeing South Carolina factory. CAPS

Growing with the Dream

Air Europa is the first airline to operate the 787 in Spain

BY KEELAN MORRIS

When Air Europa began scheduled operations in 1993, it started in direct competition with Iberia on the Madrid-Barcelona route, taking on the challenge to break the monopoly of Spain's national airline.

Today, Air Europa serves more than 40 global destinations through a modern mixed fleet of nearly 50 airplanes—including its first 787-8 Dreamliner, delivered in March. With 21 additional Dreamliners on order, the airline says the twin-aisle jet is key to its ambition to challenge Iberia's market share.

The Dreamliner order, the only to date that has been placed by a Spanish carrier, has repositioned the airline, based in Palma, Mallorca, for the long term as it transitions to an all-Boeing widebody fleet in the coming years, according to Juan Jose Hidalgo, owner and president of Air Europa.

"We started out with the aim to challenge the competition on a single route—as we have grown, so has our ambition," he said. "The delivery of our first 787 is the result of that ambition, and it is the airplane that we believe will grow this airline and drive our expansion into Latin America and the Caribbean."

Air Europa's story is intertwined with that of its charismatic owner, who purchased Air Europa in 1991. Hidalgo started his leisure travel business in 1960 using buses to take Spanish tourists to holiday destinations in Europe. Today, Hidalgo presides over one of Spain's largest travel companies, which includes hotels and travel agencies as well as Air Europa.

"I started out with a fleet of buses," Hidalgo said. "Over the years I acquired a fleet of airplanes, and today I have the most modern jet in the industry—the 787. We are deeply proud that we are the only carrier flying the Spanish flag on the 787."

Air Europa's new Dreamliner is already in service to Miami, debuting the airline's redesigned livery and new business-class cabin. New routes to Latin America are planned this year as the airline takes delivery of three more 787s.

Before adding the Dreamliner to its fleet, Air Europa had taken delivery of 27 Boeing airplanes—all 737s.

"The 737 has been an important aircraft in helping us challenge the domestic market," Hidalgo said. "The 787 will position us to do that in the international market now. Air Europa and Boeing have a strong relationship, going back to our first order in 1999, and Boeing will be our supplier for many more years to come." ●

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Ageless warriors

Two U.S. Air Force B-52s from Barksdale Air Force Base, La., arrive at Al Udeid Air Base, Qatar, last month in support of Operation Inherent Resolve in the battle against Islamic State forces. The drag chutes are deployed to slow the large bombers after landing. According to the Air Force, the B-52 offers diverse capabilities for the mission, including the delivery of precision weapons. The B-52 made its first flight on April 15, 1952, and has been continually upgraded to meet evolving threats. **PHOTO: U.S. AIR FORCE**


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