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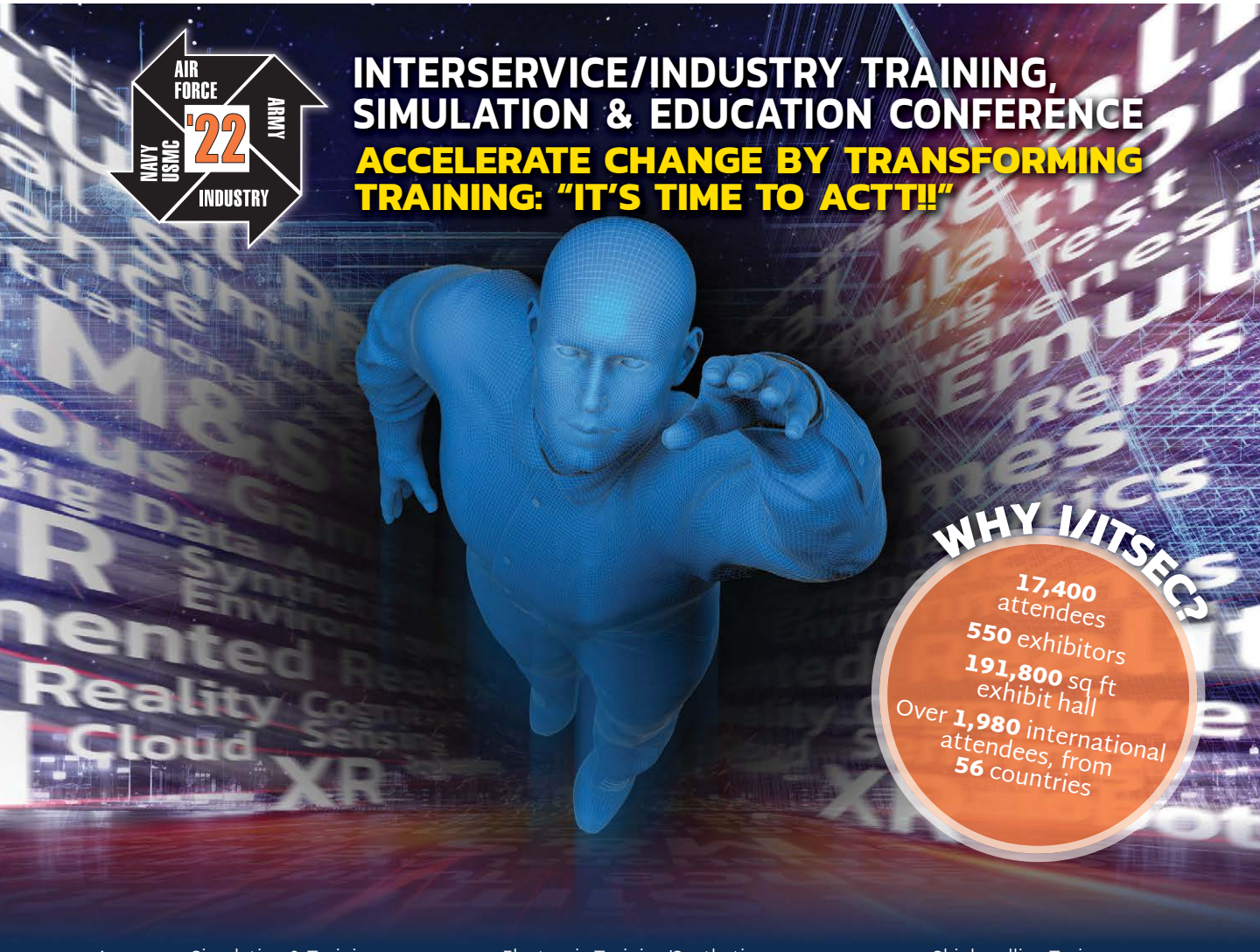

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ON THE COVER

Boeing's long-running ecoDemonstrator initiative now plays a key role in the company's research and development plans as it strives for sustainable and net-zero-carbon operations. Senior Editor Guy Norris reviews the work planned for the latest aircraft in the series—a 777-200ER—and associated recent sustainable aviation fuel tests with NASA, while Executive Editor for Technology Graham Warwick evaluates Boeing's sustainability strategy. Boeing photo by Paul Weatherman.

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FEEDBACK

ELECTRIC DREAM

As a 30-year pilot flying small, leaded-gas-burning airplanes, I have an insight to share with the aviation community. We have watched as the work to remove lead from aviation fuel has progressed oh-so-slowly. But it looks like we have a workable solution now *(Check 6 "Podcast: Power Progress—New Engine Technologies Update," Oct. 13)*. My family and I are exposed to this more than anyone, by the way, so it's really important to me.

I expect the process of removing lead will take 8-10 years. During this time, we will see the development and wide availability of affordable electric motors and the batteries that drive them as a wholesale replacement of gasoline as an aviation fuel. Within 10 years, we will have batteries that can duplicate the performance of gas-powered small aircraft.

Electric motors are inherently safer than gas-powered ones—and quieter. Any airplane burning gasoline is a potential candidate.

The U.S. alone has a huge fleet of small airframes not flying because of powerplant costs. This could make flying a small airplane safer and affordable again! A Cessna 172 with a 190-hp three-blade electric motor would finally turn that little safe airplane into what it always dreamed of being—or what I dreamed of.

Luke Banks, Mason, Ohio

NOT EQUIVALENT

I'm a recently retired military and major airline pilot. Having spent three years as a pilot recruitment interviewer, I have been following the recent attempts by Republic Airways to lower the required hours for its pilots to obtain an airline transport pilot (ATP) license *("Fast Five: Republic Airways President and CEO Bryan Bedford" Sept. 26-Oct. 9, p. 38)*. One of the factors that Republic claims validates its request is that "Republic's pilot training is equivalent to military pilot training."

That claim is incorrect for a simple reason. "Military trained" pilots do not finish up their one year of basic pilot training and then go directly to the airlines. The current military pilot commitment after training is 10 years. Thus, the soonest a military pilot can apply to the airlines is after four years of college and 11 years of military flying.

GUY NORRIS/AW&ST

There is no requirement for a college degree to qualify for an ATP license, so a civilian Republic Airways candidate could potentially get hired at around age 20 with 750 hr. of primarily light general aviation aircraft flight experience. That may very well be sufficient, as several European airlines have successfully placed 250-hr. pilots in the right seat of their airliners. However, that is not equivalent to a 33-year-old military pilot with 5,000 hr. of C-17 time, involving numerous night air-to-air refuelings, beaming out across the Indian Ocean from Djibouti to Diego Garcia, and landing a 500,000-lb. aircraft on a blacked-out gravel runway at night in the mountains of Afghanistan.

Robert M. Steven, West Yellowstone, Montana

BOOST THE BOARD

The four former NTSB chairs correctly state in their recent Viewpoint "Safeguarding Space" *(Sept. 12-25, p. 66)* that the NTSB's leadership in investigating space accidents will benefit commercial space operations and the American public, even though the NTSB recently had to ask the FAA for travel funds to attend a space conference.

It is well-known that the NTSB is significantly understaffed and marginally funded for the tasks it presently has. To the credit of the NTSB, the FAA, commercial aviation operators and the aircraft OEMs, it has been 13 years since the last major fatal commercial aviation accident in the U.S. But every year, well over a thousand general aviation accidents claim hundreds of lives and overburden the NTSB's aviation staff.

For the five-year period from 2016 to 2020, there was an annual average of 1,217 general aviation accidents with 369 fatalities, according to NTSB statistics. Investigating these accidents, issuing final reports and making recommendations to reduce similar accidents took more than 12-18 months.

Repeated recommendations to the FAA to mandate flight-data-recording devices for general aviation have been ignored, despite the availability of very small, very low-cost recorders that leverage "smartphone" technology. Such recording devices would drastically reduce both the time and manpower needed to determine causal factors accurately and quickly and recommend mitigations to reduce the horrendous loss of lives and aircraft.

It is worth noting that the current board has only four of the five authorized board members because successive administrations have historically ignored the importance of having a full board, with three of the five members technically competent (i.e., engineers, mechanics, experienced pilots, etc.).

If the NTSB takes on additional functions related to exploration and commercial use of space, it will need additional staff with special, relevant, technical skills and additional funding.

Dick Healing, Lewes, Delaware, and John Goglia, Ashland, Massachusetts, former NTSB board members

CORRECTION:

"10 Programs Shaping the Future of the U.S. Air Force" *(Sept. 12-25, p. 49)* should have stated that the General Electric F110-GE-129 engine was selected to power the F-15EX. It should not have connected the engine type to the ability to carry more weapons.

Address letters to the Editor-in-Chief, *Aviation Week & Space Technology*, 2121 K Street, NW, Suite 210, Washington, DC, 20037 or send via email to: **awstletters@aviationweek.com** Letters may be edited for length and clarity; a verifiable address and daytime telephone number are required.

FIRST TAKE

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DEFENSE

Northrop Grumman will unveil the B-21 Raider, the U.S. Air Force's new stealth bomber, on Dec. 2 in Palmdale, California. Six B-21s are in production inside Northrop's facility in Palmdale.

A group of 15 nations led by Germany has signed the European Sky Shield Initiative to strengthen ground-based air defense capabilities using off-the-shelf systems.

U.S. and international partners are focused on providing an integrated air defense system to Ukraine in the wake of a barrage of Russian attacks (page 36).

North Korea claimed successful launches of two long-range cruise missiles on Oct. 12.

Malaysia has selected the Leonardo ATR72 MP and Turkish Aerospace Industries Anka for its maritime patrol and uncrewed aircraft system (UAS) requirements.

France is to arm its future fleet of Eurodrone medium-altitude, long-endurance UAS with MBDA's Akeron LP air-to-ground missile.

COMMERCIAL AVIATION

The International Civil Aviation Organization on Oct. 7 adopted the formal Long-Term Aspirational Goal of net-zero emissions by 2050.

A second Irkut MC-21 prototype equipped with Russian-made PD-14 turbofans flew on Oct. 7 (page 14).

Delta Air Lines signed a deal with Joby Aviation to provide a premium home-to-airport electric vertical-takeoff-and-landing service, beginning in New York and Los Angeles (page 20).

American Airlines has made a second strategic investment in hydrogen-powered aviation, backing logistics startup Universal Hydrogen.

Raytheon Technologies has made a minority investment in Swiss electric propulsion startup H55.

JOE ANSELMO/AW&ST

BRETT SCHAUF

AWARDED

Brian Everstine (left) and **Steve Trimble**, Aviation Week defense editors, accepted the Defence Media Award for Best Military Aviation during an Oct. 9 event at the National Press Club in Washington. They won the award for their March 21-April 9, 2022, article about the U.S. Air Force's new concept for classified uncrewed aircraft systems that would be used to accompany future fighters and B-21 bombers. Trimble also won the Best Defence Electronics Submission for his Feb. 7-20, 2022, article "Broken Links" about how the FAA is limiting the Defense Department's access to the vital Link 16 battlefield communications system.

Bill Carey, Aviation Week senior editor, won the 2022 National Business Aviation Association (NBAA) Gold Wing Award for Journalism Excellence. The NBAA presents the award annually to "someone who has written a definitive article related to business aviation." Carey's feature "AAM on the Ground: Do FBOs Have a Role?" examined the infrastructure that advanced air mobility will need to succeed and the role fixed-base operators could play. The award was presented Oct. 17 at the NBAA-BACE show in Orlando, Florida.

VIEW FROM DIMORPHOS

DART Mission Slows Asteroid Orbit

NASA has declared its Double Asteroid Redirection Test (DART) mission a major success. On Sept. 26, the 1,260-lb., refrigerator-size DART impactor slammed into the 560-ft.-wide Dimorphos, a moonlet of the larger host asteroid Didymos, at a velocity of 14,000 mph.

Since then, two kinds of ground-based telescopes have observed the orbital period of Dimorphos around Didymos—measured at 11 hr. 55 min. before the impact—has been reduced by 23 min. Pre-impact modeling ranged from a change of just 73 sec. to 10 min., NASA says.

"It was a bullseye," NASA Administrator Bill Nelson said. "If an Earth-threatening asteroid was discovered, and we could see it far enough away, this technique could be used to deflect it."

Earth-based observations using both visible light and radar telescopes as well as the Hubble Space Telescope verified the change in the orbital period of Dimorphos, noted Lori Glaze, director of NASA's Planetary Science Division.

Ground-based observations are expected to continue for months to better assess the composition of Dimorphos and Didymos as well as the size of the particles in the comet-like ejecta plume created by the DART blast. The goal of the analysis is to provide a more in-depth assessment of the physics involved in the operation.

AVIATION WEEK NETWORK

ASK THE EXPERT

Breaking the Law of Rising Development Costs With Strategic Digitalization

John O'Connor
Director of A&D Strategy
Siemens Digital Industries Software

Augustine's "Law XVI" noted that every generation of aircraft is more expensive than the last, and for decades this "law" seemed to be true. Now the spiral of rising aircraft development costs has finally been conquered, thanks to new digital capabilities to handle the complexity that drives it.

John O'Connor of Siemens explains why advances in A&D tend to increase complexity, and how Siemens Xcelerator can bring that complexity under control with digital threads running from design through planning and production and right into machines on the production line.

What is Augustine's XVI Law and how is Siemens Xcelerator helping companies break it?

Augustine's XVI "law" is a tongue-in-cheek observation by Norm Augustine, a former US Under Secretary of the Army and retired CEO of Lockheed Martin. He noted that aircraft were getting so expensive that by 2054 the US DoD would only be able to buy one plane.

Higher performance designs implicitly have higher levels of complexity as each generation brings more systems, more electronics, more software, more of almost everything into the product. This has led to exponentially increased costs. Although speaking humorously, Augustine was fundamentally correct in his assessment.

That has changed at last with the new B-21 bomber. Northrop Grumman is ahead of schedule and under budget on the project. Has a loophole been found in Augustine's Law? Kathy Warden, CEO of Northrop Grumman, stated recently this success was enabled by using digital design capabilities and advanced manufacturing technologies.

A decade ago, Northrop Grumman embarked on a partnership with Siemens to fully digitalize its product development processes with the Siemens Xcelerator portfolio. Today they attribute being under budget to the digital tools they use – that's how they are breaking Augustine's Law.

How does Siemens Xcelerator overcome the challenges of complexity in the design process?

Digitalization strategies built on Siemens Xcelerator recommend a systems-oriented process using high-fidelity digital twins connected by digital threads, beginning in design and extending to production.

For example, if you look at something like electrical harness design, you have fundamentally different aspects: mechanical packaging, electrical logic, functional performance. Each changes in response to requirement updates or design evolutions. And when conflicts occur between these aspects, frequently they aren't found until you actually build and install the harness.

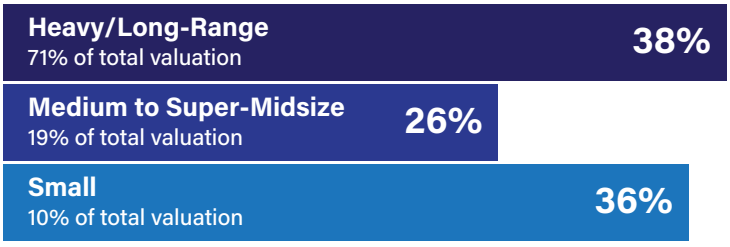
Siemens Xcelerator intersects the electrical and mechanical designs allowing you to fully understand the impact of every change. Let's say there's a requirement that certain electrical systems cannot be within a specified distance of hydraulic systems. Siemens Xcelerator automatically checks for violations and highlights them, avoiding costly changes later in the development process.

TO VIEW THE FULL INTERVIEW, GO TO:
aviationweek.com/AugustinesLawXVI

FIRST TAKE

Strong Growth Ahead for Business Aviation

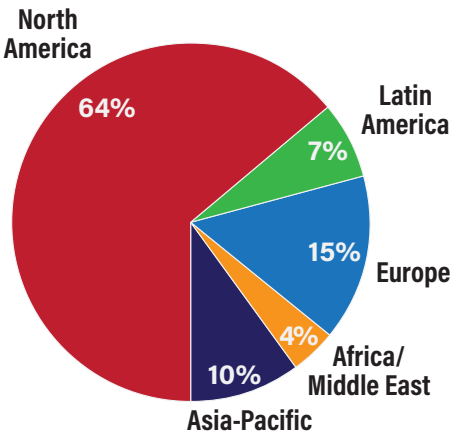
Purchase Plans by Aircraft Class



Aircraft Deliveries

2022 — Worth $274 billion — 2032

Regional Outlook



Source: Honeywell

Honeywell Aerospace's forecast for deliveries of 8,500 business jets valued at $274 billion over the next 10 years is up 15% in deliveries compared with its 10-year forecast of a year ago. Deliveries are projected to rise 17% in 2023 from 2022, returning to 2019 delivery levels much earlier than expected. New jet deliveries during the 2023-32 period are projected to grow at a 2% average annual rate, in line with expected worldwide long-term economic growth, Honeywell says. The company released the forecast Oct. 16 before the opening of the National Business Aviation Association Conference & Exhibition in Orlando, Florida.

Airbus Helicopters and Korea Aerospace Industries have handed over the first production Light Civil Helicopter to local operator Gloria Aviation.

Hydrogen propulsion pioneer ZeroAvia has acquired HyPoint, a startup developing high-power-density fuel cells.

SPACE

NASA's SpaceX Crew-5 mission reached the International Space Station on Oct. 6, replacing the quartet of Crew-4 astronauts that splashed down off the coast of Florida on Oct. 14 after a 170-day mission.

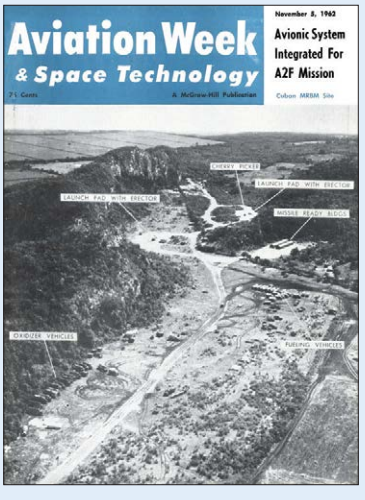
UK startup Skyrora's first attempt to launch its suborbital Skylark L failed, with the rocket falling into the sea 1,500 ft. from the launchpad in Iceland.

The Japan Aerospace Exploration Agency terminated the Epsilon-6 flight on Oct. 12 after the launch vehicle deviated from its intended path.

A pair of test satellites for Amazon's 3,236-member Kuiper broadband constellation will launch as secondary payloads on the debut flight of United Launch Alliance's Vulcan-Centaur rocket in 2023.

60 YEARS AGO IN AVIATION WEEK

The 13-day Cuban Missile Crisis ended on Oct. 28, 1962, when then-Soviet Premier Nikita Khrushchev agreed to remove intermediate-range nuclear missiles from Cuba. The imminent threat of nuclear conflict had passed. As the world drew back from the brink of Armageddon, Robert Hotz, then-editor-in-chief of Aviation Week & Space Technology, decided it was time to make a point. During high-stakes negotiations between the White House and Kremlin from Oct. 16 to Oct. 28, the Defense Department's press office refused to publicly release images of Russian missiles taken during U-2 spy plane overflights of Cuba. And that, wrote Hotz, was unacceptable. In his usual blistering prose, Hotz's editorial in our Nov. 5 issue tore into then-Pentagon Press Secretary Arthur Sylvester, likening the former journalist to a "novice trumpet player fumbling with the wrong valves and hitting a succession of sour notes." Although the Pentagon publicly released the images within days of the crisis ending, Hotz maintained that the two-week delay threatened the American system of government. "If we are now to allow the power of our own government to be used to suppress the basic elements of that freedom in this country," he wrote, "what a horrible future we have to face!"



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UP FRONT

P. BARRY BUTLER

Leveraging Data

New algorithms are **improving training**

ADVANCING AVIATION SAFETY IS A deeply personal goal for Marisa Aguiar, who earned her doctorate in aviation from Embry-Riddle Aeronautical University last year.

Her father, Simmons Airlines Capt. Orlando Aguiar, lost his life along with 67 others in 1994 when American Eagle Flight 4184 crashed in Indiana. After being instructed to hold at altitude amid freezing rain, Aguiar and First Officer Jeffrey Gagliano struggled to overcome icing that had built up on their twin-turboprop ATR 72-212. Both were highly capable aviators, but the icing was severe, and the aircraft went down. The tragedy prompted multiple FAA airworthiness directives on deicing procedures and requirements for certain turboprop aircraft.

To help pilots survive complex inflight emergencies such as the one her father faced, Marisa Aguiar's doctoral dissertation sought to advance aviation data analytics—a rapidly growing field aimed at saving lives and preventing accidents.

Her project used a safety performance indicator algorithm to detect flight and maintenance data patterns. The algorithm examined how different decisions might reduce risks within a large Title 14 CFR Part 141 collegiate flight-training operation. For instance, how would hiring more flight instructors improve operational safety? How does safety correlate with the number of maintenance technicians, flight students and aircraft in the fleet?

MARISA AGUIAR

Marisa Aguiar with her Ph.D. medal and a photo of her father.

Researchers such as Aguiar, who now teaches for Purdue University Global, are applying aviation data analytic advancements rapidly.

At Embry-Riddle, an avionics system in the university's training aircraft and simulators automatically sends flight data to safety servers. The technology allows us to spot excess speed, pilot error, maintenance problems or other issues. By year-end, we aim to take our analytics to the next level by setting up a flight safety dashboard. Initially, the dashboard will allow us to combine flight, scheduling, maintenance and other data to visualize risks more easily and measure safety performance, notes Alan Stolzer, dean of our College of Aviation at Daytona Beach, Florida. We are using these tools in our GE Digital Safety Lab for educational purposes and to prepare the future workforce, too.

Our goal university-wide will be to leverage predictive analytics. In particular, we aspire to predict the likelihood of aviation incidents such as unstable approaches, runway incursions and loss of control. "If we could develop an algorithm to do that," explains Dothang Truong, program coordinator for the aviation Ph.D. program, "the safety officer could see not only the visualizations of data patterns but also the probability that some incident might happen. That prediction would allow them to develop a strategy to prevent it from happening."

As an example of predictive analytics, Edwin Odisho, another recent graduate with a doctorate in aviation and now an American Airlines pilot, analyzed four years of data collected by NASA from 35 regional jets to build machine-learning algorithms to predict the likelihood of runway excursions. The ability to predict pilots' misperceptions of runway excursion risks could contribute to more effective simulator training scenarios and strategies, Odisho says. The information also could be incorporated into avionics displays to alert pilots to danger.

For researchers in this field, a key challenge is that airlines must deidentify sensitive safety information before sharing it, which takes time. Progress is being made, however. For example, through a public-private collaboration known as Aviation Safety Information Analysis and Sharing, spearheaded by the FAA and facilitated by The MITRE Corp., airlines and some business aviation and charter operators routinely share deidentified safety data among themselves and the FAA. By aggregating safety data, they can learn when seemingly "one-off" events are part of a more widespread problem.

On the horizon, Truong says, it should become increasingly feasible to analyze both quantitative and qualitative information to assess human factors. Natural-language processing, aided by machine learning, might even allow us to predict risks related to stress, fatigue or depression.

At our Center for Aviation and Aerospace Safety at Embry-Riddle, we work to squeeze every possible lesson from aviation safety data. The center, directed by Robert Sumwalt, former head of the NTSB, was established to improve safety for all who fly. The U.S. airline accident record over the past decade has been outstanding, Sumwalt says, yet smaller safety-related events happen daily and require scrutiny. Data analytics programs "will prove essential to helping U.S. carriers continue the quest for safety," he says, "and they will benefit global air carriers to improve their safety record also."

By advancing aviation analytics, our objective is to reduce aviation risks for everyone, in honor of Marisa's father and others gone too soon.

P. Barry Butler is president of Embry-Riddle Aeronautical University.

GOING CONCERNS
MICHAEL BRUNO

What Price, Aerospace?

For now, sticker shock **is met with open wallets**

EVERYTHING IS MOVING UP IN aerospace and defense, including the timeline for raising prices.

In October, Raytheon Technologies rolled out its new airliner-part pricing regimen—two months earlier than the giant commercial aerospace supplier and large defense prime traditionally has done when it comes to annual catalog adjustments.

According to financial analysts who have talked with Raytheon's industry partners, price increases will be in the range of 10-15%, reflecting both current inflation and the additional profit margin targeted by the behemoth, whose 2021 revenue was $64.4 billion. Consumer price index comparisons have been running 8-9% above prior-year comparisons in recent months, so double-digit increases are not surprising.

"The price increase is healthy because it recognizes the fact that costs are going up," Raytheon Chairman and CEO Greg Hayes told a September investor conference. "That is the one lever that we have.

RAYTHEON

"It's not popular with the airlines, but they have seen price increases, and they're going to see price increases in their supply chain as well," he added.

So will almost everyone. After more than a generation of tame increases, price spikes could return as a fact of life in aerospace and defense. But will all the higher costs dampen business?

Probably not in the near term, since practically everyone has to pay—and, so far, seems able and willing. Indeed, for key suppliers with pricing power—such as Raytheon, TransDigm International, providers of castings and forgings as well as some others—major price hikes, along with cost savings, are returning to the top of the list of tools to protect profits.

"Price has been the key lever in this environment to pass on costs as productivity is largely capped at 3-5% gains," analysts from Jefferies say in a recent investor report on TransDigm, famous for its own price ratcheting.

Aftermarket providers can pass on catalog increases more immediately because such sales are more responsive to the spot-market demand. But OEM-oriented manufacturers operate under long-term contracts, and price-sets roll over only annually. For OEM-focused manufacturing, 2023 will be the first window of opportunity to catch up with 2022 cost increases.

There will be pushback, of course, and suppliers expect to have to justify new prices over existing contracts. The Jefferies team found that commercial OEM-oriented respondents in the industry expect gross price increases of only 3.5% and net increases of 3.3% in 2023—levels that the analysts characterize as "likely low," given that inflation is running in the high single digits lately. Commercial aftermarket providers expect 4.5% gross, 3.5% net.

Even if catalog prices are so restrained next year, many expect that the long-term trend will be up and to the right due to a host of factors. Speaking about inflation on the sidelines of the recent U.S. Chamber of Commerce aerospace summit, Boeing CEO and President David Calhoun reportedly observed that industry is in a "wage-price spiral" and that he sees "five years of trouble" ahead.

At an investor conference in September, Textron Chief Financial Officer Frank Connor said his company was focused on above-inflation price increases even before the pandemic. In recent quarters, the company has enjoyed price increases 1.5% over inflation.

"We were very focused early on on inflation not being transitory and likely to be stickier," he said. "As we built the backlog that we have, we were very focused on making sure we were maintaining price increases that we believe are in excess of inflation."

At another investor conference in September, Spirit AeroSystems Chief Financial Officer Mark Suchinski used the analogy of running quickly just to keep up. "Energy and fuel costs are putting a lot of pressure on our cost structure and have had a negative impact on cash" usage, he said. "And we know that the labor markets are tight and that there's going to be pressure from a labor wage-growth standpoint over the next couple of years."

On the defense side, prices will rise also, albeit more slowly than in commercial aerospace or the aftermarket. Even when annual consumer price inflation averaged only 2.5% in recent decades, Pentagon leaders across presidential administrations stressed that the defense budget must rise by mid-single digits on top of that every year just to keep up with internal inflationary drivers.

In the end, significant price increases may become the new normal inside the supplier base for the next generation. Well, everywhere except in real prices paid to OEMs for large commercial aircraft—but that is another story for another time.

INSIDE BUSINESS AVIATION
WILLIAM GARVEY

A SUCCESSFUL AVIATION marketing veteran shared an insight into a characteristic of the general aviation community with me a long time ago. I don't recall the actual product that caught my attention, but it was something new, innovative, specialized and not inexpensive, and I expressed surprise at the interest it seemed to generate among potential buyers.

"You can sell a dozen of anything to this market," my sales savant observed. "But those 12 could be all."

With that as background, Stratos Aircraft President and CEO Carsten Sundin and his 18-member team in Redmond, Oregon, may have identified their initial target perfectly. What they have in mind is something both relatively modest and unquestionably ambitious.

The "something" is the Stratos 716, the first several of which will have an "X" suffix, making them among the rarest of rare.

In development for more than 14 years, the Stratos 716 is a single-pilot, six-place, pressurized, high-performance personal aircraft with a composite airframe, a single turbofan engine and Garmin G3X avionics. Its promise is a seats-full cruise of Mach 0.7 and a 1,500-nm range.

While the production model will likely cost $4 million, the slightly less capable, Pratt & Whitney Canada JT15D-5-powered 716X is priced at $2.95 million, or roughly the same as the Cirrus SF50 Vision Jet, its closest competitor.

But then again, the popular Cirrus jet is a type-certified, fully instrumented, production aircraft, complete with a whole-airframe parachute, Garmin emergency auto return and a two-year warranty.

By comparison, the 716X comes as a kit. That is to say, as with any "homebuilt," the owner must put the aircraft together, though the purchase price includes a builder's assistance program at the Stratos factory, "at least initially." And once that hands-on, estimated 12-15-month process is completed, the FAA places the jet in the "Experimental" amateur-built category—thus the "X" branding—restricting its operation in several ways.

There's more. New Cirrus Vision Jet pilots receive factory-supplied type-rating training, and Stratos is considering providing training as well. However, since there will be no type rating for the 716X, any pilot intent on flying one needs to earn special authorization from the FAA to do so. This involves specific ground and flight training by an appropriately certificated instructor and then passing a practical test overseen by an Experimental Aircraft Examiner using air transport pilot standards.

Hull and liability insurance coverage availability, as well as affordability, ongoing maintenance and resale values are other matters altogether.

Notably, Sundin, a veteran aeronautical engineer with yearslong stints at Lancair and Epic Air, emphasizes that the 716X simply represents an intermediate step in the very light jet (VLJ) program. The company's intent has always been to earn Federal Aviation Regulation 23 type and production certificates. He says the real purpose of the kit program is to stimulate interest in the 716 and refine Stratos' manufacturing processes—which should be done by delivery of 10-12 kits and mark the end of the build-it-yourself phase.

"We have no illusion about being a long-term kit manufacturer," Sundin says.

Meanwhile, flight testing of the 716 is well underway, having logged some 800 hr. to date, including flutter tests and flight envelope expansion in two proof-of-concept aircraft. Sundin readily admits that achieving FAA certification will likely require a "really astronomical" investment, possibly hundreds of millions of dollars—funding that has yet to materialize. And thus, the focus on kits for which, he says, Stratos has the financial wherewithal.

The company has refrained from an active sales effort for the 716X until kit groupings are complete. "We want to check all the boxes first," Sundin says. But that process is nearly done, with most components at hand for the first two aircraft. And now, he adds, "we have interested customers."

Nevertheless, he cautions that "it is too early to announce dates or other details pertaining to the start of the first customer aircraft," though he might have that information "later this year."

He seems confident that Stratos and the 716X are going to bullseye that general aviation marketing target I learned of years ago. Doing so will provide a dozen doggedly determined buyers bragging rights to something truly unique within the community: Mach 0.7 VLJs they built themselves.

High-Performing Homebuilt

Stratos 716X—some assembly required

JOHN SMOKER/STRATOS AIRCRAFT

William Garvey was editor-in-chief of Business & Commercial Aviation *from 2000 to 2020.*

THE LAUNCHPAD
IRENE KLOTZ

NASA AND UNITED LAUNCH Alliance are kicking off what they hope will be a series of orbital flight tests to scale up the size of heat-resistant aeroshells that inflate to provide safe, low-cost and efficient transportation through planetary atmospheres—including Earth's—at hypersonic speeds.

The technology is designed to address the challenge of landing heavier payloads using hardware that, when deflated, fits inside a launch vehicle payload fairing.

"A rigid structure is limited," says NASA Technology Demonstrations Director Trudy Kortes, with NASA Headquarters in Washington. "Ultimately, this technology can enable new missions to Mars, Venus and even Saturn's large moon Titan, and it can be used for payload returns to Earth as well."

United Launch Alliance (ULA) is developing a so-called Hypersonic Inflatable Aerodynamic Decelerator (HIAD) for future recovery of its Vulcan rocket's core-stage engines so that they can be reused.

With the rigid structures currently in use—designed to fit within a 15-16-ft.-dia. fairing—NASA can land up to about two metric tons on the surface of Mars. HIAD technology could expand cargo loads to 22-49 tons.

"That's what you need to put humans on Mars," says Loftid Project Manager Joe Del Corso, with NASA's Langley Research Center in Hampton, Virginia. "The larger the aeroshell, the more down-mass capability you have to the surface of a planet."

HIADs also would be able to land in higher elevations on Mars than can be accessed with current systems.

Ideas for inflatable aeroshells date back more than 50 years, but the materials that could withstand the high temperatures of atmospheric reentry did not exist. HIADs, which resemble a child's stacking-ring toy, feature giant fabric hoops covered by flexible thermal blankets made of ceramic-fiber fabric, layers of insulation and a gas barrier to prevent hot gases from reaching the inflatable structure. The thermal system drapes over the cone-shaped, inflatable structure.

About 10 years ago, Langley spearheaded a program to develop HIAD technologies. The work led to a series of flight tests aboard sounding rockets, culminating with the Inflatable Reentry Vehicle Experiment (IRVE-3) on July 23, 2012.

During the test, a 10-ft.-dia. fabric aeroshell inflated at an altitude of 288 mi. and successfully reentered Earth at Mach 10. Temperatures during descent reached 1,000F and exposed the vehicle to forces up to 20gs.

The next series of tech demos kicks off with the Low-Earth-Orbit Flight Test of an Inflatable Decelerator, or Loftid. This HIAD is to be nearly 20 ft. in diameter—twice the size of IRVE-3—and face heat loads 180 times greater, says John DiNonno, Loftid chief engineer at Langley.

Loftid is scheduled to ride as a secondary payload aboard the upcoming NASA-National Oceanic and Atmospheric Administration Joint Polar Satellite System-2 (JPSS-2) mission, which is due to lift off on Nov. 1 aboard a ULA Atlas V rocket from Vandenberg Space Force Base in California.

The experiment is planned to remain powered down until after the rocket's Centaur upper stage deploys the JPSS-2 spacecraft and conducts a deorbit burn. A portion of the ULA-provided payload adapter that covers the Loftid reentry vehicle (RV) would then be jettisoned, exposing the aeroshell.

The RV would send a command to the aeroshell to begin to slowly inflate with nitrogen gas until it reaches full pressure at 19 psi. The Centaur then would spin the RV to 3 rpm, providing enough stabilization for ballistic reentry.

During the descent, the RV is set to travel at hypersonic, supersonic, transonic and finally subsonic speeds. The experiment is expected to end at about Mach 0.7, at which point a data recorder would be ejected for recovery and the RV would descend under parachute to a splashdown point about 500 mi. east of Hawaii in the Pacific Ocean. ULA is supplying a ship that will attempt to recover the vehicle.

During the flight, data also is set to be transmitted in real time via email through the Iridium satellite network, Del Corso adds.

ULA is looking to scale up to a 39-ft.-dia. HIAD to recover its Vulcan rocket's BE-4 engines. NASA is looking at HIADs up to about 65 ft. in diameter for Mars missions.

The Loftid program is costing NASA just under $93 million. ULA is working on the project under an unfunded Space Act Agreement. Separately, ULA holds a JPSS-2 launch services contract worth $170.6 million.

Liftoff for Loftid

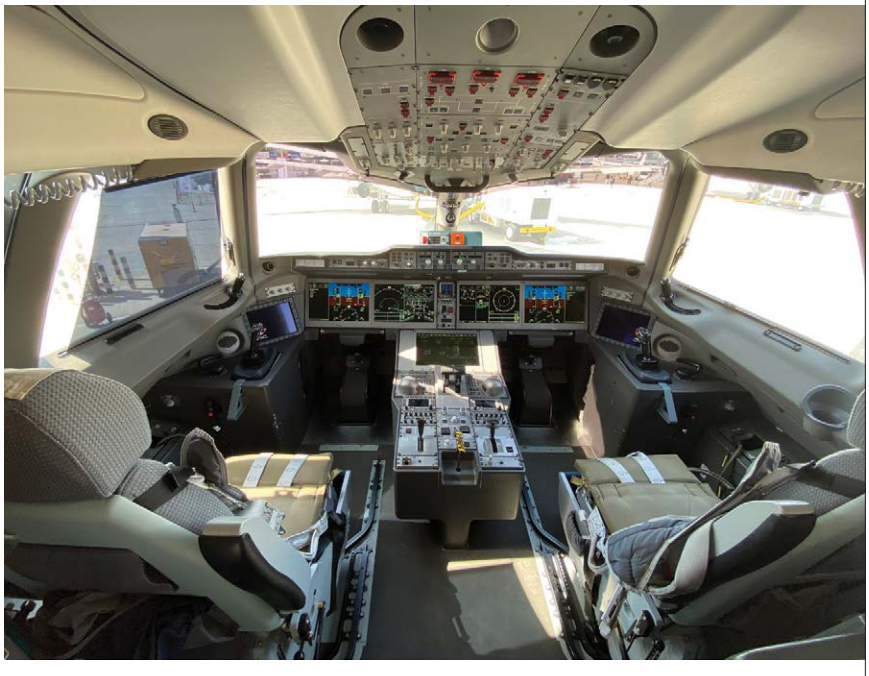
Inflatable **heat shield** poised for flight test

The Low-Earth-Orbit Flight Test of an Inflatable Decelerator (Loftid) is scheduled for Nov. 1.

PAST THE GOLDEN AGE

- COMAC C919 PASSES CERTIFICATION
- UAC MC-21 IS TO BE RECONFIGURED FOR 2024 ENTRY INTO SERVICE
- CHINESE AND RUSSIAN AIRLINES PLAN TO OPERATE NEW NARROWBODY TYPES

AVIATION WEEK NETWORK STAFF



Chen Chuanren Singapore, **Jens Flottau** Frankfurt and **Aviation Week Network Staff**

During the golden age of globalization and world trade in the early 2000s, there seemed to be a chance that the Airbus-Boeing aircraft duopoly might end in the foreseeable future. China had launched the Comac C919 narrowbody and Russia had started to develop the United Aircraft Corp. MC-21 in efforts to establish their industries in the world market. But that outlook has dramatically shifted.

The C919, about to enter commercial service in China, looks like it might be confined to its domestic market for some time. The MC-21, which was also on the verge of entering service, has instead been forced into an extensive redesign as Russia tries to replace Western suppliers with local companies.

The C919 attained its airworthiness certification from the Civil Aviation Administration of China (CAAC) on Sept. 29, about five years after the aircraft made its first flight in 2017. President Xi Jinping attended the ceremony, indicating how important the project is for China. The certification date, 9/29, might not have been a coincidence; it could be interpreted as a hint about Comac's next major aircraft project, the CR929 widebody, to be jointly developed with Russia. China commonly marks major operational milestones ahead of its National Day, on Oct. 1, as a "birthday present" for the country.

Xi once called the C919 a "reflection of China's national capabilities." Its development is the second step in establishing the country's aerospace sector in the commercial aircraft market, following development of the ARJ-21.

With a seating capacity of about 168, the C919 is similar in size to the Airbus A320neo or Boeing 737-8. In a document for airport planning, Comac says the maximum takeoff weight (MTOW) of the standard aircraft is 165,500 lb. and that of a C919ER (extended range) would be 174,000 lb. Its range is cited as 2,200-3,000 nm. These numbers are significantly less than those of the 737-8 (which has a range of 3,550 nm and an MTOW of 181,200 lb.) and the A320neo (which has a range of 3,400 nm and an MTOW of 174,200 lb.).

Due to sanctions, Irkut has to replace systems in the MC-21 made by Western suppliers.

The Aviation Week Network Fleet Discovery database shows that the C919 orderbook includes 583 orders and 120 options, mostly from Chinese operators and lessors (see table, page 17). Comac's hometown carrier, China Eastern Airlines, will be the first operator; it signed a purchase agreement for five aircraft in March 2021. Earlier this year, the carrier announced it would receive three C919s by year-end, but that number has been adjusted to only one.

Moreover, the C919 might not be as affordable as carriers and experts initially expected. China Eastern issued a stock exchange notice to raise funds to acquire a range of aircraft, which revealed the C919's price for the first time. According to the filing, the aircraft costs $99 million, nearly twice the $50 million estimate industry analysts had expected, but a price that

Safran e-taxiing concept **p. 23**

The C919 is planned to enter commercial service with China Eastern Airlines following CAAC certification.

XINHUA

is close to its Western peers. However, the level of (sometimes hidden) state support for local airlines could change the equation.

Entry into service of the C919 at China Eastern will give Comac, the airline and the industry at large an opportunity to study the economics, reliability and in-service support of the aircraft. Once it is flying with acceptable reliability, Comac's next challenge will be ramping up production to levels high enough to make significant inroads into China's narrowbody market. That process, Western experts estimate, could take many years and might not lead the program anywhere near the planned A320neo or 737 MAX outputs.

Although Comac has not publicly revealed production plans, a list of 2021 infrastructure projects newly released by Shanghai's city council includes the construction of a manufacturing and assembly center, a CR929 widebody research and development center and an Avic aircraft engine facility.

Melius Research analyst Robert Spingarn is skeptical about the C919's outlook, as are many others in the industry. "The C919 is not competitive with the A320neo or 737 MAX and will have limited near/midterm market potential, even in China," he writes in a note to clients. "As with most new-entrant aircraft, the C919 is not yet as optimized as its competition. It will have fewer seats, lower range and carry lower payloads."

Chinese airlines will continue to bet on Airbus and Boeing narrowbodies, Spingarn predicts; their customers expect to fly on Western aircraft. The airlines also have no clear indication of when the C919 might be available to them or how reliable it will be.

Comac C919 Orderbook

Operator	Order	Option
ABC Financial Leasing Co. Ltd.	65	10
Aercap	20	—
Air China	5	15
Avic International Leasing	15	15
Bank of Communications Financial Leasing	30	—
BOC Aviation Ltd.	20	—
CCB Financial Leasing Corp.	50	—
CDB Leasing Co. Ltd.	10	—
China Aircraft Leasing Co.	20	—
China Eastern Airlines	5	15
China Huarong Financial Leasing	30	—
China Southern Airlines	5	15
Citic Financial Leasing	18	—
Hainan Airlines	20	—
Hebei Airlines	20	—
Huabao Leasing	15	15
ICBC Financial Leasing	100	—
Industrial Bank Co. Ltd.	20	—
Joy Air	20	—
Nuclear Construction Financial Leasing	20	20
Ping An Leasing	50	—
Sichuan Airlines	20	—
SPDB Financial Leasing Co. Ltd.	5	15
TOTAL	583	120

Sources: Aviation Week Network Fleet Discovery and Melius Research

"Regarding availability, the C919 will be slow to produce in volume," Spingarn writes. "As we have seen time and again with Airbus and Boeing, increasing production rates is no small matter, even when experienced. Regarding dispatch reliability, the development of a consistent product support system with dependable maintenance and parts positioning is a critical requirement for scheduled airlines. With these needs unlikely to be met soon, we still see C919 as a proof-of-concept type product for Comac."

Spingarn expects that China eventually will catch up on aerospace technology, but that could take decades. When it does, however, Comac will be able to satisfy local demand—particularly since the government has considerable influence on the type of aircraft that state-owned airlines fly, he notes.

The C919 certification progress has run into numerous technical and political problems. In December 2020, Comac was listed among 89 sanctioned Chinese companies, making it much more difficult to sell U.S.-made aerospace components and technologies to China.

Of course, despite being a predominantly Chinese program, the C919 relies heavily on major Western suppliers for such systems as the auxiliary power unit, landing gear, cockpit and avionics parts and engines, which all come from foreign suppliers such as Honeywell, Collins Aerospace, Eaton and CFM International.

To further complicate matters, the COVID-19 pandemic has delayed the program further into the decade. China imposed strict lockdowns, effectively closing its borders to foreign nationals. The country continues to carry out flash lockdowns even in major cities, such as Shanghai, where Comac is based, preventing production staff from going to work. A key planned milestone was flying an aircraft to Canada for cold-weather testing in early 2021, but that trip never happened.

Last December, CAAC said that only 1,694 of the 3,272 ground and flight tests scheduled for the campaign had been completed, and only 34 of 276 flight-test items had been checked. Then, in July, Comac announced that

all six C919 prototypes had finally completed all flight-test requirements, and its first production aircraft had flown on May 14.

In the weeks leading up to certification, the aircraft flew to various domestic airports, including in Dongying, Jinan, Yantai and Zhengzhou, to evaluate routing, taxiing and other ground operations. These proving flights have continued; the aircraft most recently flew to Hefei from Shanghai on Sept. 7.

Meanwhile, Russia's Irkut Corp. has been thrown back into reconfiguration mode as Western sanctions against the country take effect. The company is completing the reengining of the first MC-21 prototype in its Irkutsk facility in western Siberia. The aircraft, registered RA-73051, now has Russian-made PD-14 turbofans installed instead of Pratt & Whitney's PW1431G-JM engines as originally planned. Irkut is expected to start engine certification trials this month.

UAC

Irkut has equipped the first MC-21 test aircraft with PD-14 engines to speed up flight trials.

The PD-14-powered version is designated MC-21-310 to differentiate it from the baseline MC-21-300 variant. The first—and thus far only—MC-21-310 test aircraft, registration RA-73055, flew for the first time in December 2020.

The reengining process is part of a broader Irkut effort to develop an MC-21 variant on which Russian products replace all imported components and systems. As with its smaller sibling—the Superjet 100 regional jet—the MC-21 initially attracted a broad pool of leading global suppliers. The baseline MC-21 includes avionics elements from Honeywell, Thales and Elbit Systems; active sidesticks from Raytheon Technologies; and various subsystems from Collins Aerospace, Eaton, Meggitt, Orbit Communication Systems and Safran.

The share of foreign components in the MC-21, however, is lower than that in the SuperJet because Russia's access to Western technologies began to shrink in 2014, when the first sanctions hit the country's aerospace sector in response to the annexation of Crimea.

The West's sharp response to Moscow's invasion of Ukraine this year left no chance for the new Russian mid-range passenger airliner to continue to rely on components from the U.S., the European Union or their allies. The MC-21-300 baseline variant achieved Russian type certification in December, and Irkut was preparing for first deliveries to Rossiya Airlines, a subsidiary of Russia's largest carrier, the Aeroflot Group. The aircraft handover was scheduled for this fall.

Yury Slyusar, the head of Irkut parent United Aircraft Corp. (UAC), remarked in August that he still expected to deliver a few assembled MC-21s with Pratt engines to Rossiya for trial operations. But the OEM is now focused on developing the import-substituted MC-21-310 modification.

The MC-21-310 development formally includes several design and test efforts. The first one is the certification of the aircraft with PD-14 engines. Irkut tells Aviation Week that, as of late September, the first MC-21-310 prototype had made 140 of the 240 test flights planned for the certification effort. The flight program is expected to be completed by year-end, which is also when the PD-14-powered aircraft should receive a supplemental type certificate.

An additional effort that will include the testing of other non-Western components is expected to start in 2023. According to Irkut, more than 30 Russian suppliers have been added to replace the Western components—the same number as with the import-substituted SuperJet-New program. The manufacturer did not disclose which Russian suppliers joined the program.

The only replacement known so far is the new wing. The baseline MC-21-300 was certified with the composite wing made of foreign components, but all serial aircraft wings will consist of Russian composites manufactured by UAC subsidiary Aerocomposit. Flight trials with a Russian composite wing started in December. According to earlier statements, the supplemental type certificate for the new wing is expected to be received in the next few months.

Irkut also plans to expand the MC-21 operational envelope this year through additional testing in high-altitude conditions, strong crosswinds and low and high temperatures. Trials at temperatures colder than -30C (-22F) were completed in February. It is unclear whether the manufacturer continued with other tests that had been planned for the baseline MC-21-300 variant, which will not go into serial production.

The multiple additional efforts make the certification schedule for the MC-21-310 challenging, particularly since the new government program for development of the air transport industry calls for deliveries of the first six aircraft to take place in 2024. Russia assumes 270 MC-21-310s will be delivered by 2030, and the production rate is planned to increase to 72 aircraft per year beginning in 2029. The Russian government allocated 15 billion rubles ($240 million) in September to launch MC-21 serial production.

The PD-14 manufacturer, United Engine Corp. (UEC), received a loan of another 4 billion rubles from government-owned Novikombank in August to start serial production of the powerplants. UEC Deputy General Director Alexander Inozemtsev was quoted by Russian TV channel Zvezda as saying that his company was tasked to increase production to 160 PD-14s by 2030.

The government expects the MC-21 to play a key role in replacing Western-made commercial jets on the Russian market this decade. The Aeroflot Group signed a letter of intent for 210 MC-21-310s in early September, which represents almost 80% of the type's planned output through 2030. According to Slyusar, UAC will sign a firm contract by year-end. The government promised to subsidize deliveries through the national wealth fund in order to compensate UAC for the difference between the aircraft's price and production costs.

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Challenging Changes

> U.S. PILOTS SPLIT OVER 737 MAX CREW ALERTING NEED

> DEBATE CENTERS ON COMMONALITY VERSUS IMPROVED DESIGN

JOE WALKER

Sean Broderick Washington and **Ben Goldstein** Newport, Rhode Island

A split among U.S. pilot groups over the safest way to proceed with the last two Boeing 737 MAX variants highlights the complexity of integrating changes into cockpits without risking pilot confusion over recognizing slight variations between nearly identical aircraft models they are qualified to fly.

Boeing has until Dec. 22 to meet a congressionally mandated deadline by which the 737-7 and 737-10 are to be certified with FAA-granted exemptions from some current flight crew alerting requirements. A 2020 law set the deadline and gave Boeing two years to wrap up certification work on the last two 737 MAX family variants. But a combination of factors has placed both programs at risk of not making the deadline.

The company is adamant that keeping the 737 MAX family's flight deck similar—and similar to the 737 Next Generation (NG) family that preceded it and is flown by most 737 MAX customers—is the safest path forward, arguing that having cockpit system variations within the same aircraft family could confuse pilots (*AW&ST* May 30-June 12, p. 21). Securing FAA approval on designs that do not meet current flight crew altering regulations after Dec. 22 would require Congress to grant an extension to the 2020 law's deadline permitting the agency to certify them without more advanced crew alerting functionality. The FAA weighed in years ago when it granted—at Boeing's request—the partial exemptions to the 737 MAX family. The 737-8 and 737-9 were certified with the exemptions.

Two pilot groups have weighed in publicly on how Congress should proceed. The Allied Pilots Association (APA), which represents American Airlines pilots, spoke out first, voicing strong opposition to any extension. Its argument: Giving pilots more insight will help them diagnose problems more quickly and minimize the "startle effect" of aural or visual alerts that come with little context.

"Boeing needs to proceed with installing modern crew alerting systems on these aircraft to mitigate pilot startle-effect and confusion during complex, compound system malfunctions," APA President Edward Sicher says. "Once these systems are installed and pilots have been properly trained on them, our crews will be better able to identify system failures and prioritize corrective actions that could save lives."

American operates 737-8s but has not committed to 737-7s or 737-10s.

Pilots at all-737 operator Southwest Airlines, which has 737NGs and 737-8s in its fleet as well as 737-7s on order, agree with Boeing.

"There is a commonality issue for us," a Southwest Airlines Pilots Association (SWAPA) spokesperson says. "The way Southwest uses a short-to-medium-haul airplane like the 737, our pilots can touch four or five [different] planes in a day. And so keeping that commonality just fosters and creates a more shared mental model between our pilots."

The Air Line Pilots Association (ALPA), which represents pilots at four airlines that have committed to multiple 737 MAX variants, has not commented publicly on the extension. But ALPA has told lawmakers it supports keeping the 737 MAX family flight decks common regardless of the deadline, sources with knowledge of meetings between the two sides tell Aviation Week.

"While it is up to Congress to determine whether or not to grant the manufacturer an extension, we are confident in the safety of the aircraft," ALPA tells Aviation Week, citing its "extensive" reviews of changes required by regulators following two fatal 737-8 accidents, in 2018 and 2019, respectively.

The 737-10 includes new safety enhancements but not an updated flight crew alerting system.

ALPA based its stance in part on a human-factors analysis of instances where flight deck variations introduced into the same fleet types created issues, the sources say. Examples include airline mergers that created subfleets of the same models with slightly different flight decks because of various customization options.

A September 2011 incident highlights the risks that seemingly minor flight deck variations can introduce. An All Nippon Airways (ANA) pilot operating a 737-700 during cruise attempted to unlock the flight deck door. Instead, he toggled the aircraft's rudder trim switch, causing the aircraft to roll left, dive and drop 5,000 ft. in about 30 sec. before the crew recovered, a Japan Transport Safety Board probe found. Two flight attendants were injured.

Investigators determined that similarities between the design and location of the 737-700's rudder trim switch and the flight deck door lock switch on an older 737 variant the pilot flew for ANA likely contributed to his mistake.

"During the investigation of this incident, numerous [737-family] aisle stand configurations were identified due to the multitude of supplemental type certificate installations and significant variability in the Boeing-delivered configurations," a 2014 FAA bulletin on the issue states. "This creates a potential for confusion when pilots transition between aircraft."

The incident contributed to Boeing's decision to develop new design guidelines for in-production aircraft that reduced potential aisle stand switch-position variations.

The APA argues that targeted training can help pilots safely switch between similar aircraft models. The group cites the 757 and 767, which have a common type rating, meaning pilots can easily transition between the two

with minimal additional instruction, as an example. But a common type rating relies on making two aircraft as similar as possible for pilots, not bridging gaps between aircraft system functionality. Depending on how different systems are configured on two similar aircraft, pilots may be required to undergo full-flight simulator sessions—Level E difference training, in FAA language—to transition from one model to the other.

"The FAA will establish an additional type rating if . . . a Level E difference training is required," agency training guidance says.

Having different type ratings within one fleet expands a carrier's training and pilot-resource requirements.

"There would have to be a decision made on a corporate level whether [Southwest would] want to continue on this route," the SWAPA spokesperson adds. "If [the 737-7] is certified, is it a new type? Would we have a subset of pilots? These are the kinds of concerns we have about forgoing commonality."

None of the groups dispute that a 737 MAX with a full or partial engine indicating and crew alerting system (EICAS) is safer. But those arguing that keeping the family common is the lowest-risk approach point to both the human-factors ramifications and the safety record of aircraft that do not have current-day alerting systems as evidence that the current design, while not compliant with the latest regulations, is safe.

"We're not going out on a limb and saying it's less safe or more safe [without the updated crew alerting systems]," SWAPA says. "But with the way we operate airplanes—and the number of airplanes we touch a day—we just believe that commonality is the safest factor here."

"Not to say that the MAX 7 or MAX 10 won't be safe, but it will be safer with EICAS, and that should be our goal," says an American Airlines 737 pilot.

Boeing CEO Dave Calhoun has suggested the company will abandon the new models before adding EICAS (*AW&ST* July 11-24, p. 15). For now, Boeing is proceeding without regard to the deadline, focusing on getting the two models approved as designed. The Dec. 22 deadline is not chiseled in stone; Congress could grant an extension retroactively, meaning the issue may not be decided until well into 2023.

The 2020 law was prompted by findings from the two 737 MAX accidents and related probes into the model's certification. Investigators pointed to a poorly designed software addition to the 737 flight control computer as the primary factor in both accident scenarios. Boeing modified the software as part of changes ordered by regulators while the 737 MAX fleet was grounded (*AW&ST* Nov. 23-Dec. 6, 2020, p. 16).

But experts also cited as a risk the pilots' confusion over a series of alerts and warnings triggered by the faulty software—an issue that more modern alerting systems help minimize. Boeing's latest changes address some of these issues. Among them: switches added to the baseline 737-10 model that turn off nuisance stall warnings. Boeing plans to roll them out for the other three 737 MAX variants (*AW&ST* Aug. 29-Sept. 11, p. 26).

Taking the Taxi

> JOBY WILL OPERATE DELTA'S HOME-TO-AIRPORT eVTOL SERVICE

> BOOKING TO BE INTEGRATED INTO DELTA'S PREMIUM CHANNELS

JOBY AVIATION

Graham Warwick Washington

Premium customers with the world's biggest airlines can look forward to taking an electric air taxi over traffic to the airport, but the carriers' leaders caution that vertiport infrastructure and airspace integration remain hurdles to be overcome.

Delta Air Lines is the latest to embrace the promise of electric vertical-takeoff-and-landing (eVTOL) vehicles. But rather than buy aircraft, as American Airlines and United Airlines plan to, the carrier has signed a deal with Joby Aviation to provide a premium home-to-airport service, beginning in New York and Los Angeles.

Atlanta-based Delta has invested $60 million in Joby and taken a seat on the startup's board. This stake could grow to $200 million as milestones are met for the "Home to Seat" service. The partnership is exclusive in the U.S. and UK for an initial five years after service launch, expected in 2025, with the potential to be extended.

Joby's eVTOL service will be integrated into Delta's premium channels to provide seamless booking of time-saving short-range flights to and from airports. This will run alongside Joby's standard air-taxi service in priority markets and is expected to be the first eVTOL service to market, the partners say.

There are caveats. As first reported by The Air Current, Delta has the right to terminate the agreement if Joby has a serious accident with its aircraft—even during precertification flight testing if it involves injury or a fatality or is judged by the airline as likely to cause it "significant reputational harm."

Joby is targeting FAA certification of its piloted four-passenger S4 tiltprop eVTOL by the end of 2024 but has yet to fly a production-representative aircraft. One of the startup's two full-scale engineering prototypes crashed during a remotely piloted test flight in February, but no one was injured.

Joby has already received its Part 135 operating certificate from the FAA and is flying small fixed-wing aircraft in the San Francisco Bay Area to gain experience before transitioning to eVTOL air taxis. Delta will conduct safety audits and require Joby to maintain Wyvern and/or Argus safety certification.

Exact timing of the launch and buildout of the service will be determined by availability of landing infrastructure, says Joby founder and CEO JoeBen Bevirt. Delta will work with airports to establish vertiport locations close to its terminals to shorten transit times for users of the air-taxi service.

The airline also will work with Joby to establish "neighborhood vertiports" close to where its premium customers live or work, taking advantage of the low acoustic signature of the eVTOL. Ground transport to and from the vertiports likely will be provided through Joby's partnership with Uber.

Both New York and Los Angeles have multiple existing helipads, but few are approved for commercial operations, and Joby is working to reactivate rooftop helipads, Bevirt says. Building air-conditioning systems typically have intakes on the rooftop and must be shut down before a combustion-powered helicopter can use the helipad. "Electric propulsion, because it's clean, allows us to use that existing infrastructure and bring it back online," he says.

Joby will operate Delta's home-to-airport eVTOL service from "neighborhood vertiports."

Delta's rivals American and United have already made investments in and placed preorders with eVTOL startups Vertical Aerospace and Archer Aviation, respectively. But both airlines plan to operate their own branded air-taxi services.

By 2030, United expects to have "100 or so eVTOL aircraft flying routes in our most congested cities," Mike Leskinen, United Airlines Ventures president, told a CNBC event on Oct. 6. "Think about San Francisco and New York, flying our customers from city center to airport." There are challenges, however.

"Adoption, air traffic control, how you integrate that into congested airspace, how you land the aircraft at the airport, how and where you build infrastructure . . . to make sure it's convenient to offices where you have business executives," Leskinen said. "All of that's going to take a lot of planning, a lot of capital."

Not everyone is convinced eVTOL air taxis make sense. "The challenge is at the moment we're looking at four-seaters with a pilot," Aengus Kelly, CEO of AerCap, the world's largest lessor, told a Eurocontrol conference on Oct. 4 in Brussels. "It's very hard to see how you could ever make money out of that.

"Also, the question is: Will they ever be able to land airside? Do they have to land outside the airport if they're bringing people to an airport?" he asked. "The concept that they're going to pick up passengers at the top of a skyscraper in London or Sao Paulo: No way. The owners of those skyscrapers will never let random people into their building to go up to the top floor."

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New Pilot Program Could 'Rescue' Regional Business, Mesa CEO Says

> MESA DEVELOPMENT PROGRAM AIMS TO FINANCE PILOT-TRAINEE TIME-BUILDING TO 1,500 HR.

> TO JOIN, CANDIDATES MUST HAVE 250 HR. AND COMMERCIAL RATING

Ben Goldstein Washington

The chief executive of Mesa Airlines is holding out hope that his company's new Mesa Pilot Development Program could help the U.S. airline industry recover from an ongoing regional pilot shortage, but he has no illusions about the magnitude of the challenge at hand.

MESA AIR GROUP

Mesa Air Group has placed 29 firm orders for Pipistrel Alpha Trainer 2 aircraft, which will initially be based at its training center in Inverness, Florida.

"COVID lulled us into a false sense of security, in that we didn't see much pilot attrition," Mesa Air Group Chairman and CEO Jonathan Ornstein tells Aviation Week. "We're excited about this program, and we think it could potentially even rescue the industry. . . . My only concern is that it may be too little, too late."

Unveiled in late September, the Mesa Pilot Development (MPD) Program plans to offer aspiring commercial aviators the opportunity to build time toward 1,500 hr.—the minimum required to qualify for an air transport pilot (ATP) license—using a new fleet of Pipistrel Alpha Trainer 2 aircraft.

Critically, the airline plans to fully finance the cost of flying at a rate of $25 per hour, with the funds to be repaid by graduates without interest over three years during their tenure as Mesa first officers. From there, they can enroll in the United Airlines Aviate program, which could move them onto lucrative legacy airline careers "within five years," Ornstein says.

While Mesa plans to absorb the cost of funding pilot training upfront, Ornstein says "it's actually not that expensive" for many students to reach 1,500 hr. He notes that about 25% of those enrolled in the MPD's inaugural class will require around 250 hr. to earn their ATP. Others are less experienced and will need to be in the program longer. All candidates must have at least 250 hr. and their commercial ratings to join the program.

As students approach 1,500 hr., Mesa plans to schedule them for formal training classes to ensure their smooth transition to first officers operating the company's Bombardier and Embraer regional jets.

The initial Pipistrel trainers are to be based at Mesa's training center in Inverness, Florida, before expanding to its Arizona base in 2023. Ornstein says Mesa has already received the first four aircraft, which were already built by the OEM. Initial deliveries of an additional 25 Pipistrel trainers on firm order are expected by year-end.

While Ornstein acknowledges some criticism of the choice to go with the Pipistrels, he defends the aircraft as ideal for time-building, observing that the type is commonly used for training in Europe, as well as by the Indian government and U.S. military. He also points to the model's affordable price tag—at just around $130,000 per unit—as well as its lower fuel burn and the reliability of its "bulletproof" Australian-built Rotax motors as added perks.

Ornstein says he is hopeful that the Pipistrels will be able to operate around 10 hr. per day. Even if they cannot, its price would allow Mesa to simply add more aircraft. "For another five or six aircraft, you're talking about around $750,000," Ornstein says. "We can always go out and buy more."

Flying a single-engine piston trainer is hardly the same as operating large regional jets in a Part 121 environment. But Ornstein says that criticism misses the point of the MPD. "We never said it was training—we said it was time-building, which is what the rule requires," he says.

That said, Mesa's MPD instruction is planned to go beyond simply providing an aircraft on which aspiring pilots can build hours. As part of the program, cadets will undergo computer training and get familiarized with Mesa's operating procedures and checklists, with "everything to be done as if it's in a commercial environment," he notes.

"The fact of the matter is, we will do training," Ornstein says. "It will not just be us tossing them the keys so they can go off and fly circles around the airfield. We're going to have them on specific routes with specific tasks. It's not formal training, but it will certainly be a learning experience."

The Mesa training program is the latest in a series of initiatives launched by U.S. regional carriers hoping to find alternative ways to shore up their pilot pipelines. SkyWest Airlines has applied to the Transportation Department for Part 135 commuter-airline authorization for a new charter unit, which would allow first officers to fly with just 250 hr. under less stringent charter airline rules (*AW&ST* July 25-Aug. 7, p. 35).

Republic Airways, meanwhile, had petitioned the Transportation Department for a restricted pathway that would allow graduates of its Leadership In Flight Training Academy to earn their ATP with just 750 hr. (*AW&ST* Sept. 26-Oct. 9, p. 38), but that proposal was shot down by the department in September.

Safran Takes a Fresh Look at Electric Taxiing Concept

> NEW VERSION DESIGNED AS ORIGINAL EQUIPMENT

> GOAL IS TO REDUCE FLIGHT-CYCLE FUEL BURN BY 4%

Thierry Dubois Velizy-Villacoublay, France

Using turbofans for taxiing is particularly inefficient, and finding a system that burns less fuel on the ground sounds like common sense. However, if the system adds weight, the business case can be challenging. That is the situation Safran has faced for a decade with designing and promoting its electric taxiing system.

Fluctuating fuel prices have marred the project. The business case looked good when prices were high and degraded when they dropped. Now that the environmental pressure has stepped up and become the priority of the entire commercial aviation industry, Safran may be confident electric taxiing will be among the technical solutions.

However, the company may still need to exercise some patience. The first version of the system, which failed to attract customers, was thought of as a retrofit. The company is now designing a more integrated, lighter system to be fitted on future aircraft as original equipment. Therefore, it will have to wait until a new program is launched—the only one in sight in the short term is an Embraer regional turboprop in the 70-90-seat category.

But Safran engineers and senior executives are unlikely to be deterred by the wait, having shown persistence since the beginning.

In 2013, the joint venture Safran created with Honeywell performed a spectacular demonstration: An Airbus A320 taxied with engine covers at the Paris Air Show. By 2016, Honeywell had left the joint venture. A year later, Safran and Airbus gave "authorization to market" the system on the A320 family. And in 2019, Airbus terminated its participation in the joint eTaxi program with Safran. The eTaxi did not offer "a level of maturity and performance compatible with its integration in the constrained fuselage of a single-aisle aircraft," Airbus said.

An electric taxiing system uses electric motors in the landing gear, powered by the auxiliary power unit (APU), to taxi without using the aircraft's engines. Over a flight cycle, fuel burn can be cut by up to 4%, Safran says.

The electric taxiing system Safran began to design in the early 2010s was intended as an add-on for in-service aircraft. The A320 retrofit would have involved extensive system modifications and another APU, according to Safran Landing System CEO Cedric Goubet. "Partial recertification of the A320 was required, which Airbus was not keen on doing." The original eTaxi system weighed 450 kg (1,000 lb.).

THIERRY DUBOIS/AW&ST

The first version of the electric taxiing system relied on an external layout with a possibility for retrofit, but Safran is working on a more integrated, lighter system that will essentially fit inside the wheel.

"A lesson learned is that the system should be integrated to the aircraft from the beginning," Goubet says.

Safran engineers returned to the drawing board and changed the system's architecture. The new approach will notably translate into weight savings. Every component will have its weight reduced, Goubet adds. The weight improvement remains unspecified but is said to be significant.

Specifications have been thoroughly reviewed. Safran has been asking operators about the minimum speed they need for taxiing. The faster the taxiing, the heavier the system, says Walid Hamzeh, Safran Landing Systems executive vice president for strategy, research and technology programs.

Moreover, a shallow and temporary pit forms under aircraft wheels after a long stay, such as 12 hr., on the apron. The breakaway force to leave a parking position therefore must be greater, Hamzeh points out. Designing the system for a high-breakaway requirement if operators do not need it would lead to an unnecessarily powerful—and thus heavy—motor, he adds.

While the former design relied on an external installation, the new system will be installed within the wheel. Two wheels will be powered by the main landing gear, one on the left and one on the right, Hamzeh says. Power will be close to 20 kW for each motor.

The device, which interfaces with 19 other aircraft systems, includes a motor, a gearbox and a clutch. The clutch ensures the motor is disengaged at takeoff and landing when the wheel needs to rotate fast.

Due to weight, electric taxiing does not make sense for all operations. It is suitable for short- and medium-range commercial aircraft—they perform several cycles a day with a considerable portion of operating time spent taxiing. But a business case can be found from four cycles per day, Hamzeh says.

The gearbox and the motor on the taxiing system will be removable so a lessor can take them off the aircraft when transitioning it to an operator that does not need electric taxiing capability. The weight savings will be two-thirds of the system's total.

Going Vertical

- JOBY PLANS TO BUILD "VAST MAJORITY" OF eVTOL AIRCRAFT IN-HOUSE
- COMPANY LEANS ON TOYOTA FOR MANUFACTURING EXPERTISE
- STARTUP EXPECTS TO BE ABLE TO INNOVATE MORE QUICKLY BY DOING MORE WORK ITSELF

Garrett Reim Marina, California

Executives at Joby Aviation know that some people are skeptical of the company's plan to manufacture the "vast majority" of components for its electric vertical-takeoff-and-landing aircraft in-house.

JOBY

Joby wants to dispel skepticism about vertical integration.

With that in mind, the startup invited more than 100 industry analysts, government regulators and stakeholders, as well as a handful of journalists, to its pilot manufacturing facility in Marina, a small town on California's northern coast, on Oct. 14.

"We sometimes get knocked around: 'Why are you spending so much money? Why do you have so many people? Why aren't you outsourcing things?'" says Paul Sciarra, executive chairman of Joby. "We hope that actually seeing some of the facilities today gives a sense of when you're doing something very new—we've seen this in other categories as well—it's really important to have a really tight coupling between the design work that gets done, and the manufacturing work that gets done, and the testing that gets done."

Citing vertically integrated operations such as Elon Musk's SpaceX and Tesla as well as the growing electric vehicle industry in general, Joby asserts that its process should allow it to build aircraft more quickly, more cheaply and better.

The Santa Cruz-based startup also says it did not have much choice but to vertically integrate.

"A lot of traditional aerospace companies have largely become systems integrators. They are taking developed components, and they're putting them together into an aircraft," Sciarra says. "Here, in this brand-new category—where there isn't someone to go to for aerospace-grade batteries, where there isn't someone to go to for the right kind of motors, where there isn't someone to go to for the right kind of software to control this—we've had to, by necessity, build it ourselves."

Joby acknowledges that vertical integration will require more time, people and capital. However, the company, which raised just over $1 billion via a special-purpose acquisition company merger in 2021, says it does not need to raise additional capital to execute its plans. "We can reap the rewards for that on the back end if we do it correctly, because we've got those capabilities in-house to move really quickly," Sciarra says.

At its pilot production plant, Joby plans to manufacture "tens" of aircraft per year as it works out the kinks in its process and moves toward FAA certification by the end of 2023 and operations in 2024. Aircraft being fabricated at the site currently will be used for the certification process, and some may eventually carry paying passengers.

Joby is aiming to produce the majority of its aircraft in-house, including all of the composite structures, flight electronics, actuation, integrated electric propulsion systems and most of the flight software, it says.

"We procure lithium-ion cells from a supplier and build battery modules, including sensors, thermal management, power distribution systems and wiring," the company says. "Outside suppliers include Garmin for the modified G3000 flight deck that we use aboard the Joby aircraft and Toray for our carbon-fiber materials."

The company is seeking outside help from Toyota to design its manufacturing process. Toyota invested $394 million into the electric vertical-takeoff-and-landing (eVTOL) developer in 2020 and has about 10 employees embedded at Joby's facilities here helping to design a manufacturing process that will scale up.

"It's really about applying the Toyota way of thinking to aviation," says Jamie Clark, general manager of flying mobility with Toyota Motor North America. "Toyota's strength is its process. We are teaching Joby a lot of that."

Joby employees talk of implementing the Japanese lean manufacturing principle of jidoka: "Automation with a human touch."

Clark, who previously managed a plant in Canada that manufactured the Toyota Corolla sedan, says automation is used to increase precision, eliminate ergonomic burdens and for high-throughput activities.

"The equipment is very similar to how we would build a car," he says, noting that the main difference is that vehicles are put together via bonding instead of spot welding. "We have all the components here for high-volume manufacturing."

Still, when Aviation Week toured the pilot production facility, many carbon-fiber pieces were being made by hand in lay-ups. Workers also wheeled pieces around the factory floor by hand.

Joby does boast an automated fiber-placement machine that is used to make larger components for the air taxi, including the 36-ft.-long wing skin. Automated fiber placement is used for less than 1% of components, but because fiber is used for larger pieces, it accounts for about 40% of the composite weight of the aircraft, the company says.

Joby also employs a robotic pulse-echo ultrasonic inspection system and a robot that applies adhesives to composite parts while simultaneously and automatically inspecting the work. The company uses automation to test its software as well.

The startup says vertical integration has allowed it to shrink and improve components drastically. For example, it notes that its flight computer, which was developed internally and has been through several iterations, now weighs less than an iPhone. Joby says the overall aircraft is more tightly integrated due to vertically integrated operations than it would be otherwise.

Joby is confident it has everything it needs to certify and bring its eVTOL to market, says JoeBen Bevirt, CEO and founder. Another generation of batteries is not needed for the aircraft, he says, declining to disclose whether the aircraft's batteries are based on pouch or cylindrical cells.

The company is researching with Toyota the use of thermoplastics on future variants of its air taxi but does not expect to need the technology initially.

"We're very pleased with the performance of thermoset," Bevirt says. "We were excited about the potential of thermoplastics as we scale to quantities that push into the thousands a year. But we think that thermoset is a good spot for both our pilot [plant] and Phase 1 production."

Over the long term, keeping as much production in-house as possible should allow Joby to iterate lessons learned into versions of its aircraft quickly, Sciarra says.

"Making sure that flywheel moves really quickly is the key to progressing very, very fast," he says.

Europe's Free Route Airspace Push Is Delayed by the Russia-Ukraine War

> NEW SYSTEM SHOULD LEAD TO FUEL, COST AND EMISSIONS SAVINGS

> FRANCE HAS IMPLEMENTED IT OVER HALF ITS AIRSPACE

Helen Massy-Beresford Brussels

Europe's air navigation service providers are pushing ahead with the implementation of free route airspace—though completion is scheduled for 2024, about a year later than initially planned—with the long-term aim of boosting efficiency and unlocking cost and fuel savings.

The delays are linked to the Russian invasion of Ukraine, Eurocontrol Director General Eamonn Brennan told Aviation Week Oct. 4 at a conference called "Where to Next for European Aviation?" at Eurocontrol headquarters in Brussels.

The application of free route airspace (FRA) should bring about major fuel, emissions and cost savings, boosting efficiency through better routing and more flexibility for operators. With FRA, pilots are now able to plan a route between a defined entry and exit point rather than having to follow a set route mapped out by air traffic controllers.

"Estimates show that FRA could save as much as 1 billion nm, 6 million [metric tons] of fuel, 20 million [metric tons] of CO_2 and €5 billion [$4.8 billion] in fuel savings," Simon Hocquard, director general of the Civil Air Navigation Services Organization, said at the conference. "While Europe is along this journey of FRA, there is still much to do."

"Realistically, it's going to be 2024 before we have free route airspace really operable all over Europe," Brennan said. "The Russian invasion has definitely slowed that down because there are a lot of other priorities—security issues become a top priority when you have a crisis like this."

FRA projects are, however, in place across more than three-quarters of European airspace.

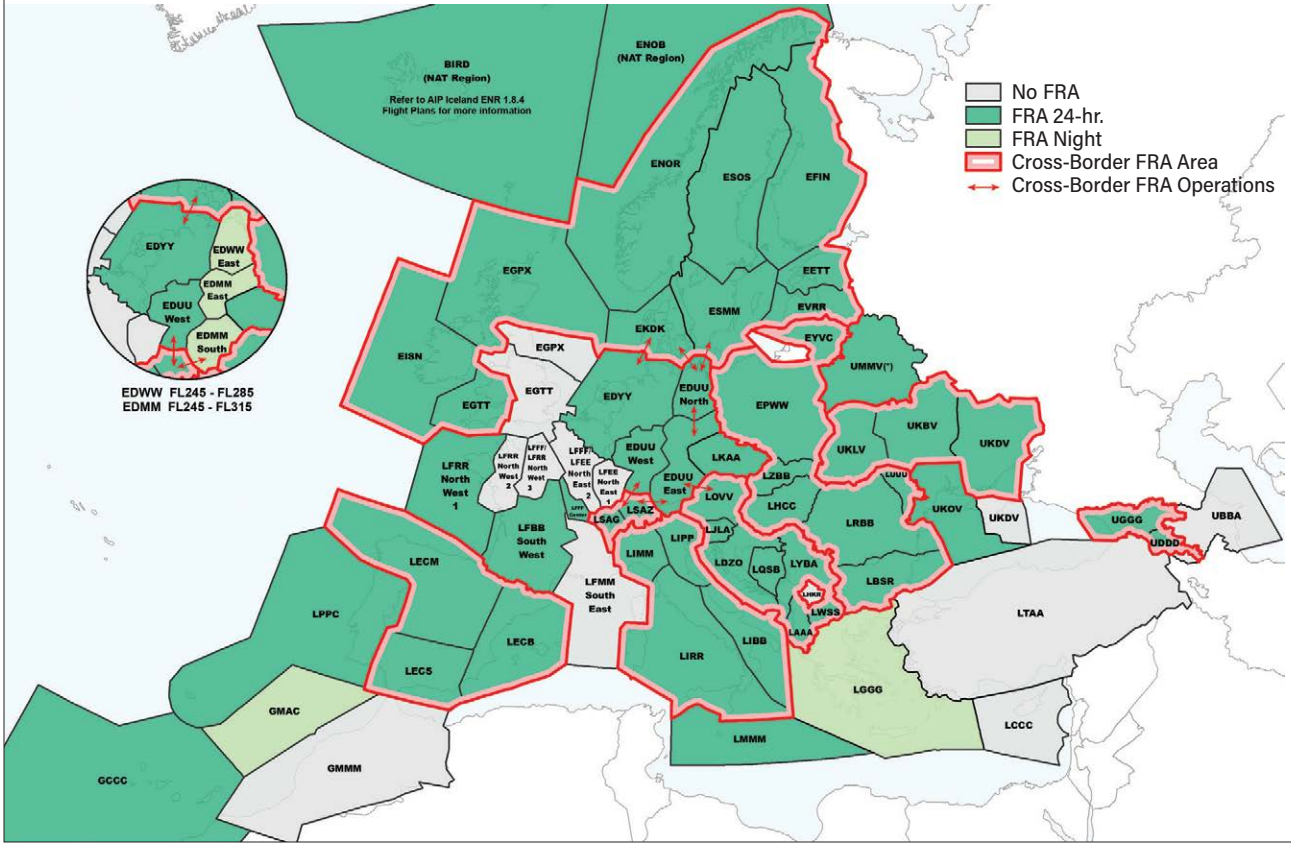
Eurocontrol says FRA is a key milestone in achieving free routing across European airspace on the road to the Single European Sky ATM Research (SESAR) program's business trajectories and 4D profiles, which will make it possible to meet the demands of future airspace users for the next 50 years, including civil and military uncrewed aircraft systems, supersonic and hypersonic transport, spaceplane operations to suborbit and orbit, high-altitude pseudo-satellite platforms, plus balloons and airships.

Florian Guillermet, director of

FRA implementation is just one area of technological progress for Eurocontrol.

By End of 2022

Eurocontrol Free Route



France's DSNA, said at the conference that the air navigation service provider (ANSP) is moving ahead with changes including FRA, despite the ongoing lack of clarity at a European political level about Single European Sky 2+ (SES) reforms.

"For sure, a change of regulatory framework will force things onto us," he said. "On the other hand, I think we've all acknowledged today that we have to move ahead regardless of whether SES 2+ will become reality. I think we can do much better with what we have today."

The ANSP implemented FRA in France in half its airspace a year ago, Guillermet said. "That's work we have done in coordination with Eurocontrol, other states and airlines. Our controllers have been trained and are happy to work on it because they feel they are contributing to the sustainability issue."

Brennan described that long-awaited SES revamp, which the aviation industry says could lead to fuel savings of 10%, as "the elephant in the room." He said: "I don't think it'll ever happen in the way we all would like it to happen—a real Single European Sky. But we can make improvements."

Eurocontrol is also looking ahead to a technology upgrade with its investment in a new network management system "The system is the way to do this. One of the big answers about how to start using the Single European Sky is just technology," Brennan said.

That new system is part of the overarching integrated network management program, which is planned to include the incremental renewal of all the network manager's main operational systems, resulting in a new digital architecture by 2030. The program encompasses issues such as enterprise architecture, agile development, artificial intelligence and machine learning, big data and data analytics, probability modeling, predictive analysis, cloud solutions, scalable systems and cyber-resilience.

The network management system is expected to go live at the end of the first quarter of 2024. At that point, Brennan said, "[the system will] go stratospheric . . . with one of the most modern systems in the world, and I think it will give us an additional 10% capacity boost by about 2025."

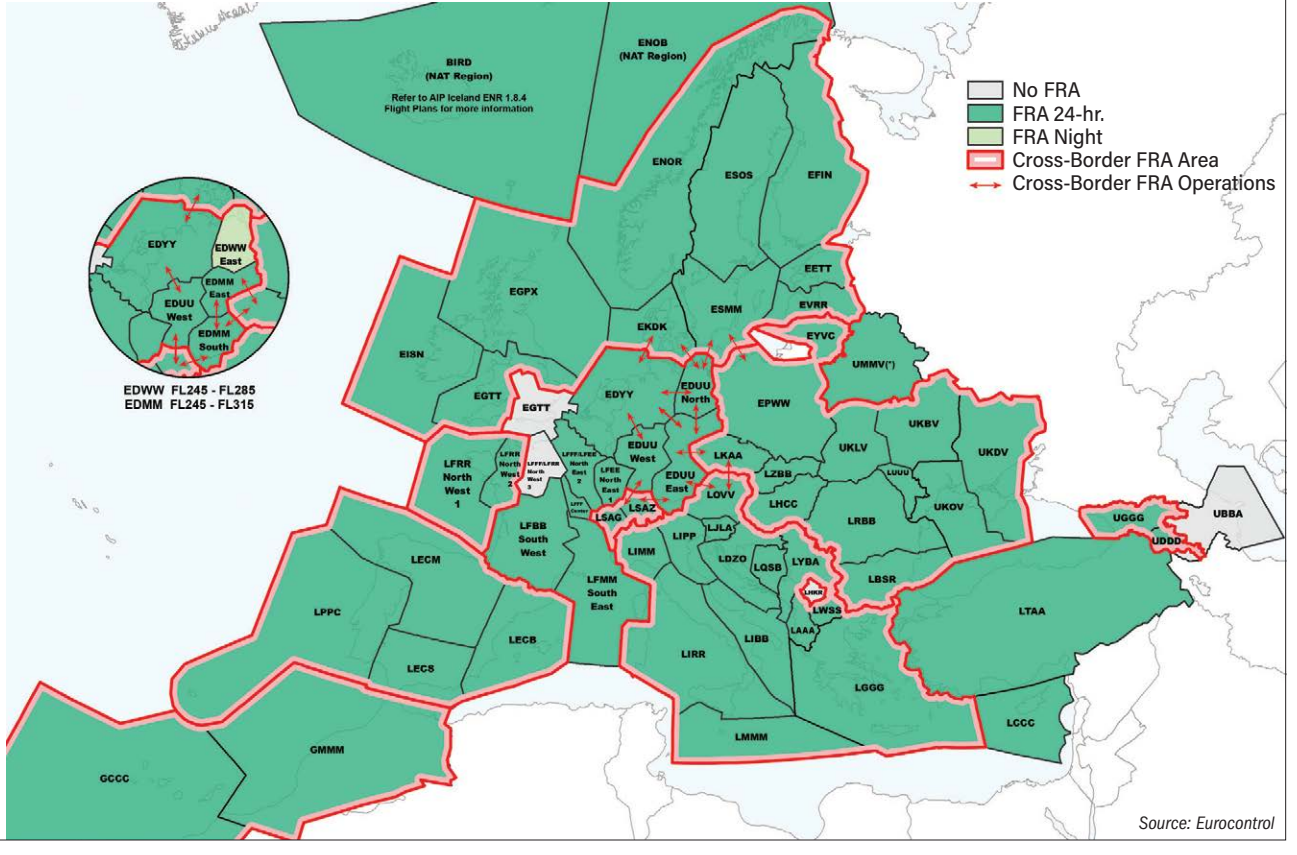
Legacy systems will evolve gradually over the following five years toward the new integrated network management system, which is designed to be able to manage 13.8 million flights per year, up from the 9.5 million (or 85% of 2019 levels) expected this year.

Between now and then, the industry and its ANSPs will have to face a challenging 2023 as capacity continues to ramp up, putting more pressure on the network, partly as a result of the invasion of Ukraine and its consequences for European airspace.

Brennan said one area of improvement for the region would be smoother cooperation between the civil and military sectors. "We're seeing a huge amount of airspace operating military flights [due to the Russia-Ukraine war]," he said. "This year we're operating 90% of 2019 flights with 80% of the airspace."

Airspace Implementation

By End of 2025



Source: Eurocontrol

New Biden Strategy Aims for Balance in Nuclear Spending and Rhetoric

- SUBMARINE-LAUNCHED CRUISE MISSILE PLAN TO BE REVERSED
- POLICY HIGHLIGHTS THE NEED FOR MORE DEFENSE INDUSTRY SUPPORT

Brian Everstine Washington

The Biden administration wants to reduce the role of nuclear weapons in America's national security, prioritizing issues such as competition with China and climate change. But experts say that the White House will face opposition in its attempt to cancel development of a low-yield sea-based nuclear cruise missile.

The White House on Oct. 12 released its long-awaited National Security Strategy (NSS), stating that the Pentagon needs to continue modernization of the nuclear triad as part of military spending required to compete with China.

"To ensure our nuclear deterrent remains responsive to the threats we face, we are modernizing the nuclear triad—nuclear command, control and communications and our nuclear weapons infrastructure—as well as strengthening our extended deterrence commitments to our allies," the strategy states.

But this modernization comes as President Joe Biden's strategy reinforces its goal of nuclear arms reduction. The administration outlines plans to take "further steps to reduce the role of nuclear weapons in our strategy" and to pursue "realistic goals for mutual, verifiable arms control, which contribute to our deterrence strategy and strengthen the global nonproliferation regime."

National Security Advisor Jake Sullivan said during a recent briefing that the NSS is the foundation for the upcoming public release of the Pentagon's National Defense Strategy and Nuclear Posture Review (NPR). The Biden administration has outlined goals to reverse the Trump administration's 2018 NPR plans to develop a low-yield, submarine-launched nuclear missile while also continuing nuclear modernization plans such as the Ground-Based Strategic Deterrent (GBSD) ICBM.

"You'll see with respect to the Nuclear Posture Review that, in fact, it does depart from some of the Trump-era formulas," Sullivan said.

With Russia more belligerent on the global stage amid its invasion of Ukraine, the U.S. needs to "strike a delicate balance of continuing to field a credible deterrent while also upholding its [Nuclear Non-Proliferation Treaty] obligations," says Heather Williams, the director of the Project on Nuclear Issues at the Center for Strategic and International Studies.

The Biden administration reiterated its position on the Sea-Launched Cruise Missile-Nuclear (SLCM-N) in a statement of policy regarding the Senate version of the fiscal 2023 defense policy bill, stating that the SLCM-N is "unnecessary and potentially detrimental to other priorities.

"Further investment in developing SLCM-N would divert resources and focus from higher modernization priorities for the U.S. nuclear enterprise and infrastructure, which is already stretched to capacity," the administration says. "It would also impose operational challenges on the Navy."

The SLCM-N has been contentious since it was announced, with politically appointed officials opposing it, though uniformed military commanders have supported it during congressional hearings. The divide is not necessarily partisan, with many in Congress inclined to support military commanders, says Army Maj. Gen. (ret.) John Ferrari, who is a nonresident fellow with the American Enterprise Institute.

The administration has long shown its lack of interest in the Trump policy-created missile, with the overall nuclear enterprise busy enough with extensive modernization programs, says Hans Kristensen, the director of the Nuclear Information Project with the Federation of American Scientists. That list includes the Northrop Grumman B-21, GBSD, Long-Range Standoff Missile and Columbia-class submarines, he adds.

KEVIN DIETSCH/GETTY IMAGES

President Joe Biden, pictured with Secretary of State Anthony Blinken (left) and Defense Secretary Lloyd Austin, released his long-awaited National Security Strategy in October.

"Additional weapons would overload the system and potentially jeopardize existing and more nuclear important modernization programs," he says, not to mention "compete for funding needed for more useable non-nuclear capabilities."

While some stakeholders, such as former U.S. Strategic Command (Stratcom) boss Adm. Charles Richard, have highlighted the need for the SLCM-N, Kristensen argues there has not been enough justification for more weapons.

"Yes, China is increasing its arsenal, but it will still be far below the size of the U.S. arsenal," he says. "And it's the Chinese leadership we need to deter, not their silos. Frankly speaking, Stratcom should focus on implementing the administration's policy instead of pushing its own agenda."

Broadly, the new strategy continues the existing plans for military modernization to compete with China while also deterring Russia. The U.S. is in a "decisive decade" dealing with these two powers, along with transnational challenges from climate change, inflation and the pandemic, Sullivan says.

The NSS notes Russia's ongoing invasion of Ukraine and the subsequent delivery of billions of dollars' worth of military equipment by the U.S. and across the West.

"The war in Ukraine highlights the criticality of a vibrant defense industrial base for the United States and its allies and partners," the strategy says. "It must not only be capable of rapidly manufacturing proven capabilities . . . but also empowered to innovate and creatively design solutions as battlefield conditions evolve."

China's military aviation surge **p. 34**

Ramjet-Rocket PRSM Variant Nears Competitive U.S. Army Award Decision

> INTEGRAL ROCKET-RAMJET DOUBLES RANGE TO 1,000 KM

> NEW VARIANT ADDS OPTION FOR MID-RANGE CAPABILITY BATTERIES

Steve Trimble Washington

A contract is expected to be awarded by the end of October to start a development program for the fourth long-range, surface-to-surface missile created by the U.S. Army since 2019 and the first featuring an ambitious, integral rocket-ramjet propulsion system.

Several companies have submitted bids for the Precision Strike Missile (PRSM) Increment 4 contract. Lockheed Martin, which is building the first two increments of the rocket-only version of the PRSM, submitted a bid in September. Boeing and Northrop Grumman also sent offers to the Army. Raytheon has not confirmed whether it is competing for Increment 4, but it participated in the original competition for the baseline PRSM program. The winner will have the opportunity to develop the most advanced version of the mobile, medium-range PRSM.

The baseline, 500-km-range (310-mi.) version of the PRSM now being developed by Lockheed is required to augment the 300-km range of an MGM-140 Army Tactical Missile System (Atacms) when launched from an M142 High-Mobility Artillery Rocket System (Himars), while doubling the loadout with two 13-ft.-long missiles per launcher.

The Increment 4 version of the PRSM is being designed to double the range of the baseline version to more than 1,000 km, without altering the length or width of the missile so that it can still fit into the same Himars launch pod.

The additional range would be achieved by adding an integral ramjet to the PRSM's rocket. This combined-cycle propulsion system seeks to offer the best of both worlds, uniting the energy density of a solid-fuel rocket with the greater efficiency of an air-breathing ramjet. The result hoped for would be a doubling of range using the same missile body.

Adding an air-breathing propulsion system will change the flightpath. The baseline PRSM launches on a steep ballistic arc that reaches a peak altitude in space. The missile then reenters at near- or faster-than-hypersonic speed during a terminal dive on the target. Since a ramjet cannot operate outside the atmosphere, the Army will likely launch the Increment 4 version on a depressed trajectory. By staying within the atmosphere, the Increment 4 missile would not reach the same top speed as the baseline PRSM.

Lockheed Martin plans to start fielding the PRSM Increment 1 near the end of next year.

KINSEY LINDSTROM/WHITE SANDS MISSILE RANGE

As the variant's name suggests, Increment 4 is one of several versions of the PRSM but the first one that the service has reopened to competitive bids. In addition to Increment 1, Lockheed also is developing the PRSM Increment 2, which will add an Army-developed, multimode seeker for maritime and poorly located land targets, along with about 100-200 km of additional range. Increment 3 also will be opened for competitive bids; it proposes to add a new front end that can dispense submunitions prior to impact.

The service originally planned to start developing Increment 3's submunition variant first but later decided to prioritize the combined-cycle propulsion version in Increment 4 to enter into service sooner. The Increment 3 version may benefit from the integral rocket-ramjet introduced with the Increment 4 propulsion system.

A possible factor in the Army's decision to speed up Increment 4 was the success of a PRSM ground test with an integral rocket-ramjet engine last year.

The service plans to buy about 4,000 PRSMs, but it is not yet clear how many of each variant. The baseline version is expected to be fielded by the end of next year for the Army's recently established Multidomain Task Forces. Each task force is planned to have a Strategic Fires Battalion with three batteries: a Long-Range Hypersonic Weapon battery firing Lockheed-Dynetics Dark Eagle boost-glide missiles, a Mid-Range Capability (MRC) battery with ground-launched Raytheon SM-6 and Maritime Strike Tomahawk (MST) missiles and a Himars battery firing Lockheed PRSM, Atacms and Guided Multiple-Launch Rocket System missiles.

But the MRC battery's two current options—the SM-6 and MST—likely will be revisited. The Army plans to buy only five MRC batteries with ground-launched versions of the two anti-ship missiles. A PRSM Increment 4 with the Army-developed terminal seeker will offer similar range and the ability to target ships. By fielding the PRSM Increment 4 with Himars launchers, the Army also would improve the mobility of the MRC battery. The baseline MRC battery is being fielded on a flatbed truck modified with hydraulics to raise and lower the launch tubes.

The question now is whether the Army can deliver Increment 4 as advertised. The solicitation process was released through the Aviation and Missile Technology Consortium rather than the traditional acquisition process. By using the consortium to administer the Other Transaction Authority solicitation, the Army can speed up the acquisition process, but many of the details of the requirements and schedule are being kept secret among the bidding teams.

U.S. NAVY

Future GE Engine Could Work With the F-35B, Study Finds

- GENERAL ELECTRIC, LOCKHEED MARTIN, ROLLS-ROYCE AND THE F-35 JOINT PROGRAM OFFICE CONDUCTED THE STUDY
- PRATT & WHITNEY SAYS THE WEIGHT OF THE ADAPTIVE ENGINE WILL HAMPER VERTICAL LIFT

Guy Norris Colorado Springs and East Hartford, Connecticut

As a U.S. Defense Department decision looms over the potential use of adaptive engines in the Lockheed Martin F-35, General Electric says a study has concluded the XA100 advanced propulsion system could work in the short-takeoff-and-vertical-landing variant.

But Pratt & Whitney, which continues testing and development of its own XA101 adaptive engine, remains critical of GE's proposal—particularly for the short-takeoff-and-vertical-landing (STOVL) variant. The study result comes as Pratt steps up a campaign to push the advantages of developing an F135 enhanced-engine-package (EEP) upgrade as a more practical and affordable alternative to replacing the existing powerplant with an all-new, three-stream propulsion system.

The GE XA100 STOVL option study was undertaken with the F-35 Joint Program Office (JPO), Lockheed and Rolls-Royce—the provider of the lift fan system that enables the F-35B version to operate in STOVL mode. The study outlined the feasibility of modifying the variable-cycle engine for operation in future versions of the F-35B. Italy, Japan, Singapore, the UK and the U.S. Marine Corps operate the variant.

The study was completed in time for the fall meeting of the Joint Strike Fighter Executive Steering Board to evaluate how the XA100 fan and compressor could be modified for the role. This included ways to attach the new low-pressure system to the lift fan's driveshaft and gearbox clutch. Other required changes included integrating the XA100 with the roll posts and other elements of the lift system.

GE says the evaluation, which was supported by Lockheed, recently was concluded "for the F-35 Joint Program Office, which looked at how we would address the unique B-variant integration requirements. It was a collaborative and productive effort, and we were happy our results showed a path that could meet the customer's technical goals."

Developing an adaptive engine for the F-35B faces challenges of weight and power offtake requirements.

Pratt is skeptical that GE's adaptive engine can fulfill the current F-35B mission. "All adaptive motors are heavier than today's," says Jon Niemeyer, chief engineer at Pratt for the F135. "You start looking at STOVL as an application, but what happens to the weight, especially where weight is a key parameter? So that combination of getting the increased weight plus increased power demands with all this other stuff going on—can they actually even beat today's motor?"

Aside from the complexities involved in integrating an adaptive engine architecture to the unique offtake demands of the STOVL mission, "there's a chance [GE] can't overcome the weight obstacle and meet the vertical-landing bring-back [mission requirement for returning with unused stores], even if they compromise everything," Niemeyer tells Aviation Week. "Typically, it takes almost a two-times factor in how hard you push the core to deliver capability in the lift fan.

"If I've got bigger power offtakes, the low-pressure turbine needs to be redesigned to meet the amount of additional pressure ratio," he continues. "So it's most likely going to be increased diameter and increased length. And now the question is: How do you make space for it? Now you have this adaptive architecture that's got three streams, and that's what allows you to generate commercial-like fuel burn by shifting the modes of the motor. As you start doing some of these changes on STOVL, you start compromising what a three-stream architecture was trying to do by consuming space in both directions."

The challenge is made more difficult in the F-35 by the need to install the new engine within the confines of the fuselage. "It has to fit in an existing weapon system like the F-35," Niemeyer notes. "You now have to start talking about what to do to the exhaust system to make it work. The nozzle for STOVL is unique; it's not clear how you make that work. In my opinion, everything's solvable, always. The question is: Under what schedule and at what cost?"

Lawmakers meanwhile have sent

a bipartisan, bicameral letter to the Defense Department, urging it to continue funding the development of adaptive propulsion systems for fighter aircraft in the fiscal 2024 budget submission. Drafting of the letter was led by Ohio Sens. Rob Portman (R) and Sherrod Brown (D) and Ohio Rep. Brad Wenstrup (R). It warns that without continued support for new engine technology, "we risk opening the door for U.S. adversaries to overtake our advantages."

In this area at least, both GE Aerospace and Pratt appear to be on common ground, as work on the XA100/101 nears an end under the current Adaptive Engine Transition Program (AETP). Pratt says it "is committed to the continued maturation of the technology suite in AETP, as it is foundational for the sixth-gen capabilities needed for the Next-Generation Air Dominance (NGAD) family of systems in the 2030s."

Although initial adaptive engine study contracts were issued in August for the prototype phase of the Next-Generation Adaptive Propulsion (NGAP) engine program for NGAD, it is not clear whether funding for additional rounds will be secured for the fiscal 2024 budget and beyond. The existing awards were made to GE and Pratt in addition to Boeing, Lockheed and Northrop Grumman.

Coming two years after the acknowledged first flight of at least one prototype demonstrator vehicle, the awards also indicate the two enginemakers have been stepping up the level of propulsion-integration work with the airframe manufacturers. The engine contracts emerged after the Air Force declared it is planning to ramp up spending on the NGAD program ahead of fielding by 2030, with $1.7 billion in research, development, test and evaluation funding.

In the meantime, Pratt's proposed outline for the EEP configuration is focused largely on a power-module upgrade, which has had its roots in technology tested since 2013 in the U.S. Navy Fuel-Burn Reduction (FBR) program. The package also would include some minor upgrades to the gearbox for additional power offtake and associated connections to the F-35 power and thermal management system, as well as some unspecified adaptive features from the company's Adaptive Engine Technology Demonstration (AETD) and more recent AETP work.

The EEP core changes apparently are focused on upgraded materials, blade-geometry refinements and coating improvements in the high-pressure compressor, turbine and combustor, many of which are refined elements of the Growth Options 1 (GO-1) upgrade package that Pratt began offering in 2017.

At the time, GO-1 provided either a 6% fuel-burn reduction or as much as a 10% thrust improvement. In the case of the EEP, the FBR/GO-1-related improvements are likely to be traded for the F-35's much-needed Block 4-plus thermal-management upgrade requirement, as the more efficient core also would provide additional heat capacity.

U.S. Army 'Learns Quick' With Contractor-Owned ISR Jets

> ATHENA-R SELECTION AND DEPLOYMENT ARE SLATED TO COME NEXT

> ACQUISITION STRATEGY SEEKS TO AVOID FAILURES LIKE THOSE OF THE AERIAL COMMON SENSOR

Steve Trimble Washington

When the U.S. Army's intelligence branch deployed a newly modified, contractor-owned surveillance jet to Japan in July 2020, problems were expected. It was the Army's first foray into high-altitude spying, representing the biggest leap in the service's fixed-wing intelligence-gathering fleet in several decades.

The L3Harris-owned ARES jet is flying ISR missions in the Pacific theater from Kadena Air Base in Okinawa, Japan.

L3HARRIS

Sure enough, there were problems with the Leidos-owned Bombardier Challenger 650 serving as the Airborne Reconnaissance and Targeting Multimission Intelligence System (Artemis).

"We got screaming back from the commands we gave it to, and they said: 'Fix this, that and the other,'" Lt. Col. Matt Paladino, the aerial branch chief of the Army's Aerial Intelligence, Surveillance and Reconnaissance (ISR) Task Force, tells Aviation Week.

But that was the plan. As the Army aims to field a fleet of sensor-equipped high-altitude jets in several years, the cancellation of the similar Aerial Common Sensor program nearly 17 years ago offers a cautionary tale. The Army is taking a fly-first approach to the new acquisition program, deploying a variety of new intelligence sensors on a series of contractor-owned business jets first. But program officials know there are still limits to the trial-and-error approach.

"People say that we're 'failing fast,'" Paladino says, invoking an innovation buzzword. But "it's really hard to survive failing fast. What they mean is 'learn quick,' and we did that."

The Artemis jet continues to operate in the European theater. In addition, the L3Harris-owned Airborne Reconnaissance and Electronic Warfare System (ARES) on a Bombardier Global 6500 is supporting Army intelligence operations from Kadena Air Base in Okinawa, Japan. A second Artemis jet is poised to join the fleet. Finally, the Army plans to select contractors soon to operate a fleet of sensor-equipped business jets for several years under the Army Theater-Level High-Altitude Expeditionary Next Airborne ISR Radar (Athena-R) program.

Artemis, ARES and Athena-R will perform real-world surveillance missions around the world, filling a deep sensing gap in the Army's intelligence-collection systems. At the same time, the aircraft also are functioning as testbeds, informing requirements for the follow-on program of record. By 2030, the Army's intelligence arm hopes to replace a fleet of turboprop-powered RC-12s and RC-7s with a fleet of business jets.

In parallel with the contractor-owned jet deployments, the Army is developing a new high-altitude sensor payload with the High-Accuracy Detection and Exploitation System (HADES). L3Harris and Raytheon have entered Phase 2 of the competitive development effort, which is intended to deliver electronic- and communications-intelligence payloads. A synthetic aperture radar with a ground moving-target-indication mode also is expected to be integrated on the Army-owned fleet.

The HADES acquisition strategy—deploying contractor-owned prototypes to serve missions and inform development—differs from the Defense Department's traditional approach but is familiar to U.S. Special Operations Command (SOCOM). In fact, Col. Joe Minor, the program manager for the Army's fixed-wing acquisition programs, came from SOCOM and sees the similarities.

"The SOCOM model is very, very tight between the requirements folks and the acquisition folks, and I think we're seeing that here in this community," Minor says.

The Army is still learning how to perform the high-altitude sensing mission. The contractor-owned jet deployments are helping the service understand how sensors perform at higher altitude and speeds. The operational missions are also demonstrating which capabilities are valued by operational commanders, and sometimes that depends on whether the target is in Europe or the Asia-Pacific region.

The program also is showing its utility despite moves by the U.S. Air Force to reduce its high-altitude sensing fleet. The Air Force canceled the J-Stars recapitalization program in 2019, citing the vulnerability of business-jet-class ISR aircraft in future operations. The E-8C J-Stars fleet will be retired in fiscal 2025 with no airborne replacement. The Army still sees value in operating airborne ISR jets, collecting intelligence until hostilities erupt.

Gen. Charles Flynn, commander of Army forces in Indo-Pacific Command, lent his endorsement on Oct. 11 during a panel discussion at the Association of the U.S. Army's annual meeting.

"We need deep sensing out there, and we're starting to work on that with an aircraft called ARES flying out of Kadena," Flynn said. "If I had an empty checkbook, I'd buy five ARES aircraft because of the deep-sensing requirements of the joint force."

Joint Qatari-UK World Cup Defense Helps Clinch Eurofighter Deal

> QATAR RECEIVED FIRST EUROFIGHTER BATCH IN THE SUMMER

> AERIAL-REFUELING SERVICE PROVIDED THROUGH UK-QATAR AGREEMENT

Tony Osborne RAF Coningsby, England

Football fans gathering in Qatar during November and December to cheer on their national teams in the FIFA World Cup likely will be blissfully unaware of the enormous security operation that has been developed to protect them.

Part of the Arabian Gulf state's much enlarged armed forces will be devoted to the event's security, and they will be supported by a joint UK-Qatari fighter squadron flying the Eurofighter Typhoon through Project Thariyat (Arabic for "Typhoon"), a spinoff from Qatar's £6 billion ($6.7 billion) acquisition of 24 Eurofighters agreed to in December 2017.

Creation of the joint Royal Air Force (RAF) and Qatar Emiri Air Force (QEAF) unit—12 Sqdn.—in 2018, the RAF's first joint squadron since World War II, is one of several pillars of the UK's Qatar Air Programs initiative that appears to have helped seal the Typhoon deal and has become central to strengthening UK-Qatari defense ties.

Another pillar of the program is the creation of a second joint squadron, flying BAE Systems Hawk jet trainers, based in the UK but dedicated to training Qatari fighter pilots. The UK also is providing Qatar an air-to-air refueling service with one of its Airbus A330 Voyager Multi-Role Tanker Transport aircraft through a series of six 10-day deployments during 2021 and 2022. That service has allowed QEAF pilots—primarily from Dassault Rafale squadrons—to perform aerial refueling training, as Qatar lacks its own tanker capability.

After qualifying as pilots through Doha's air force academy, the Qatari pilots complete the UK training system with English language and basic UK flight-training courses to enable them to become comfortable with flying in the UK before they fly the Hawk and the Typhoon.

"These initiatives are part of a deepening UK-Qatari relationship," Air Cmdre. Richard Yates, the RAF's senior officer responsible for the Qatar Air Program, tells Aviation Week. "Qatar is an impressive, technically adept and ambitious nation. Its air force has grown quickly, becoming highly technically competent. And, importantly, they like what they see with Typhoon."

One goal of the joint unit is for Qatari crews to gain 2-3 years of Typhoon flying experience before they receive their first aircraft, Yates adds. This enables Qatar to make operational use of its first batch of Typhoons, which were delivered during the summer, flying them alongside the joint RAF-Qatari unit in support of World Cup security.

SAC. TOMAS BARNARD/ROYAL AIR FORCE

The skyline of Doha will become a familiar sight to aircrews of the joint RAF-QEAF squadron over the coming weeks in their mission to help protect the FIFA World Cup.

In the UK, Qatari Typhoon pilots are trained in the full multirole capabilities of the aircraft, says Sqdn. Ldr. Luke Wilkinson, 12 Sqdn.'s executive officer and a pilot on the unit. Qatari Typhoons are equipped with largely the same weaponry as the RAF's, including the MBDA advanced short-range air-to-air missile and Meteor air-to-air missiles. The Qatari fighters also carry the Lockheed Martin Sniper targeting pod, which was selected for commonality among the country's three fighter fleets. The new-build aircraft being delivered to the QEAF are fitted with the European Common Radar System Mk. 0 active, electronically scanned array radar, too, whereas the RAF-owned Typhoons flown by the joint unit carry the mechanically scanned sensor.

Training on the radar is provided through what Wilkinson calls a delta training package provided by BAE Systems, although the radar is operated through the Eurofighter's human-machine interface in the same way as it is for the mechanically scanned array.

Yates says this UK approach to partnership could be extended to future Eurofighter exports and perhaps eventually the Tempest Future Combat Air System.

The joint squadron has been deployed and is ready for World Cup security operations and training with the QEAF from the newly constructed Al-Dukhan Airbase in the west of Qatar for up to six months. The future of 12 Sqdn. beyond the deployment is under discussion.

Qatari fighter pilots are slated to train with the Hawk squadron in the UK for the next six years, with options for another six years. The RAF will train its own fighter pilots through the unit as well, allowing it to raise training output at a time when it has been facing criticism over pilot training delays. The aerial refueling service may continue too, potentially paving the way for Qatar to invest in its own tanker capability.

Qatar's Eurofighter order follows contracts with France for the Dassault Rafale and with the U.S. for Boeing's F-15QA "Ababil" Advanced Eagle. This three-pronged fleet of 96 aircraft is meant to replace Doha's Dassault Mirage 2000 force, growing the country's fighter inventory eightfold.

Future Chinese Military Aircraft

H-20 Strategic Bomber

Official U.S. sources expect a stealthy, flying-wing, subsonic bomber to become operational by the end of this decade. Avic, the manufacturer, has said the project was officially launched in 2008, but concept development activity likely began in the 1990s. In November 2016, then-PLAAF commander, Gen. Ma Xiaotian, officially confirmed the existence of the program, saying a long-range bomber was in development. Since then, Avic has teased the shape of the aircraft in brochures and advertisements, with a veil shrouding an aircraft shaped generally like a Northrop Grumman B-2. The aircraft's actual shape has not been released.

JH-XX Tactical Bomber

This is a long-rumored concept for a possibly stealthy, supersonic medium bomber to complement the Xian H-20. Although never officially confirmed, images of unidentified concepts sometimes linked to the JH-XX have appeared since 2011. A "fighter-bomber" developmental project appeared in the 2019 China Military Power report published by the U.S. Defense Intelligence Agency. The report described the bomber as having an active, electronically scanned array radar; long-range air-to-air missiles; and precision-guided munitions, but it lacked sources or citations.

J-?? Next-Generation Fighter

A sixth-generation fighter will enter service by 2035 or earlier, said Wang Haifeng, chief designer at Chengdu Aircraft Research and Design Institute, in January 2019 interview with the Xian-based journal *Ordnance Industry Science Technology*. Such an aircraft may have improved stealth, adaptive engines, laser weapons and hypersonic missiles, Wang added. Although some analysts believe China's next fighter will replace the lightweight J-10, Yang Wei, chief designer of the Chengdu J-20, has proposed an alternative vision. In an essay published in July 2020 by *Acta Aeronautica et Astronautica Sinica*, a monthly Chinese journal, Yang wrote that a future fighter jet will generally require greater stealth, endurance, range and weapons load than current aircraft. The next-generation fighter also will collect so much information, Yang said, that artificial intelligence algorithms will be needed to make sense of the data for the pilot.

Y-19/Y-30 Tactical Airlift

Various concepts have appeared of a long-term replacement for the Shaanxi Y-8/Y-9 transport fleet, which is derived from the late-1950s-era Antonov An-12. The Y-19 may be a twin-turboprop replacement based on the proposed WJ-10 engine, according to some sources. Alternatively, Avic showed off a concept at the 2014 Zhuhai Airshow of a four-engine, 130,000-lb. airlifter called the Y-30.

China's Military Aviation Surge

> TIMING OF H-20 PROGRAM STILL A MYSTERY

> ZHUHAI EVENT TO FEATURE TIANGONG SPACE STATION REPLICA

Steve Trimble Washington

A new combat aircraft with "strategic and historical" significance to the Chinese military was close to an important flight-test event in July.

Xian Y-20

The *Global Times*, a daily newspaper published by the Chinese Communist Party, quoted Ge Heping, the political commissar of the Chinese Flight Test Establishment, as urging his staff to work harder to achieve the milestone test. The identity of the new aircraft has not been confirmed.

Beijing has made a number of advances in the last two decades on the combat aircraft front. Nearly a dozen years ago, the first Chengdu J-20 stealth fighter broke cover during high-speed taxi tests. The first images of the Xian Y-20 airlifter emerged a decade ago, and the first flight of the Harbin Z-20 utility helicopter took place more than nine years ago.

As the 14th China International Aviation and Aerospace Exhibition, also known as Airshow China 2022, prepares to open in Zhuhai on Nov. 8, the status of the fourth, final and possibly most interesting of the People's Liberation Army Air Force's (PLAAF) "20-series" military aircraft remains unknown: the Xian H-20 stealth bomber.

Speculation about the timing of a public debut for the long-range strategic bomber has been circulating for years. A meeting of Chinese military leaders concluded in 2015 that the PLAAF needs such an aircraft. In 2016, Gen. Ma Xiaotian, the then-PLAAF commander, publicly confirmed that China was developing a new bomber. Avic, the manufacturer, teased the program's imminent debut at the end of a May 2018 promotional video. The U.S. military has acknowledged the program's existence, saying in a 2020 report to Congress that the "advanced bomber" may not enter service for a decade.

Chengdu J-20

The scheduled rollout of the Northrop Grumman B-21 Raider in December comes a month after Airshow China, giving the PLAAF and Avic a public stage on which to steal the spotlight from the U.S. Air Force's new stealth bomber.

Shenyang WS-10

STEVE TRIMBLE/AW&ST PHOTOS

Chinese Military Aircraft in Development and Production

People's Liberation Army Air Force | People's Liberation Army Ground Force | People's Liberation Army Navy Air Force

Programs in Development | Aircraft in Production

Type	Origin	Program of Record Quantity	Percentage Delivered (estimated)
BOMBER			
Xian H-20	Possibly new design	34	0
Xian H-6N	Tu-16 modified for aerial refueling and carrying long-range missiles	24	15-20
Xian H-6J	Tu-16 modified with turbofan engines	43	50-55
FIGHTER			
Chengdu J-20/ J-20A/J-20AS	MiG-1.42/44, modified with internal weapons bay. May include F-22-style forward fuselage and F-35-style inlets.	186	45-60
Shenyang J-16	Strike aircraft derived from two-seat J-11BS, which is based on the single-seat Su-27	440	30-35
Shenyang J-16			
Shenyang J-16D	Electronic warfare version of J-16	32	25-30
Chengdu J-10C	Appears to leverage general airframe layout of the Israel Aerospace Industries Lavi, with Chinese-developed fly-by-wire and avionics	195	25-30
Shenyang J-15D	Electronic attack version of Su-33-derived J-15	15	0
Shenyang J-15T	Two-seat variant of Su-33-derived J-15	25	35-40
TRAINER			
Hongdu JL-10	Yak-130 with modified aft fuselage	145	25-30
Guizhou JL-9G	Two-seat trainer variant of J-7, which is a Chinese version of the MiG-21	50	60-65
COMMAND and CONTROL/INTELLIGENCE, SURVEILLANCE and RECONNAISSANCE			
Shaanxi Y-9G/ W/X/XZ	Psychological operations and electronic-intelligence versions of Y-9, which is a stretched and upgraded version of Y-8. The Y-8 is derived from the An-12.	25	65-70
Shaanxi Y-8Q	Anti-submarine version of the Y-8, which is based on the An-12	54	55-60
Xian KJ-600	A development of the JZY-01 demonstrator, featuring more compact fuselage and Northrop E-2-style vertical tails	11	10-20
AIRLIFT/TANKER			
Shaanxi Y-9	A stretched and upgraded version of Y-8, which is a deriviative of the An-12	58	75-80
Xian Y-20A	New design with Russian D-30 engines, with possible assistance by Antonov	34	90-95
Xian Y-20B	New version of the Y-20A powered by Chinese WS-20 engines	68	0
Xian Y-20U	Tanker variant of the Y-20	45	5-10
HELICOPTER			
Changhe Z-8G/L	Modernized version of the Harbin Z-8, derived from the Aerospatiale Super Frelon	289	20-25
CAIC Z-10A	New design that resembles the Mangusta and Rooivalk, although Kamov claimed in 2013 that it secretly provided China with the Z-10 design in 1995	312	45-50
CAIC Z-10K	A Z-10 modified for Airborne Corps attack mission	52	75-80
Changhe Z-18F	Anti-submarine warfare variant of Z-8	25	25-30
Changhe Z-18J	Airborne early warning variant of Z-8	6	50-70
Harbin Z-19	Attack/scout helicopter developed from the Harbin Z-9 utility rotorcraft, a license-built Airbus AS365 Dauphin	187	80-85
Harbin Z-20	Battlefield utility helicopter with a strong similarity to Sikorsky S-70. Uses five-blade main rotor and features fly-by-wire flight controls	252	10-15
Harbin Z-20F/S	Anti-submarine warfare variant of the Z-20	73	10-15
Mil Mi-17/171	Russian medium twin-turbine helicopter	282	75-80

Source: Aviation Week Intelligence Network

But there is scant evidence that the Chinese plan to seize the opportunity. Despite Ge's comments suggesting an imminent first flight of something in July, no confirmation from any program, including the H-20, has appeared in the intervening time.

The press conference prior to Airshow China in Zhuhai on Sept. 27 prompted another wave of speculation. A Chinese journalist asked the PLAAF spokesman, Senior Col. Shen Jinke, about whether a new member of the "20-series" aircraft family could appear in the static display. Shen replied that the PLAAF would display new achievements in "long-range strategic delivery," along with equipment the audience "has never seen before," the *Global Times* reported.

A new bomber qualifies as a long-range aircraft capable of "strategic delivery," but there are other options. Shen's comments also could be interpreted as referring to the Xian Y-20U, a refueling variant of the indigenous airlifter that might support the H-20 bomber on long-range missions. Chinese state media "unveiled" the Y-20U in July, showing the tanker refueling fighters during predeployment training. The aircraft made a public debut in late August at the Changchun Airshow in northeast China.

An air show also is an unlikely venue for a public unveiling. Some aircraft, such as the Y-20, appeared at Zhuhai within two years of first visual evidence of the program's existence. But most Chinese military aircraft are revealed in photographs long before they appear at an air show.

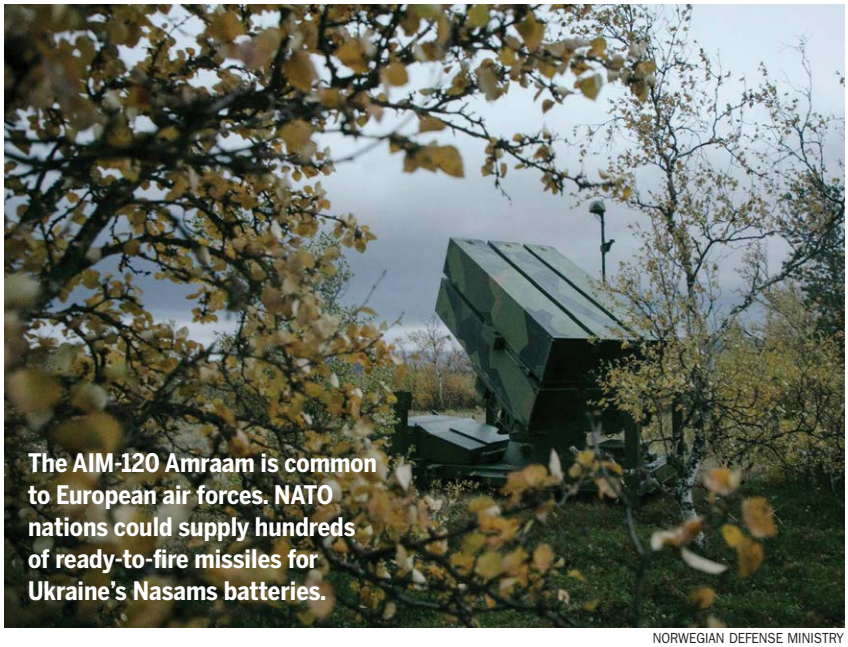
For example, the J-20 first appeared at Zhuhai in 2016, which came nearly five years after the twin-engine fighter entered flight testing. The PL-15 missile was officially unveiled at Zhuhai in 2018, which also came five years after the first photographs of the long-range air-to-air weapon appeared. Last year, China showed off the Shenyang J-16D for the first time. The 2021 Zhuhai event had been delayed by a year due to the COVID-19 pandemic, but if the show had been held as scheduled, the electronic warfare aircraft also would have made its debut five years after its first flight.

Instead, the event is expected to reveal progress across China's aviation and space industry. The Chinese government has confirmed it will display a full-scale replica of the roughly 100-ton Tiangong Space Station for the first time.

Closing Ukrainian Skies

> RUSSIAN CRUISE AND BALLISTIC MISSILES AND IRANIAN-MADE DRONES STRIKE UKRAINE'S CITIES

> 15 EUROPEAN COUNTRIES ARE PLEDGING TO INVEST IN AIR DEFENSES



The AIM-120 Amraam is common to European air forces. NATO nations could supply hundreds of ready-to-fire missiles for Ukraine's Nasams batteries.

NORWEGIAN DEFENSE MINISTRY

Tony Osborne London

After waves of recent devastating cruise and ballistic-missile and loitering-munition strikes against Ukraine's cities, President Volodymyr Zelenskyy hopes the arrival of advanced Western air defense systems can help close his country's skies to Russian strikes.

Zelenskyy wants an integrated system, a "sky shield," that would link Ukraine's existing Soviet-era surface-to-air missile (SAM) systems with the Western-built ones now beginning to arrive in the country.

Implementation of a sky shield requires the transfer of medium- and long-range SAM systems rather than short-range and point-defense weapons that Western nations provided prior to and in the early days of the conflict and that proved highly successful against Russian helicopters and combat aircraft.

"When Ukraine receives a sufficient number of modern and effective air defense systems, the key element of Russian terror—missile strikes—will cease to work," Zelenskyy told G7 leaders on Oct. 10.

Despite intelligence suggesting Russian stocks of guided missiles are running short, the need for more air defense capability may become more acute since it emerged that Moscow also could begin receiving Fateh-110 and Zolfaghar ballistic missiles from Iran.

Russia already is using Iranian-made loitering munitions to pound civilian targets, with the Ukrainian government suggesting that Moscow may have ordered as many as 2,400 delta-wing Shahed-136 systems from Tehran (*AW&ST* Oct. 10-23, p. 32).

European nations are responding, with NATO defense ministers announcing transfers of air defense systems and the munitions to arm them at a meeting in Brussels on Oct. 13, but many of the nations transferring equipment do not have many systems available to hand over.

"Ground-based air defense has been a recognized area of weakness for European militaries for a long time," Douglas Barrie, senior fellow for military aerospace at the London-based International Institute for Strategic Studies, tells Aviation Week.

"When you have spent the last 20 years fighting a counterinsurgency in Afghanistan or Iraq, national invest-

ment profiles were not focused to deal with cruise missiles or combat aircraft," he says.

There has been a "benign neglect" of ground-based air defense, Barrie notes. After the Cold War, many European countries believed control of the air was possible through conventional airpower and that it would be enough to provide ground forces with the freedom to maneuver.

Such a vision was part of UK doctrine even during the Cold War. The British Army was only equipped with short-range air defense systems. Air defense was provided through combat aircraft, a viewpoint that is shifting as the UK invests in new-generation, short- and medium-range SAM systems.

"The threat environment has changed," Barrie says. Air forces now lack the combat airpower and are not equipped to deal with emerging threats such as loitering drones or advanced cruise missiles and their launch platforms.

Ukraine's experience is even prompting a major review in governments across Europe.

On Oct. 13, 15 European nations, led by Germany, signed a letter of intent to work cooperatively on the European Sky Shield Initiative, an ambitious plan designed to fill in national ground-based air defense gaps by sharing the costs of procurements across nations.

The initiative is aimed at speeding up and facilitating the acquisition of new air defense systems and then examining cooperation opportunities, with a focus on off-the-shelf systems.

NATO Deputy Secretary General Mircea Geoana says implementing the initiative "would significantly enhance our ability to defend the alliance from all air and missile threats."

But use of the alliance initiative is unlikely to help Ukraine in the short term, and establishing a similar shield across Ukraine will not be easy.

The country's size will mean Kyiv will need to make difficult decisions about where to place systems it does receive from the West. It will have to decide whether to use them to protect critical national infrastructure or the population, notes Barrie.

Nonetheless, Ukraine's existing air defenses have been "effectively used," Gen. Mark Milley, chairman of the U.S. Joint Chiefs of Staff, told reporters in Brussels on Oct. 12. He said Ukraine's SA-6 "Gainful" (2K12 Kub), SA-8 "Gecko" (9K33 Osa), SA-10 "Grumble" (S-300) and SA-11 "Gadfly" (9K37 Buk) had been "effective at denying Russian air superiority" and in turn had prevented the Russians from conducting ground combined-arms maneuvers.

Milley says development of an integrated system that includes Western systems would be "complicated from a technical standpoint," as the systems, some dating back to the 1970s would have to be linked with command-and-control and communications systems to ensure the radars can operate together to acquire incoming targets. "[Integration] is achievable, and that's what we're aiming at," Milley says.

Systems so far promised by Western nations include Raytheon Homing All-the-Way Killer (Hawk) launchers and MBDA Aspide SAMs, both being provided by Spain, while France reportedly is planning to deliver MBDA Crotale point-defense systems.

Milley says Ukraine was interested particularly in the medium-range Hawk system, which despite its age, has been modernized regularly, with examples of the Improved-Hawk or I-Hawk continuing in service with Greece, Romania, Sweden and Turkey, in addition to Spain.

The most advanced air defenses delivered so far, however, come from Germany with the first of four fire units of the Diehl IRIS-T SLS, a ground-launched variant of the IRIS-T air-to-air missile. They originally were destined to form part of Germany's planned, but subsequently shelved, TLVS air-defense system that would have had the Lockheed Martin/MBDA-developed Medium Extended Air Defense System (MEADS) as its backbone. As a result, Ukraine will receive a system that has yet to enter service with Germany.

Following them will be fire units of the Norwegian-developed National/Norwegian Advanced Surface-to-Air Missile System (Nasams), which uses the Raytheon AIM-120 Amraam air-to-air missile (AAM).

With arguably one of the most common AAMs in the inventory of NATO nations, Ukraine could have access to hundreds of ready-to-fire missiles for its Nasams batteries, once they are delivered. The UK and the Netherlands have committed to delivering stocks of Amraams to support Nasams, with more European nations likely to follow suit.

More advanced systems such as Raytheon's Patriot, with its proven capability against ballistic missiles, may follow. Zelenskyy also has called on France and Italy to provide Eurosam SAMP/T systems, which are analogous to the Patriot, but they may be reluctant to hand over such complex and expensive systems. More opportunities to supply air defenses may emerge as nations step up capacities in their industrial bases, says U.S. Defense Secretary Lloyd Austin.

"It's that kind of initiative, that kind of activity that will create other opportunities for us as we go forward," Austin says.

NATO Air Defense Deliveries to Ukraine*

Sender	System
France	MBDA Mistral, Thales Crotale
Germany	Raytheon Stinger, KB Tocmash Design Bureau Strela, Krauss-Maffei Wegmann Gepard, Diehl IRIS-T SLS
Netherlands	Raytheon Stinger and AIM-120 Amraam (for Kongsberg/Raytheon Nasams)
Norway	MBDA Mistral, Kongsberg/Raytheon Nasams
Poland	Mesko Piorun
Slovakia	NPO Almaz S-300
Spain	MBDA Aspide, Raytheon Hawk
UK	Thales Starstreak HVM, Raytheon AIM-120 Amraam (for Kongsberg/Raytheon Nasams)
U.S.	Raytheon Stinger and AIM-120 Amraam (for Kongsberg/Raytheon Nasams)

*As of Oct. 17, 2022.

Not Only the Moon

- MANY LAUNCHERS EMERGE FROM CHINA'S CREWED LUNAR PROGRAM
- FUEL HAS CHANGED TO METHANE TO SUPPORT REUSE
- CHINA STILL TARGETING HUMAN MOON MISSION AROUND 2030

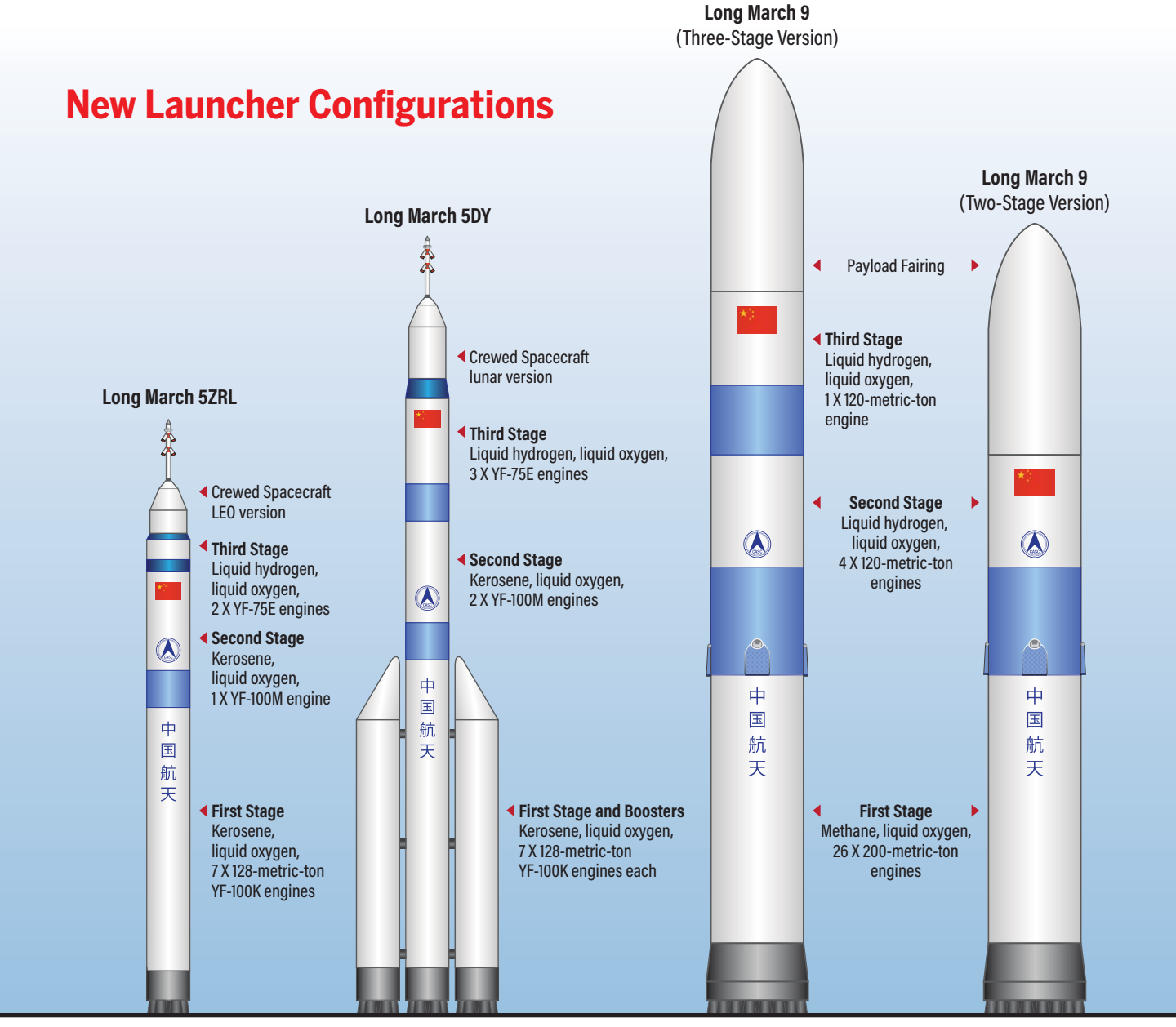
Bradley Perrett Newcastle, Australia

At first, all they wanted was a Moon rocket.

What began about 12 years ago as a conventional superheavy launcher for China's crewed lunar missions has now broken into two development streams that have themselves divided into further designs. These include a set of rockets that will introduce two-stage reusability and are obviously intended to become the mainstay of the country's launch effort beginning next decade.

The date for entry into service of the Moon rocket itself, the Long March 9, is now quite unclear, though it was slipping even before reusability was adopted as a goal.

To keep the crewed lunar program on track, launcher-maker Calt has firmed up plans for a new human-rated rocket that will use mostly current technology but offer only half the capability of the Long March 9. This effort, Project 921, itself has at



least one spin-off, also human-rated.

Since studies were first mentioned in 2010, the Long March 9 has progressed through more than 20 design iterations. These have been dominated by conventional configurations with kerosene-burning first stages plus side boosters using the same fuel or solid propellant.

Things have changed, as eminent Calt designer Long Lehao revealed when describing the latest configuration in July. The most remarkable change is incorporation of reusability.

To perform the Moon mission, the giant rocket has always had a third stage, but now there is a smaller, two-stage version to economically provide lesser capability. All stages now have a diameter of 10.6 m (34.8 ft.)—whereas 10 m was previously the largest width, used only for the first stage.

As in a design shown last year, there are no side boosters.

Liftoff fuel has become methane, which burns cleanly and therefore suits reusability.

Very-low-resolution pictures that Long displayed (the basis for Aviation Week interpretations published with this article) revealed grid fins on the interstage above the first stage, for control in propulsive descent. But there was no sign of how the second stage could return; it notably lacked fins for lift and control like those on the SpaceX Starship.

The current liftoff thrust, 5,200 metric tons (11.5 million lb.), is the same as in several earlier designs, but iterations have drifted toward more liftoff engines of smaller size. There are now 26.

This, too, is presumably intended to support reusability, since a stage with numerous engines can shut down all but one or two to reduce thrust to the very low levels needed for return to Earth.

The Moon rocket has grown a little in capability from earlier iterations. It is still intended to hurl 50 metric tons to translunar injection (TLI), but payload to low-altitude, low-inclination Earth orbit (LEO) is now 150 metric tons, up from the long-standing figure of 140.

Whether that performance is available in reusable mode is unstated.

There is no word on progress in developing the Long March 9's first-stage engine, but the 120-ton hydrogen-burning engine for its second and third stages has commenced "half-system" hot testing, Calt says.

The giant launcher is now described as only a member of a family of reusable rockets that will also include a series with a diameter of 5 m. Two-stage reusability will be achieved before 2035, Long says in remarks that imply, without complete clarity, that this will apply to both the 10.6-m (Long March 9) and 5-m series.

That leaves open the question of exactly when the Long March 9 will appear.

A design in the 5-m series that Long depicted was evidently the minimum version for that type, since it had two stages and no boosters. Again, the only sign of aerodynamic provision for return flight was the appearance of grid fins on the interstage.

A first-stage methane engine design smaller than the 200-metric-ton one planned for the Long March 9 will presumably be needed for the 5-m analog. Notably, Long mentioned in relation to the program that an 85-metric-ton methane engine from a private company was about to go into full testing.

A wide range of launch capabilities quoted for the family indicates that the 5-m series will have several versions.

Presumably they will replace the entire collection of rockets that national space contractor Casc began putting into service in 2015: Long Marches 5, 6, 7 and 8. Those still-new launchers, built by subsidiaries Calt and Sast, might be called Casc's kerosene family, since for liftoff they all rely entirely or mainly on the YF-100 engine, which burns that fuel.

The kerosene family remains far from achieving its main project objective: replacing Casc's venerable hydrazine-fueled rockets, Long Marches 2, 3 and 4, which are still carrying the main load of the Chinese launch effort.

The lowest cited capabilities for the planned new methane family, 5 metric tons to LEO and 4 metric tons to sun-synchronous orbit, are presumably the performance of the minimum version in fully reusable mode. For comparison, the SpaceX Falcon 9, with an airframe volume perhaps 40% smaller, can carry 16.7 metric tons to LEO, but only its first stage returns for reuse.

Calt mastered with difficulty the fabrication of rocket structure of 5-m-dia. for what is currently its largest launcher, the Long March 5. All other Casc liquid-propellant orbital launchers have diameters of 3.35 m.

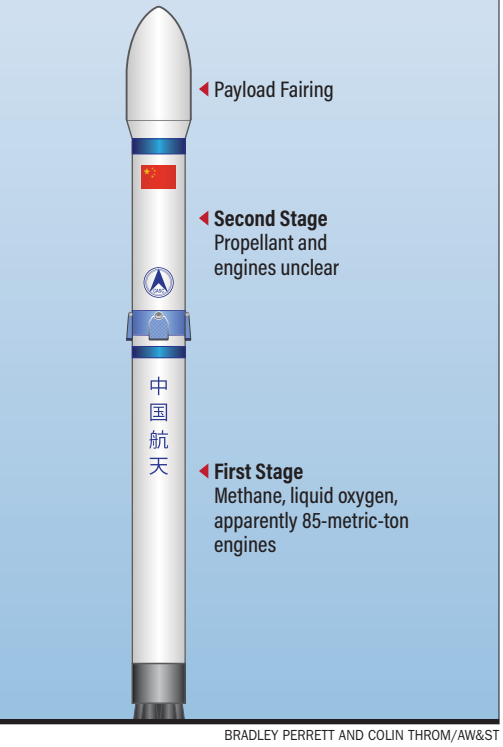
The new family has emerged from a shakeup in the Long March 9 effort that evidently began around four years ago. Calt appears to have decided then that the Long March 9 would probably not achieve the target for a crewed Moon mission in 2030.

Its response was to see what it could do with propulsion and structural technology that it already had. At Airshow China in November 2018, the manufacturer displayed a concept of what it then called the New-Generation Manned Launch Vehicle, which used the YF-100, the also mature YF-75 hydrogen engine and the 5-m structure diameter to offer a payload of 25 metric tons to TLI.

That was only half the payload that had been required of the Long March 9. But the proposed mature technology design could be ready sooner and could still support a crewed lunar mission by using two launches and a spacecraft rendezvous in lunar orbit, which has become the intended configuration.

It seems that top managers at Calt, Casc and higher in the government system then lifted technical ambitions for the Long March 9 because it was

5-m Analog of Long March 9
(Minimum Version)



BRADLEY PERRETT AND COLIN THROM/AW&ST

China's Planned Space Launchers Compared

	Current	Current-Technology Derivatives		New-Technology Reusables		
Model	Long March 5	921 (Project Name)		Long March 9		5-m Analog
Version	Long March 5**	Long March 5ZRL	Long March 5DY	Three-stage	Two-stage	Two-stage
Entry Into Service	2016	Before 2030	Crewed Moon mission ~2030	Before 2035?***	Before 2035?***	Before 2035?***
Function	Various	Crewed launch to LEO	Crewed Moon missions	Moon missions	N/A	N/A
Ruling Diameter (m [ft.])	5 (16.4)	5 (16.4)	5 (16.4)	10.6 (34.8)	10.6 (34.8)	5 (16.4)
Height (m [ft.])	57 (187)	~70 (230)*	88.5-91.6 (290-301)	110 (361)	~90 (295)*	~67 (220)*
Liftoff Mass (metric tons)	867	N/A	2,187-2,189	4,122	N/A	N/A
Liftoff Thrust (metric tons)	1,077	893*	2,680	5,200	5,200*	N/A
Payload to (metric tons):						
Low Earth Orbit	25	N/A	70	150	N/A	5
Sun-Synchronous Orbit	N/A	N/A	N/A	N/A****	N/A****	4****
Geosynchronous Transfer Orbit	14	N/A	N/A	65	N/A	N/A****
Translunar Injection	N/A	N/A	27	50	N/A	N/A
Reusability	None	Some	Some	Apparently first and second stages***	Apparently first and second stages***	Apparently first and second stages***

*Aviation Week estimate based on incomplete Calt information.

**The standard, 2.5-stage version of Long March 5 is also called Long March 5.

***At least one member of the family is due to enter service before 2035 with two-stage reusability.

****In other members of the family, up to 14 metric tons to sun-synchronous orbit and at least 7 metric tons to geosynchronous transfer orbit.

Source: Calt

no longer under such heavy schedule pressure. They perhaps saw two-stage reusability as necessary because SpaceX was already well along that path, and Chinese private companies would eventually go there, too.

As for the half-size Moon rocket, it is now called the Long March 5DY—for "deng yue," or Moon landing. Its Project 921 has expanded to include a much smaller sibling called the Long March 5ZRL for launching crewed spacecraft to LEO.

The Long March 5DY has grown a little in capability in the past two years, now credited with a TLI payload of 27 metric tons. Comparison between the latest, fuzzy pictures and a large-scale model displayed at the 2018 show reveals that the propellant tanks of the boosters have been shortened and those of the hydrogen-burning third stage lengthened.

For all seven liftoff engines in the core first stage and each of the boosters, the specific version is the YF-100K. It was also exhibited in 2018, described as a major modification of the original YF-100 with gimbaling below the pumps and therefore a lower moving mass for improved control.

Casc has also been working on providing greater throttling to the YF-100K, for propulsive first-stage landings.

Long says a start will be made on reusability with the Long March 5DY, so at least some of it should be able to fly again.

The latest data implies the YF-100K will have about 6% more thrust than earlier YF-100s.

Officials are still quoting around 2030 for China's first crewed lunar mission, so the Long March 5DY will presumably begin flying in the second half of this decade. The program is reportedly ready for development and manufacturing of sample parts.

The Long March 5ZRL is due to replace the Long March 2F, the launcher that China now uses for crewed missions, before 2030. Long March 7 was originally earmarked for that role, but the decision to go ahead with the Long March 5DY obviously offered a more economical path to a human-rated LEO launcher.

A Free Ride for Hubble?

> PRIVATE ASTRONAUT AND SPACEX PITCH SPACE TELESCOPE REBOOST PLAN

> ALTITUDE IS NOT THE ONLY LONG-TERM CONCERN

Irene Klotz Cape Canaveral

One of the first things then-astronaut John Grunsfeld and his spacewalking partner Drew Feustel tackled during the final servicing mission to the Hubble Space Telescope was to install a soft-capture mechanism onto the observatory's aft bulkhead.

With just nine flights remaining before the 1981-2011 shuttle program was to end, NASA outfitted its flagship observatory with a Low-Impact Docking System (LIDS) interface and associated relative navigation targets so a potential future servicing vehicle—which did not exist at the time—could capture the telescope without a shuttle-like robot arm for grappling. At the very least, Hubble would need a propulsion system either to make a controlled reentry into Earth's atmosphere or boost itself into a higher graveyard orbit.

Grunsfeld and his STS-125 crewmates left Hubble in May 2009 poised for what has become a largely unbroken series of astronomical observations, including cooperative studies with the infrared James Webb Space Telescope, which began operations in July.

But since that final servicing call, half of the observatory's six gyroscopes have failed, though the remaining three are of a more robust design. Regardless, the Hubble operations team has backup plans for pointing the telescope if another gyro—or even two—should falter. In addition, the fine guidance sensors, which Hubble uses to lock on to a target, are showing signs of wear. Last year, Hubble lost its spare science instrument-command and data-handling unit.

"The team continues to stay on top of issues as the spacecraft ages," Hubble Project Manager Patrick Crouse tells Aviation Week. "We're able to forecast what we think our problems are most likely going to be and start working on those issues . . . so we avoid downtime in case something were to happen."

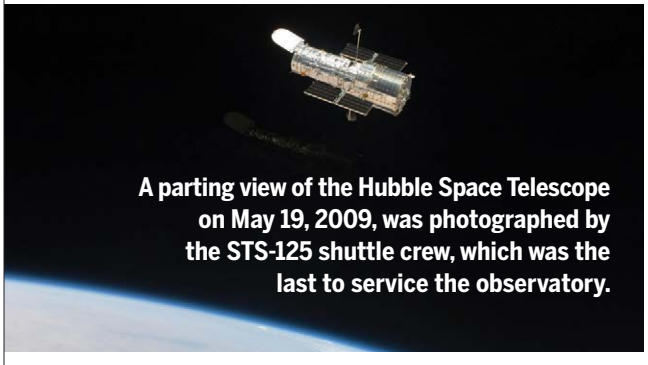
One situation NASA cannot control is the observatory's slow but steady loss of altitude, the result of friction with atmospheric particles that have escaped into space. The last shuttle servicing crew left Hubble 351 mi. above Earth. Currently, it orbits at 332 mi. The latest assessment is that without intervention, Hubble has a 50% chance of reentering Earth's atmosphere in 2037, Crouse notes.

Enter SpaceX with a bold and unsolicited proposal to send a Dragon capsule to boost Hubble—and maybe provide additional services—at little to no cost to taxpayers. "We're working on crazy ideas all the time," NASA Associate Administrator for Science Thomas Zurbuchen told reporters during a Sept. 29 conference call. "We're always supposed to push the envelope, and this is really compelling."

The proposal is now the focus of a six-month study under an unfunded Space Act Agreement between NASA and SpaceX, in partnership with the Polaris Program, a three-flight technology demonstration initiative funded and led by entrepreneur and private astronaut Jared Isaacman.

Isaacman, who chartered SpaceX's first private Dragon mission, is preparing to return to orbit under the new Polaris initiative. That program's first flight, named Dawn, will have a goal of eclipsing Gemini 11's 851-mi.-high altitude record set in 1966 for a spacecraft in Earth orbit. Issacman and three crewmates also plan to depressurize the Dragon capsule and conduct a spacewalk, which would be the first by non-professional astronauts. The mission is targeted for March 2023, about the same time the NASA-SpaceX Hubble reboost study is expected to conclude. Issacman hopes a visit to Hubble will become the second flight in the Polaris program.

"The primary objective [of the study] is going to be how you can safely leave Hubble in a healthier state than it is today," Isaacman tells Aviation Week. "We've gotten through the analysis and mission design to know that it is achievable," he says, noting that some of the technical requirements to service Hubble will be demonstrated during the first Polaris flight.



A parting view of the Hubble Space Telescope on May 19, 2009, was photographed by the STS-125 shuttle crew, which was the last to service the observatory.

NASA

"The second stage [of the Falcon 9 launch vehicle] is going to burn longer. [We] also had to figure out a way to reenter in the event of a contingency from such a high altitude, which would create additional considerations for [Dragon's] thermal protection system. That necessitated developing alternative reentry angles," Isaacman says.

For the third and final Polaris mission, Isaacman plans to be part of SpaceX's first crewed flight test of the Starship, a fully reusable super-heavy-lift transportation system currently in development.

Grunsfeld, who served on three of Hubble's five shuttle servicing crews and later as NASA's associate administrator for science, says at first blush a Dragon reboost-only mission to Hubble appears to be relatively low-risk.

"A very reasonable thing to do, in a development-program sense, would be to go up to Hubble, give it a boost—that would give it decades of additional time—and then use that mission to gather data on the performance of Dragon, such as how easy the docking was and what forces were imparted to Hubble," Grunsfeld tells Aviation Week "There is a risk that if you dock too hard, you could break something such as a high-gain antenna bearing or a solar array," he adds.

Data collected during the reboost mission then could be used to develop a servicing mission, perhaps five years later.

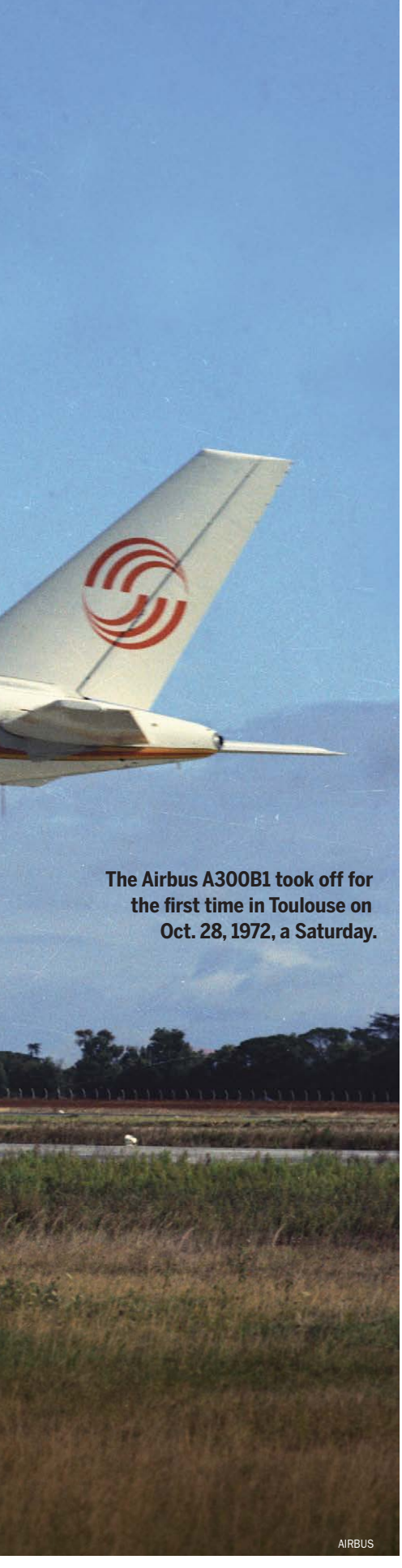
The study team will be led by Barbara Grofic, Astrophysics Project Division program manager at NASA Goddard Space Flight Center. Team members include Crouse; Brian Roberts, robotic technologist at NASA's Satellite Servicing Projects Division; Jennifer Wiseman, Hubble project scientist; David Haskins, Hubble mission operations manager; and Jackie Townsend, deputy project manager for the Roman Space Telescope.

Family Business

- THE AIRBUS A300, WHILE NO FINANCIAL SUCCESS, WAS A KEY BUILDING BLOCK FOR AIRBUS
- THE FIRST AIRBUS AIRCRAFT INTRODUCED WIDEBODY TWIN CONCEPT
- SUBSTANTIAL FREIGHTER FLEET REMAINS IN SERVICE WITH FEDEX AND UPS

Jens Flottau Frankfurt

The incident happened early on in the flight-test program. On Dec. 6, 1972, pilots Jacques Grangette and Pierre Baud took off for the 17th sortie of the A300B1. Two flight-test engineers and a mechanic were also on board. Shortly after they started the day's test program, the two pilots found that the aircraft reacted excessively when they initiated turns. Baud, a former fighter pilot who had joined Airbus just three months earlier, was not too worried, but Grangette decided to cancel the rest of the schedule and return to base.



The Airbus A300B1 took off for the first time in Toulouse on Oct. 28, 1972, a Saturday.

AIRBUS

ORIGINS

In hindsight, there were many instances in which the A300 program—and with it the entire Airbus project—could have failed for technical, commercial and political reasons. Some are more well known, such as the struggle to launch the program via an extremely tedious process spanning most of the 1960s and then kickstarting enough sales momentum in the 1970s to allow a level of production that made some economic sense. That flight on Dec. 6 turned out to be one of the many lesser-known hiccups, but in some ways it was a close call for the program. More on that later.

On Oct. 28, 1972, the first A300B1 test aircraft took off on its first flight, marking the start of an industrial, political and ultimately economic success story that is called Airbus and continues today.

The A300 itself was no commercial success. The 561 orders for all A300 versions and another 251 for the A310 before the program was terminated after 35 years of production tell their own story. At peak demand, Airbus delivered 46 of the aircraft in 1982 but only 19 the next year. From 1997 on, annual output was mostly in the teens. But the A300 was the catalyst for the launch of Airbus and a more united European aerospace industry that would eventually be able to compete with the big players in the U.S. at the time: Boeing, Lockheed Martin and McDonnell Douglas. The enormity of that accomplishment is indicated by the fact that only one of the three initial competitors is still building commercial airplanes and that none of the other national or binational European projects such as the BAC 1-11, Caravelle, Concorde or Mercure were successful.

In addition to starting to integrate the European industry, the A300 marked technical and industrial milestones. It was the first European widebody aircraft, and it introduced the concept of only two engines on a widebody, an idea met with massive skepticism by the establishment for years and one of the reasons the airliner's commercial breatkthrough took so long. "The Americans told us we were crazy," Gerard Guyot, one of the initial A300B2 and -B4 flight-test engineers, remembers. Boeing followed up with the 767, which entered service in 1982 and later superseded the A300 because of its longer range.

In the early 1980s, Airbus also switched to a two-pilot cockpit from the traditional setup of three on the -B2 and -B4.

"The real reason why this aircraft was successful is because it brought something different to the market," Airbus Chief Commercial Officer Christian Scherer says. A widebody with two engines was "a new economic proposition," he asserts. For comparison, Scherer points to the introduction of the Comac C919 this year. While gaining technological sovereignty in aviation is perfectly legitimate for a country the size of China, as it was for Europe in the 1970s, "[the C919] is an imitation of something that already exists," he says.

The A300 was the design primarily of three men: Henri Ziegler, Roger Beteille and Felix Kracht. Ziegler was named as the first CEO of the Airbus Industrie consortium, Beteille became chief operating officer, and Felix Kracht, who had played an important role in the background, headed production.

In 1967, Kracht became managing director of Deutsche Airbus, which was to consolidate Germany's workshare in the upcoming program. Along with Beteille and Ziegler, he was the mastermind behind the A300B, a technically ambitious aircraft. He pushed to use the best technology available, wherever it came from. "If the Chinese have the best engine, we will use it," he once said. Beteille, Ziegler and Kracht also agreed that Airbus would not succeed in the long term with only a single product. The A300 would have to be developed into a family of aircraft if the Europeans were to compete with Boeing, Lockheed and McDonnell Douglas. To say so publicly early on did not seem prudent politically, so they kept the idea to themselves initially.

Of course, the idea of the family concept and communality even across different types of aircraft has been an Airbus leitmotiv for decades.

Efforts to pull together the project in the first place took years, mainly because of industry politics. The UK was largely focused on developing Concorde, which many expected would be the future of civil aviation. Only Hawker Siddeley showed an interest in the A300 project. Germany was initially lukewarm at best. And even in France, the picture was complex: Dassault was aiming at the civil market with its Mercure project, an

aircraft roughly the size of the A320 developed by Airbus later. Like in the UK, France was working on the Concorde, and anyone not immune to prestige thinking wanted to be on the program. When the first A300 test aircraft was rolled out along with another Concorde prototype in September 1972, no one really paid attention to the Airbus, even though Concorde had been in flight tests for some years.

Key airlines were underwhelmed, too. Air France did not want any political interference in its order decisions. Lufthansa chief Herbert Culmann also made it clear what he would do if he felt that kind of pressure: "If someone wants to force me to buy this Airbus, I will take my hat and leave tomorrow."

COURTESY OF GERARD GUYOT

During a 1973 demo tour, pilot Max Fischl and flight-test engineer Gerard Guyot waited for repairs in Mexico City.

ENGINE TROUBLE

The project nearly died several times. The original A300 was planned to have around 300 seats, aimed at large-volume, short- and medium-haul routes mainly in Europe and the Asia-Pacific region, rather than the U.S., a market dominated by incumbents Boeing and McDonnell Douglas. The aircraft was supposed to be equipped with Rolls-Royce RB207 engines. But in May of 1968, the British engine-maker presented a price for the powerplant that was out of the question for Beteille and Ziegler. "The difference in price of the RB211 for the Lockheed L-1011 was simply unacceptable, and we realized that Rolls was playing another game without admitting it," Beteille said at the time. "By continuing in that way, we would have ended up with nothing more than a superb glider."

The high price was Rolls-Royce's way of saying that it actually did not want to build an engine for the A300. The company was already building the RB211 for the Lockheed L-1011, a three-engine aircraft that would later compete with the first Airbus.

On Oct. 6, 1968. Ziegler hosted Beteille at his home on Avenue Stephane Mallarme in Paris. The two prepared major changes to rescue the project and decided to put forward the idea of a scaled-down version about 80% the size of the 300-seater. That way, the Airbus partners would spend less on development and be able to choose between two engines: the RB211 and the General Electric CF6. Given the tense relationship with Rolls-Royce, it was no surprise that Airbus came to an an agreement with GE. The Pratt & Whitney JT9D was added later as a second engine option in the program.

Decades later, Rolls-Royce played a role at Airbus as part of the International Aero Engines (IAE) consortium building the V2500 and then delivering the RB211-derived Trent engines for the A330, A350 and A380 widebodies.

On May 29, 1969, the French and German governments agreed on a memorandum of understanding at the Paris Air Show to jointly develop the A300B. At the time, it was not a momentous event: The news was buried in this magazine's report on the Paris Air Show (*AW&ST* June 9, 1969, p. 33). But the Airbus project was a reality.

Following the engine sourcing, the quandary over the A300's wings nearly ended the development program. While UK-based Hawker Siddeley was willing to take on the wing work, the British government refused to provide development money. The German government came to the rescue by agreeing to fund the work, removing one of the last major hurdles to program launch.

TAKING FLIGHT

Soon it was time for flight testing, but few people took notice. The first flight was scheduled for Friday, Oct. 27, but dense fog prevented the crew—pilots Max Fischl, Bernard Ziegler, flight-test engineers Gunter Scherer and Pierre Caneill and flight-test mechanic Romeo Zinzoni—from taking off. "No one was interested in the A300," recalls Barbara Kracht, daughter of Airbus founder Felix Kracht who spent her entire professional career working for the company. In 1969, she was in university and was able to attend the first flight only because it was delayed to a Saturday, when she had no classes.

Not only did very few people actually witness the flight—at least compared to later first flights that were orchestrated as social media events—Airbus' hometown newspaper *La Depeche du Midi* in Toulouse also buried the story on an inside page. This magazine did the same (*AW&ST* Nov. 6, 1972, p. 22).

The A300's first sortie was remarkable in several ways. Fischl and Ziegler (Henri's son, hailed by his colleagues as a formidable test pilot and equally capable boss) put the aircraft through a wide range of configurations, speeds and altitudes, switched the autopilot on and tested all the important systems. It was a more comprehensive program than would be undertaken on a first flight today. There was one unplanned aspect: As the weather deteriorated quickly, Fischl had to land the aircraft with a 28-kt. crosswind gusting to 34 kt. As it turned out, that was above the aircraft's later certification limit. Baud, who witnessed the landing from his position on the apron, says Fischl did well to put the A300 back on the ground under the circumstances.

AIRBUS

A300 Timeline

1969 May 29 | Governments of Germany and France sign memorandum of understanding to develop the Airbus A300 jointly

1972 Sept. 28 | First A300B1 test aircraft rolls out
Oct. 28 | A300B1 makes first flight

1973 Feb. 5 | Second prototype makes first flight

1974 September | First non-European airline, Korean Air, orders four A300s

1975 March 15 | France and Germany certify the A300
May 23, | Air France introduces A300 on the Paris-London route

1978 April | Eastern Air Lines orders 23 A300s

1982 April 3, | A310 makes first flight

1983 July 8| A300-600 makes first flight

1984 Dec. 21 | PanAm takes delivery of its first four A300B4s

2007 July | Last A300-600F delivered to FedEx; production ceases

Christian Scherer, 10 years old at the time, watched the A300's first takeoff and landing from the rooftop of the old Toulouse airport terminal building. His father, Gunter, was onboard as the flight-test engineer. "[I was] holding my mom's hand," Christian Scherer recalls, and noticed that the landing included "quite a bounce" and that the aircraft was "going sideways" on the final approach because of the crosswinds. Only about 25 other people had assembled on that platform.

Baud had just joined Airbus a month before the first flight, and like most of the test pilots, he was still very new to the program when he participated in his own first test flights. One of them, the 17th overall, proved to be a critical one. Grangette, who was in command, instinctively felt that the strong lateral moves could not be right. After landing, the available data was analyzed and extreme loads were discovered on Frame 90, where the tailplane and fin are attached to the fuselage. "Thanks to Grangette's decision, a disaster was avoided," Baud says.

The fix was rather straightforward. Frame 90 was reinforced and the settings for the spoilers and ailerons were reduced so that loads would be guaranteed to stay well below limits. The new configuration was validated on the 42nd flight in February 1973.

Another issue took somewhat longer to fix. During avoidance maneuvers at high altitude, pilots discovered a risk of the aircraft pitching up and causing them to lose control, a phenomenon discussed since early in the development. As it turned out, a shockwave

A large order from Eastern Air Lines in 1978 provided the commercial breakthrough for the A300.

disturbed lift at the tip of the wing, leading to a loss in speed and increased angle of attack. Airbus engineers found that the only way to reduce the shockwave was to add a wingtip.

Much to the chagrin of Airbus, French weekly news magazine *L'Express* argued that the A300 program should be scrapped because of the allegedly poorly designed wing. The paper's founder and editor, Jean-Jacques Servan-Schreiber, was a strong supporter of the Dassault Mercure project, so other considerations may have influenced his judgment of the wing situation.

The first two prototypes were A300B1s, but to make the aircraft more attractive to Air France, Airbus stretched the fuselage to accommodate three more seat rows, creating the B2. The third test aircraft was already a B2, a version that morphed into the B4 (with an added center fuel tank and Krueger flaps for additional range). The A300-600, introduced a decade later, involved a slight further stretch of the fuselage and featured several upgrades including the the forward-facing crew cockpit, Airbus' move from a flight crew of three to two.

TOUGH SELL

Although flight testing was going smoothly overall, sales were not. Airbus was completely new to everyone in the industry. It launched demo tours around the world to introduce itself and the A300. The first was a monthlong Americas trip starting Sept. 15, 1973. Ziegler and Baud flew the aircraft from Toulouse to Sao Jose dos Campos, Brazil (via Dakar, Senegal, and Recife, Brazil), to participate in a local air show. Guyot was also on board, as were mechanics, Airbus sales representatives—and a lot of spare parts, just in case.

"We were like an autonomous circus," remarks Barbara Kracht, who was a member of the Airbus communications staff at the time.

"We were unknown, going from one city to another," Guyot says.

Airbus was doing demo flights inviting pilots and local VIPs, trying to build trust in the aircraft and a lobby for future orders. "We were all driven by the same pioneer spirit," Guyot says.

"What fascinated me was the emotional attachment to the mission," Christian Scherer says of his father and colleagues. He says he was "in awe of the technology" as well as of the team's ability to bridge cultures and come together. After all, his father was part of the first generation of German aeronautical engineers after World War II, who would not necessarily have been easily welcomed in France. But Gunter Scherer, who was a francophile, was an important player in building that bridge, his son recalls. And the members of French pilot school EPNER—in particular Jean Caillard, who became the elder Scherer's mentor—received him with open arms. Gunter Scherer and Bernard

Ziegler also later became best friends.

The A300B1 toured Brazil and some Caribbean destinations before stopping in West Palm Beach and Miami, Florida. Then, in Mexico City, Max Fischl's piloting skills were required again: Upon takeoff from the high-altitude airport, an engine failed. Fischl turned the aircraft around, and mechanics repaired the engine. They were able to continue on the all-important U.S. tour as planned, with demos to Pan American World Airways, Trans World Airlines, Delta Air Lines and American Airlines, among others. But it would be several more years before Airbus would achieve its commercial breakthrough in the U.S.

Following the Americas tour, Airbus sent an aircraft to Southern Africa with stops in Niamey, Niger; Libreville, Gabon; Johannesburg, Cape Town and Durban, South Africa; Kinshasa, Democratic Repulic of Congo; and Windhoek, Namibia. The Windhoek stop was also used for takeoff performance tests at high altitude.

CERTIFICATION AND PRODUCTION

May 1974 proved to be full of milestones for the aircraft. Following certification by France and Germany in March, the A300 was certified by the U.S. FAA. Airbus embarked on a third demo tour, this time to the Asia-Pacific region, with many stops in Southeast Asia, South Korea, Japan, Australia and New Zealand. On May 10, Air France took delivery of its first B2 and started commercial services on May 30, operating the aircraft initially on the Paris-London route.

Things did not become easier for Airbus, however. "Most airlines were reticent about a twin-engine widebody carrying so many passengers," Baud says. All widebodies at the time had at least three engines, and the Boeing 747 had four. Even the short- and medium-haul Boeing 727 was a three-engine aircraft. Beteille, Ziegler and Kracht were convinced nonetheless that they had the more efficient design and that the aircraft would be easier to repair than one with one engine installed high up on the tailplane. "We had to change the mindset of the airlines," Baud notes.

That effort took years. During the first six years of production, Airbus built more A300s than it delivered, parking expensive "white-tails" waiting to be sold and handed over. Between 1974 and 1979, Airbus delivered fewer than 90 aircraft. The low point was 1976; Airbus did not receive a single order between the end of 1975 and mid-1977. Production was reduced to a nominal rate of just 0.5 aircraft per month, nowhere near any kind of profitable level. By comparison, after decades of industrial optimization, currently Airbus is not making money at a rate of five aircraft per month on the A350 program.

INTO OPERATION

Air France was the first operator in 1974, followed by Air Siam at the end of the year. Korean Air and Hapag-Lloyd took their first A300s in 1975, and then Lufthansa, Air Inter, Indian Airlines and South African Airways the next year. At least some of the demo tours appeared to have paid off, with a good part of the early deliveries going to carriers in Asia, as Airbus had hoped, given the route structures and need to connect large metropolitan areas with high-capacity aircraft. Air Siam was a case in point: The carrier had leased aircraft MSN 8 for nine months to fly the Bangkok-Hong Kong route—the A300's first extended-range twin-engine operational performance standards service early on in its operational history. The U.S. remained closed to the A300 for the time being.

A Look at the Airbus A300 In-Service Fleet

Jens Flottau Frankfurt

TRACKING IN-SERVICE AIRCRAFT AND FLEET TYPES IS USUALLY not difficult using databases such as Aviation Week's Fleet Discovery. But digging out the details of the Airbus A300 in-service fleet 50 years after its first flight is complicated, and results have to be taken with some caution. Information about whether an aircraft is still flying often varies from source to source. And with a significant part of the fleet operating in Iran and Russia, even Airbus has only limited access to information, given that the sanctions imposed on those countries essentially allow no dealings with the operators there.

According to Airbus' latest operational statistics for September, a total of 229 A300s remain in operation worldwide. Fleet Discovery allows a more detailed look at the actual status of the aircraft: it lists 182 as in service, 24 in parked or parked-reserve status and 23 more in long-term storage. Fifty-four A310s are still flying, Airbus says. Of the A300s, the vast majority are freighters.

FedEx is by some margin the largest remaining operator of the type, with 70 of the aircraft. It is followed by UPS with 52 and European Air Transport (operating on behalf of DHL) with 22. Because Iranian airlines in general have been all but unable to modernize their fleets, they have been forced to stick with their aircraft much longer. That has led to Iran becoming home to the largest A300 passenger aircraft fleet, with 21 still flying in the country, according to Airbus.

There are 38 remaining operators of the A300, and the in-service fleet is 28 years old on average. An A300 typically flies about 500 cycles or 878 hr. per year, reflecting its roles at FedEx and UPS: domestic cargo flights averaging just under 2 hr. and no more than 2-3 sectors per day. There are no extended-range twin-engine operations performance standards flights anymore.

In 1975, Bernard Lathiere took over the top position at Airbus from Henri Ziegler. He warned internally that the situation had to improve, and fast. Baud remembers people leaving the flight-test department that year because there was not enough work for everyone. But Lathiere, born in Kolkata (then Calcutta), India, turned out to be in the right place at the right time, as he excelled at what Airbus needed most in the mid-1970s: sales brilliance. Seeing that none of the other U.S. carriers were prepared to go for the A300, Lathiere approached the CEO of Eastern Air Lines, Frank Borman, a former astronaut. The carrier had not made money in 10 years but needed new aircraft, and Lathiere saw an opportunity.

The two agreed on a deal that is legendary to this day and one of the reasons why Airbus still exists. The OEM sent four A300s to Eastern to test in commercial operations free of charge for six months. The test satisfied Borman, and not only did Eastern buy the four aircraft, it ordered 23 more in 1977. The order gave Airbus the credibility it needed to build sales momentum over the coming years and put it in position to expand its portfolio further and build the A320, which was launched in 1984.

Christian Scherer joined Airbus as an intern in the contracts department in September 1984. His first assignment was the final paperwork for the PanAm order for 12 A300B4s. Then, on Dec. 21, four aircraft were delivered the same day. One was going to Berlin for PanAm's air bridge service, and three more flew to New York via Gander, Newfoundland and Labrador. Scherer was on board of one of them. He recalls seeing the three parked next to each other during a refueling stop in a snowstorm at Gander: "That was one of the most emotional moments of my career."

Gallery *See more on the A300's most important milestones:* **AviationWeek.com/A300-Milestones**

Airbus A300 Operators

AeroUnion	3
Afriqiyah Airways	1
Aircompany KAP KG	1
Air Hong Kong	9
ASL Airlines	4
Cobra Jet	2
Easy Charter	1
European Air Transport	22
FedEx	70
Galaxy Aviation	2
GSS Airline	1
IrAero Airlines	11
Iran Air	3
Iraqi Airways	1
Mahan Air	11
Meraj Airlines	2
MNG Airlines	4
Qeshm Air	5
SkyJet	1
Solinair	2
Sudan Airways	2
TIACA	3
Uni-Top Airlines	7
UPS	52
Undisclosed	9
Total	**229**

Source: Airbus

Airbus figures show that MSN 80, registered as EP-IBS, is the oldest active A300. The aircraft is one of only two A300B2s still shown as in service. However, according to Aviation Week's Tracked Aircraft Utilization tool, MSN 80 has not flown since December 2020. MSN 141, an A300B4 owned by Galaxy Aviation, is the second-oldest, having been delivered in 1981 (initially to Thai Airways).

The last A300 built is MSN 878, delivered to FedEx in July of 2007. Since then, the aircraft has flown 11,507 cycles and 20,364 hr. Forty-four aircraft are younger than 20 years; another 121 are between 20 and 30 years old.

Some of the early aircraft are slowly reaching the end of their service lives. The A300B4 was initially designed for 34,000 cycles and 70,000 hr.; Airbus later introduced an extended service goal of 57,000 cycles and 118,000 hr. The A300-600's design service goal (SDG) was 30,000 cycles and 67,500 hr., but the manufacturer extended its limit twice. It is now at 51,000 cycles and 89,000 hr. The company has no plans to extend A300-600's SDG again, given the limited number of aircraft affected. The large operators, in particular FedEx and UPS, have relatively young fleets and are generally far from reaching the cycle or hourly limits of their aircraft.

In fact, UPS is making substantial investments in its A300 fleet. The airline launched a major cockpit upgrade program in 2015 that included new screens, a flight management system and weather radar, as well as an enhanced ground-proximity warning system and other changes. The majority of the fleet has been retrofitted by now, but the program is still ongoing.

At Airbus, the A300 (and A310) fleets are being managed by the out-of-production organization that is also handling the A380. They do not manage the A340, since it is seen as a sister program to the A330, which is still being built. Pascal Vialleton, the A300 head of program and chief engineer who also runs the technical directorate, says no new maintenance or in-service issues have surfaced for some time as the program is "very mature." But ensuring spares availability has become a challenge. When manufacturing of a specific part has to be relaunched, the directorate turns the initial design drawings into digital 3D models as it retro-engineers the parts.

BACKGROUND: DMYTRO BALKHOVITIN/SHUTTERSTOCK

Doubling Down

Coventry, England-based aerospace supplier Meggitt became part of Cleveland-based Parker Hannifin in September after the closing of a $7.3 billion acquisition that nearly doubled the size of Parker Aerospace. Parker Hannifin CEO **Tom Williams** and Aerospace Group President **Roger Sherrard** had a conversation with Aviation Week editors **Joe Anselmo** and **Michael Bruno** about the opportunities they see, while upholding promises made to maintain core Meggitt operations in the UK.

Tom Williams

Roger Sherrard

PARKER HANNIFIN PHOTOS

AW&ST: **How do you integrate Meggitt into Parker with the pledges you had to make to the British government?**

Tom Williams: We've closed more than 80 transactions over the last 20 years, so we have a lot of experience with integration, especially in the last eight years of larger transactions. Many of them were international companies or had an international footprint.

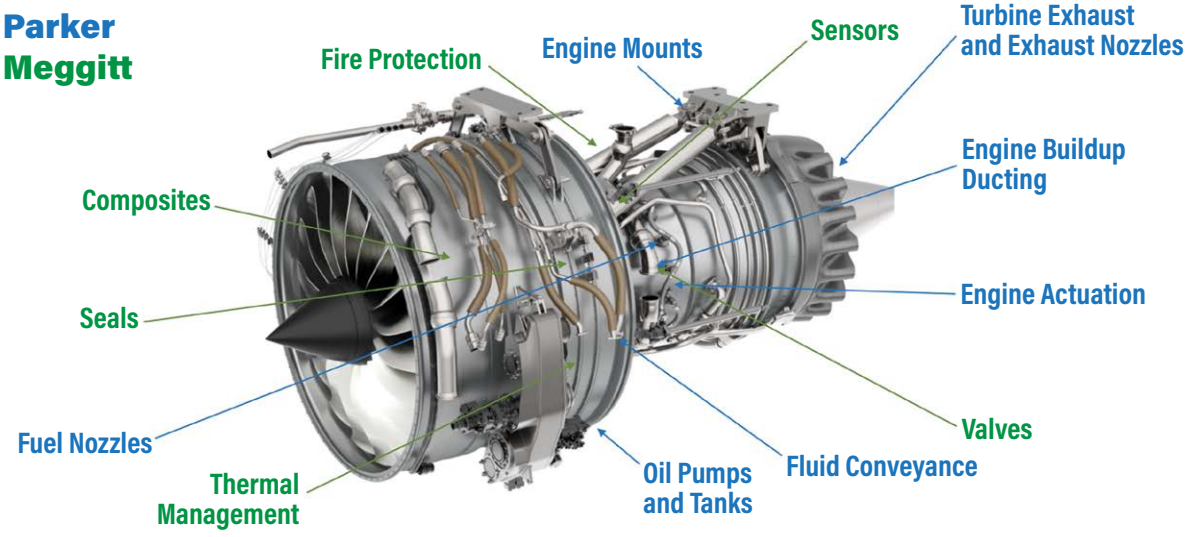
If you look at Parker Hannifin, 35-40% of our sales and people are outside the U.S. We're used to multicultural diversity. The commitments we made to the UK government were very natural and logical. We would have made them regardless of whether the government was involved, like honoring national security contracts, maintaining capabilities in the UK and continuing the center of excellence Meggitt built in Ansty Park [in Coventry]. We want to keep the engineers and the direct labor.

How will the Meggitt facilities fit into the Parker ecosystem?

Roger Sherrard: The Meggitt team, even though they've been around for 170 years, have really been just recently trying to create more processes. They're probably about 15 years behind us in that regard, and that's why we really think our strategy can help them. Bringing our processes into Meggitt to help accelerate some of the things they're doing with financial performance, customer experience, engaging

Expansion of Engine Products

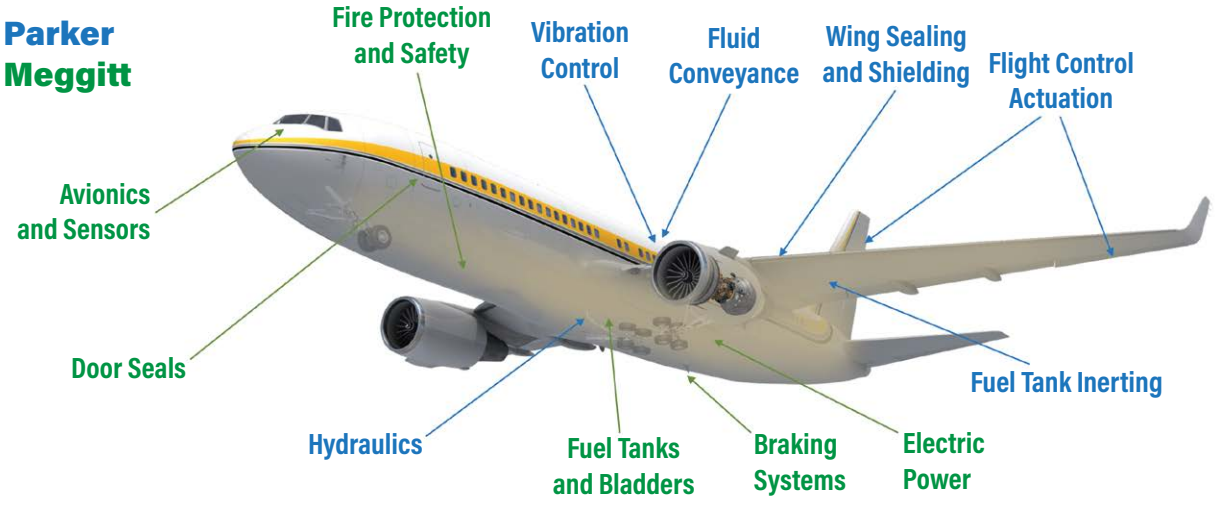
Integrated Systems and Components Across the Platform



Source: Parker Hannifin

Complementary Airframe Products and Systems

Integrated Systems and Components Across the Platform



Source: Parker Hannifin

people and growth are all very aligned with our strategy. I think the big challenge is being able to double in size but still be agile by flattening out the organization. The Meggitt team is very open to that. They look at Parker Aerospace and see the success we've had over the last six or seven years. And it's no secret they've struggled. I really think that the two companies together are not just a doubling in size and adjacent products. Now both engineering teams can solve problems for customers. And being much larger, we're on the radar screens of big customers.

Is the dramatic strengthening of the U.S. dollar against the UK pound affecting your deal?

Williams: We took that risk off the table from the beginning of the transaction. When we first took out the financing, we did a deal-contingent hedge, which guaranteed a certain rate. Also, when you look at Meggitt, about 70% of their revenues are in U.S. dollars. Roughly half of their business—people, facilities, etc.—is in the United States.

How does this combination change the role of aerospace within Parker Hannifin?

Williams: We want to be the consolidator of choice where we can be the best owner of the technology. If you think about all the motion control technologies that are going into things that fly, mobile equipment, industrial or life sciences equipment, it's roughly a $135 billion space. We're leveraging the same suite of technologies across [multiple] sectors. We've always liked aerospace. Two of our last four deals were aerospace properties, one in filtration and one in engineering materials. We would like to continue to build out aerospace.

Sherrard: We've been working on transforming our aerospace portfolio for years, rebalancing into more engine exposure, where we love the aftermarket. We were a little bit overweight on airframes, so that's what Exotic [Metals Forming, acquired by Parker Hannifin in 2019 for $1.7 billion] did for us. We'd always been looking to partner with Meggitt. We were meeting with them seven or eight years ago.

How will Parker and Meggitt leverage each other's capabilities?

Sherrard: Meggitt really didn't have a team to do polymers and composites, but Parker Hannifin has a whole business with our Engineered Materials Group, so we immediately teamed them up. That's going to fundamentally change the trajectory of those businesses. In clean technologies, Meggitt can help with advanced sensing for engine controls. We're both investing in more electric aircraft in different areas and higher-temperature heat loads. They have thermal management capabilities. There are things like climate-friendly fire-suppression systems and investments for hydrogen and sustainable aviation fuel. In the commercial aftermarket, we're approaching the significant threshold where we can take a different posture service-wise and create a much more compelling value proposition for airlines around the world because we're larger.

When should we expect Parker to make more aerospace acquisitions?

Williams: In the near term, growth will be more organic because we need to pay the balance sheet down. But longer term, we'll look at both inorganic and organic acquisition candidates. Parker Aerospace and Meggitt will have a very nice growth rate when you go out 5-10 years, and we have the opportunity to add on to it with acquisitions. With the portfolio changes and the trends around aerospace—digital, clean technology, electrification—the company is becoming much more long-cycle. About 85% of our company is either long-cycle or aftermarket. So the company is going to grow a lot differently compared to the last 10 years.

THE NEW FACES OF A&D

20 TWENTIES

Lindsay Bjerregaard Chicago

Today's aerospace and defense industry faces a host of challenges, from mitigating its impact on climate change to filling roles vacated by experienced professionals who have left the industry during the COVID-19 pandemic. Aviation Week's annual 20 Twenties program shines a spotlight on some of the people who will meet those challenges and fill those roles. We collaborate with universities around the world to identify 20 exceptional students in undergraduate or master's degree programs who are working on aerospace and defense industry innovations.

Now in its 10th year, the 20 Twenties program includes winners from 14 schools across the U.S. A panel composed of hiring managers, engineers and academics evaluates and scores nominees based on academic performance, civic contribution, obstacles to success and the value of each student's research or design project. This year's group is one of the most diverse in the program's history, with women comprising 70% of the winning students. A significant portion of this year's winners are international students or those whose families immigrated to the U.S. from other countries.

Many of the winners also are committed to making the industry more inclusive. In addition to the entire group's volunteer efforts to promote science, technology, engineering and mathematics (STEM) topics to younger students, many winners have focused time and effort on initiatives aimed at promoting gender equality, improving access for minorities and addressing challenges for international students interested in aerospace and aviation careers.

Several winners highlight the importance of making the industry more accessible. "There are so many students in disadvantaged communities who have never even dreamed of becoming an engineer," winner Anoop Kiran says. "These students are capable of becoming the next generation of STEM leaders if their interests are channeled in the right direction."

This year's many female winners also point out the importance of representation and allyship to encourage more women to pursue aerospace and defense careers and persist in the face of gender-based discrimination. Winner Margaret Kilpatrick illustrates this point while describing her support of other young women at her school: "It's hard to be the first to push for change, and while I knew that the steps I took while at my undergraduate university would not directly help me in my own situation, [they] would give others an avenue to follow and support for them, should they need it."

In addition to making the industry more welcoming for all, many of this year's winners are focused on next-generation technologies that will advance aerospace and improve humanitarian and sustainability efforts. Some of this year's winners have applied their expertise to projects such as delivering disaster relief or improving the environment. Several winners also volunteer as first responders.

This year's winners will be recognized during the 20 Twenties Awards Luncheon and the Aviation Week Network's 65th Annual Laureates Awards on Nov. 3 in Washington.

The 20 Twenties program is held in collaboration with Accenture, premier sponsor Hexcel and sponsor Boeing.

BACKGROUND: BESTBRK/GETTY IMAGES

20 Twenties Judges

Amy Bahrani
Aerospace & Defense Management Consulting Senior Manager, Accenture

Jordan Davis
Manager, Aerospace & Defense, Accenture

Brian DeMarmels
Managing Director, Accenture

Lori Garver
Co-founder, Brooke Owens Fellowship; former Deputy Administrator, NASA

Craig Gottlieb
Managing Director, Accenture

Daniel Jensen
Deputy Head of Engineering for Services, Defence, Rolls-Royce

Conor Keenan
Director, Boeing Programs, Hexcel

Joe Landon
Vice President, Advanced Programs Development, Lockheed Martin

Cary Martin
Vice President Global Fibers Technology, Hexcel

Crystal Pasiliao
Principal Technical Advisor, AFSEO 96 SK/SKC

Laura Richard
Mission Manager, United Launch Alliance

Craig Willis
Project Engineer, Gulfstream

Jesudunsin Awodele

Undergraduate Student, Aerospace Engineering • Class of 2023 • Georgia Institute of Technology

Awodele is working to advance supersonic and hypersonic research through computational fluid dynamics at Georgia Tech's aerothermodynamics lab. During his systems engineering and integration engineering internships with Boeing, he assisted with development of the MQ-25, a carrier-based uncrewed tanker capable of aerial refueling of U.S. Navy jets. He is also working to solve the challenge of untraceable space debris and Kessler's Syndrome through the Patti Grace Smith Fellowship, which was created to address racial disparity in the aerospace industry.

Awodele, whose family immigrated to the U.S. from Nigeria, is a U.S. Air Force ROTC flight commander. He devotes much time to projects such as mentoring students and developing STEM projects through the Georgia Space Grant Consortium and Hines Family Foundation. He also helped charter AeroAfroAstro, Georgia Tech's first Black aerospace student organization.

Terelle Cadd

B.S. Aerospace Engineering • Class of 2022 • Virginia Polytechnic Institute and State University

Cadd transitioned from community college studies while working full time at United Parcel Service to pursue his passion for aerospace engineering. As a research associate at NASA Langley Research Center, he worked to apply NASA technologies to solve wildfire challenges. He was appointed team lead for the NASA Academy Team, which developed an image-processing algorithm for drone technology to detect and plot wildfire perimeters in real time as well as an app to reduce miscommunication and improve reporting of fires.

Cadd's undergraduate research has included designing a 3D-printable drone and improving applied laser flow measurements to reduce uncertainties in readings from geometric scattering. He has assisted students with disabilities through note taking and volunteered with Feeding America and the United Way.

Catherine Dominic

Undergraduate Student, Aerospace Engineering • Class of 2023 • University of Texas at Austin

As director of engineering at the Texas Rocket Engineering Lab, Dominic manages the progress of 10 design teams working toward becoming the first student-run lab to launch a liquid bipropellant rocket to the Karman Line. Dominic was awarded the Brooke Owens Fellowship, through which she completed an internship at Amazon Prime Air. As part of the airline's materials and processes team, she helped design material and process configurations of primary structures on the airline's next-generation drone.

Dominic hopes to develop an aerospace study abroad program at UT Austin that will help to remove barriers to entry for minority students, such as cost, lack of awareness, and family and community influences. As part of these efforts, she performed outreach for People Centered Engineering for an experimental study abroad program in Panama this year.

Chloé Gentgen

M.S. Aeronautics and Astronautics • Class of 2022 • Massachusetts Institute of Technology
B.S. and M.S. Engineering • Class of 2020 • Ecole Centrale Paris, University of Paris-Saclay

Gentgen is researching the design of planetary exploration missions with a focus on optimizing propulsion systems and improving sustainability efforts. She was a finalist in last year's NASA RASC-AL competition, for which she proposed a crewed mission concept to Ceres. She is leading a team in this year's competition to design a mobile in situ resource utilization plant capable of producing methalox propellant on Mars. She also was selected as a systems engineer for the Caltech Space Challenge.

Gentgen has interned at NASA Jet Propulsion Laboratory, Thales Alenia and Flying Whales. She is president of MIT's Graduate Women in Aerospace Engineering student group and a member of the Space Generation Advisory Council Group. She is training to become a volunteer emergency medical technician at MIT.

Emily Herrmann

Graduate Student, Aerospace Engineering • Class of 2022 • Georgia Institute of Technology
B.S.E. Mechanical Engineering and Aerospace Engineering • Class of 2020 • Case Western Reserve University

At the Aerospace Systems Design Laboratory, Herrmann is involved in NASA's Subsonic Flight Demonstrator study to assess future civil transport aircraft designs within the context of reducing the environmental impact of aviation. She also is researching the feasibility of creating new mobility low-cost attritable aircraft for U.S. Air Force applications and how to connect manufacturing considerations to preliminary design of hypersonic glide vehicles.

Herrmann worked as an associate systems engineer at Northrop Grumman and has interned at Textron Systems, Comsat Architects and Bell Flight. She has volunteered through the Society of Women Engineers and the Women in Science and Engineering Roundtable to teach STEM activities to local Girl Scout troops. She is earning a private pilot license through the Yellow Jacket Flying Club as well.

Joshua Ingersoll

M.A. International Science and Technology Policy – Space Policy • Class of 2022
The George Washington University
B.S. and M.S. Aerospace Engineering • Class of 2019 • Georgia Institute of Technology

Ingersoll is tying together aerospace engineering and the impact of federal regulatory policy. As a graduate student, he researched the relationship between federal regulators, commercial Earth-observation companies and the U.S. Defense Department in the wake of recent changes to the Land Remote Sensing Act. He says the conflict in Ukraine has highlighted the importance of commercially available Earth-observation data.

Ingersoll is a satellite regulatory engineer for Amazon's Project Kuiper, where he conducts spaceflight dynamics and radio-frequency interference simulations in support of the company's regulatory efforts. He was a spacecraft systems engineer at The Aerospace Corp. and a systems engineering intern at Airbus-OneWeb Satellites through the Matthew Isakowitz Fellowship Program.

Tatiana Jaimes

Undergraduate Student, Mechatronics Engineering
Class of 2022 • Vaughn College of Aeronautics and Technology

Through NASA's Human Exploration Rover Challenge, Jaimes is designing and constructing a mechanical rover with a telemetry system capable of collecting data about the status of the driver, rover and operating environment. She was an electromechanical systems pathways intern at NASA's Goddard Space Flight Center, where she worked on robotic spacecraft systems.

Jaimes is vice president of Vaughn College's chapter of the Society of Women Engineers and secretary for the school's robotics team, through which she volunteers to teach K-12 students about 3D printing and robotics. As an international student from Colombia, she participated in a project for the Latin American and Caribbean Consortium of Engineering Institutions to create a low-cost agricultural robot that can analyze soil data and balance its composition preparation for reforestation following wildfires.

Margaret Kilpatrick

M.S. Aerospace Engineering
Class of 2022 • Georgia Institute of Technology • B.S. Mechanical Engineering • Class of 2019
Georgia Southern University

Kilpatrick's graduate research helped NASA analyze how near- and far-term technologies impact aircraft and jet engine performance. Her research provided NASA with a dashboard capable of projecting aircraft performance, noise and emissions analysis based on user inputs for various aircraft and engine combinations and configurations. Her research also analyzed environmental impact for application to the FAA's Committee on Aviation Environmental Protection stringency studies and future regulatory policies.

Kilpatrick interned at Lockheed Martin and the NASA Marshall Space Flight Center. She was president of the mechanical engineering honor society Pi Tau Sigma, through which she worked on community outreach and engagement programs, including volunteer work such as afterschool programs to promote STEM.

Anoop Kiran

B.S. Aerospace Engineering • Class of 2022 • University at Buffalo, The State University of New York

Kiran is focused on improving satellite structures and control in perturbed environments. He was chosen as a NASA Space Grant Scholar for his research that created an algorithm to filter measurements containing noise over time to provide estimates of satellite trajectory prediction. Kiran's research also has supported the U.S. Army Research Laboratory on maturation of eye-tracking capabilities.

He has interned at Boeing, GKN Aerospace and the NASA Jet Propulsion Laboratory.

Kiran's experience as an immigrant inspired him to perform volunteer mentor work with International Student Services and Buffalo Engineering Awareness for Minorities. He also has utilized his bilingual skills to work as an IRS-certified volunteer income tax preparer for low- and moderate-income families in his community.

Perla Latorre-Suarez

Graduate Student, Aerospace Engineering • Class of 2023 • University of Central Florida
B.S. Mechanical Engineering • Class of 2021 • University of Central Florida

Latorre-Suarez's research projects will support NASA's Artemis mission by protecting the lunar lander, rovers and other vehicle components used for lunar exploration. She is leading a project to design wear-resistant materials to protect space missions from harsh lunar environments and researching the optical properties of lunar soil. She has interned at NASA Langley Research Center and led a team competing in the NASA MINDS program to design an adaptive connection for multiple tethered drones.

Through the National Security Innovation Network X-Force Fellowship, Latorre-Suarez worked with the U.S. Army Research Laboratory to design drones for surveillance missions. Her experience moving from Puerto Rico to the U.S. mainland at age 16 inspired her to perform volunteer work helping people who speak English as a second language earn high school diplomas or GED certificates. She also leads STEM outreach events for K-12 students.

Daniel Mayper

B.S. Aeronautics and Astronautics • Class of 2022 • Purdue University

Mayper's undergraduate research is helping to refine the properties of lunar landers so they are able to withstand high landing temperatures. He was part of a team that designed and built an original experiment to measure the plume-impingement heating of lunar-lander legs during landing. The experiment is scheduled to fly on Masten Space System Xodiac rocket at Mojave Air and Space Port this year.

Mayper is a member of the Indiana Army National Guard, for which he performs maintenance and repair on helicopters. While deployed to Kuwait and Saudi Arabia, he continued his studies through remote learning. He is president of the Purdue Student Veteran Organization and volunteers with the school's Veterans Success Center to help veterans, active service members and their dependents understand and utilize their GI Bill benefits.

Hailey Nichols

M.S. Aerospace Engineering • Class of 2022 • The University of Texas at Austin
B.S. Aerospace Engineering and Aerospace Information Technology • Class of 2019
Massachusetts Institute of Technology

While researching developments to enable the safe autonomous flight of drones, Nichols founded a startup called Locus Lock that aims to provide low-cost, precise positioning technology to the commercial sector. Her startup has developed a software-defined technique using GPS and global navigation satellite systems, which she says will be key for emerging technologies such as urban air mobility vehicles, since existing aviation-certified GPS receivers are costly, heavy and do not provide the accuracy needed for urban environments.

Nichols has interned at Lockheed Martin and Kitty Hawk, and she has worked as a UAV software engineer at Aurora Flight Sciences. She was captain of MIT's varsity women's soccer team and volunteered as a tutor for the Petey Green Program, which provides supplemental education in correctional institutions.

Luisa Piccolo Serafim

Graduate Student, Mechanical Engineering • Class of 2026 • Duke University
B.S. Mechanical Engineering • Class of 2021 • Universidade Federal de Santa Catarina

Piccolo Serafim's research at Duke University's Aeroelasticity Research Laboratory is assessing high-speed flows and fluid-solid-thermal interactions for supersonic and hypersonic applications. Her research can potentially improve how the aerospace industry approaches complex aerodynamic and aeroelastic problems during technological development.

Originally from Brazil, Piccolo Serafim completed an engineering internship at Embraer. During her undergraduate studies, she volunteered to attract—and keep—youth in STEM studies, including founding a student organization to help her university better identify and address issues such as gender discrimination and biased evaluation. As a member of Duke's Diversity, Equity, Inclusion and Community committee, she supports underrepresented groups through the graduate school application process.

Grace Robertson

B.S. Aerospace Engineering • Class of 2022 • Embry-Riddle Aeronautical University

While working at Embry-Riddle's Space Technologies Lab, Robertson was part of a student team that designed and assembled a cubesat capable of capturing images of the first commercial lunar landing. The EagleCam CubeSat was delivered to Intuitive Machines, which plans to launch it in the fourth quarter of this year. She has interned at Lockheed Martin and Collins Aerospace and is now a Sierra Space systems engineer.

During her studies, Robertson was involved in various volunteer efforts focused on STEM education, bridging inequalities and environmental change. In addition to participating in monthly beach cleanups, she worked on an engineering project to design a robot that can remove microplastics from beach sand. As public relations officer for the Association for Women in Mathematics, she helped organize the Women in Science at Embry-Riddle event, which hosts STEM competitions for high school-age girls.

Alina Santander Vinokurova

Undergraduate Student, Mechatronics Engineering
Class of 2023 • Vaughn College of Aeronautics and Technology
B.S. Physics
Class of 2021 • Universidad Mayor de San Andres

Santander Vinokurova was the first Bolivian to compete in the NASA Rover Challenge, which she has participated in since 2016. At her university in Bolivia, she worked with a team at the Condensed Matter Laboratory to design for the challenge a mechanical rover inspired by the Andean hairy armadillo. She is also the founder and president of Vaughn College's NASA Rover Club.

Vinokurova was elected president of Vaughn College's chapter of the Society of Women Engineers. She has given more than 70 professional talks, including two TEDx talks about her experiences in and perspectives on the aerospace industry. Her volunteer efforts have focused on reducing the gender gap in STEM and improving access to STEM education in Latin America, including leading virtual and in-person STEM events for children.

Morgan Mackenzie Serra

Undergraduate Student, Aerospace Engineering • Class of 2023 • University of Michigan

Serra built and debugged a new Model-Based Systems Engineering Lab for the University of Michigan's Aerospace Department. This work led to her systems engineering internship at Collins Aerospace and helped her win a Department of Defense SMART Scholarship-for-Service award for her efforts. Serra is also chief engineer of M-SAAVE (Michigan Sustainability Applications for Aerospace Vehicle Engineering), an aircraft design team that partners with Air Serv International to design an autonomous vehicle for natural-disaster surveillance and delivery of food and medical supplies.

Serra is vice president of cost assistance for Resilient Engineers, where she raises emergency funds for engineering students experiencing financial hardship. She works on outreach events to promote STEM careers through the Society of Women Engineers and Women in Aeronautics and Astronautics. She is also engaged in volunteer work to help people with disabilities and to raise money for pediatric rehabilitation therapies.

Caitlyn Singam

Graduate Student, Bioengineering • Class of 2024 • University of Maryland
B.S. Biological Sciences • Class of 2020 • University of Maryland

Through the National Science Foundation Graduate Research Fellowship, Singam is working to improve communications systems to transmit scientific data for long-range astrobiology missions. She won the Best Paper Award at the 2021 International Space Operations Conference for her research on handling data transmission across disruption-tolerant networks.

Singam interned at NASA before working as a systems engineer on the Dragonfly astrobiology mission. She is involved in numerous volunteer efforts to increase economic and racial diversity in STEM and volunteers at a cardiac clinic and in the Medical Reserve Corps. She applied her studies to these roles by developing a secure communications module for use by first responders and emergency personnel.

Julia Weiss

Graduate Student, Aerospace Engineering • Class of 2022 • University of Michigan
B.S. Aerospace Engineering • Class of 2021 • University of Michigan

Weiss is working with faculty at the University of Michigan to develop an undergraduate course series that will prepare students for real-world engineering operations and systems thinking through elements previously overlooked in the engineering curriculum, such as effective teaming, scheduling and budgeting. Through this project, she works with aerospace and defense industry representatives to ensure the curriculum matches industry needs.

Weiss also demonstrated her passion for enacting organizational change as vice president of the Michigan Aeronautical Science Association, where she led transformative efforts such as new member support networks and diversity, equity and inclusion initiatives. She has completed internships at Northrop Grumman and General Atomics as well.

David Wolmark

Graduate Student, Aerospace Engineering • Class of 2022
University of Southern California
Dual B.S. Aeronautical and Mechanical Engineering • Class of 2019
Rensselaer Polytechnic Institute

Wolmark is an aerospace engineer through the Johns Hopkins University Applied Physics Laboratory Part-Time Study Program. His research is focused on demonstrating the efficacy of a moving mass control system as a means of trimming and controlling the rotational dynamics of an aircraft. He was previously an associate mechanical engineer at Northrop Grumman, where he worked on the design of structural, mechanical, electric and hydraulic parts and assemblies.

Wolmark has completed engineering internships at Pratt & Whitney and Bendix Engineering. While leading a Boy Scout group on a canoeing trip in 2013, he experienced a life-changing injury that restricted him to home instruction for half of his junior year in high school, which he says inspired him to dive more deeply into his coursework. He is now an Eagle Scout volunteer firefighter and emergency medical technician.

Angie Zhang

B.S. Aeronautical and Astronautical Engineering • Class of 2022
Purdue University

Zhang's FAA-sponsored research at Purdue helped to demonstrate the viability of profitable supersonic commercial flight using complex simulation and airline data. She completed three aerospace engineering internships at Lockheed Martin and one at Northrop Grumman, where she worked on projects such as electrical test procedures for satellite programs, analyzing risks in aircraft breathing systems and testing for modifications in aircraft software and hardware.

Zhang was president of Purdue's chapter of the Society of Women Engineers, through which she led efforts toward improved diversity and equity in STEM. She was also an ambassador for the Purdue Student Engineering Foundation, where she led tours and information sessions to support prospective students.

ECO EVOLUTION

> BOEING'S LATEST ecoDEMONSTRATOR READIES FOR EXTENSIVE FLIGHT- TEST PROGRAM

> 777-200ER TRIALS ARE PLANNED TO RUN THROUGH 2024

> NEW SMART VORTEX GENERATORS ARE BEING TESTED

Boeing's use of a dedicated ecoDemonstrator, the ninth in the program, will enable longer-term testing and more invasive modifications.

BOEING/PAUL WEATHERMAN

Guy Norris Seattle

BEARING AN IMAGE OF EARTH ON THE aft body and the words "powered by SAF" emblazoned beneath the fuselage, Boeing's latest ecoDemonstrator—a 777-200ER—is poised to begin the next flight-test campaign in the OEM's long-running program.

Set to begin just weeks after the International Civil Aviation Organization's Oct. 7 adoption of the goal of achieving net-zero carbon emissions by 2050, the role of the new-look ecoDemonstrator has taken on fresh significance as part of the company's recently unveiled approach to decarbonization dubbed "Everything for Zero."

"We've got the world on the back of the aircraft, and I really wanted to get that on this ecoDemonstrator because we are now really a global asset," says Rae Lutters, ecoDemonstrator program manager. On top of its role as a tool for testing and proving out potential new technologies, the ecoDemonstrator is seen by Boeing as a flagship for "showing how we are leaders in sustainable aviation," she adds.

Beginning in 2012 with a relatively modest test campaign involving a leased 737-800, the decade-old ecoDemonstrator program now forms a major pillar of Boeing's research and development portfolio at a vital time for the manufacturer. Despite unparalleled challenges and financial headwinds since 2019, the company has continued to invest in the initiative, recently acquiring the 777-200ER for conversion into a dedicated flying technology testbed for at least the next two years.

The first use of a 777-200ER variant in the program marks only the second time that Boeing has acquired a widebody test asset devoted specifically to the ecoDemonstrator campaign. Aside from 2019, when Boeing bought a used 777-200 for the program, every other ecoDemonstrator has been flown in partnership with an airline—or, in the case of the 2016 campaign, with Embraer using a modified E170 regional airliner. In addition to a 737-800, the program has included a 737-9, 777F, 787-8, 787-10 and a 757-200 that had been operated by a former charter airline and withdrawn from commercial service.

Having a dedicated airframe "enables us to be able to test a lot more things on our own time, where we don't have to

LOGO: ARTHOBBIT/UNDEFINED UNDEFINED/WASTESOUL/MARYLOO/GETTY IMAGES

give the airplane back to the operator," Lutters says. In addition, the aircraft does not require refurbishment after the end of the ecoDemonstrator campaign and can be configured for more invasive test equipment or modifications.

The 777-200ER, like previous ecoDemonstrators, will operate on "some blend of sustainable aviation fuel," Lutters says. "The highest blend that is available to us is up to 50%, which is the certified limit. This year we're flying typically on a 30-70 blend because that is the highest ratio we can get right now due to the limitations of the current production system."

Flying with sustainable aviation fuel (SAF) blends not only helps prove out day-to-day operability using alternative fuels, but the advent of the technology also will help add momentum to the growth of SAF refining capability on the industrial scale required for its wholesale adoption over the coming years, Boeing says. The ecoDemonstrator also forms part of ongoing studies with NASA to measure particulate emissions that will inform research on contrail formation and the associated sensitivities connected with the use of different SAF (see page 58).

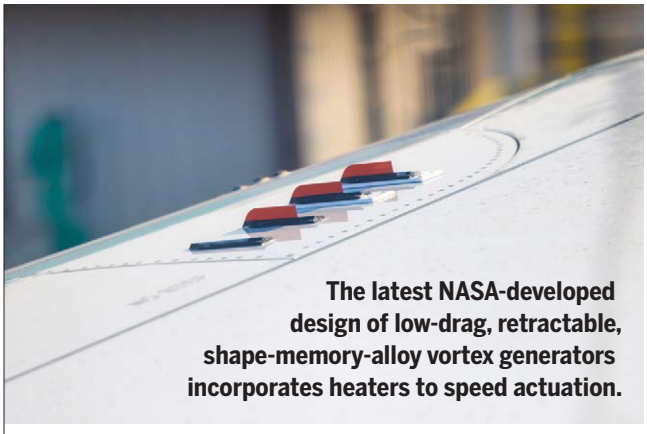
Technologies to be evaluated over an initial six-month flight-test program on the 777-200ER include several all-new features as well as the latest evolutions of technologies tested on earlier campaigns. The latter includes an actively actuated set of retractable vortex generators (VG) developed with NASA under the SMART (shape memory alloy reconfigurable technology) program, which builds on work performed during the 2019 test program.

Vortex generators reenergize flow and improve aerodynamic performance, but they generally are needed only for slower speeds at lower altitudes rather than during cruise, when the static vanes are a source of drag. The SMART program developed a set of experimental VGs that could be passively deployed and retracted to be flush with the wing by using phase-transforming shape memory alloys (SMA) that react to changing temperature.

Although tests of the VGs with an SMA rotary actuator demonstrated that the units could be integrated into a 777 wing and would passively retract in colder upper-atmospheric temperatures, the reaction time for extension was slow, particularly after the wing had cold-soaked in cruise conditions. "This year, we're adding a test with a heater mechanism that would enable the flight crew to actively deploy or retract them," Lutters says. The experimental VGs are mounted close to the wing's leading edge in a section dubbed the piano panel, where they can be filmed from a camera mounted in the cabin.

All the other technologies to be tested in the upcoming campaign are inside the aircraft's cabin, cargo holds or flight deck. The 777 will continue a long campaign of testing new fire-extinguishing agents intended to replace ozone-depleting Halon 1301, which is no longer being produced. Although non-Halon solutions have been found for cabins and lavatories, the industry is still forced to recycle Halon until effective replacements can be developed for the unique challenges of fire suppression at altitude in engines, auxiliary power units and the cargo hold.

The latest efforts build on tests from 2019 of a new blend



The latest NASA-developed design of low-drag, retractable, shape-memory-alloy vortex generators incorporates heaters to speed actuation.

BOEING

of bromotrifluoropropene (2-BTP) developed by fire-suppression specialist Meggitt, which showed promise for use in cargo holds. Tests on an Alaska Airlines 737-9 in 2021 evaluated an agent dubbed CF3i (iodotrifluoromethane) for extinguishing engine-bay fires. In 2022, these tests are focused on the discharge performance of Meggitt's 2-BTP agent—called Verdagent—for the cargo compartment.

"Testing will focus on the dispersion rate and how big an area it will go to and whether that compares to what we would see with typical Halon," Lutters says. "There's no fire or anything that we're going to be testing—that's all done in a controlled lab. But what we're going to be testing in the cargo bay is really critical because we have a mandate that we need

BOEING

New cabin systems being tested include a Diehl-developed water conservation system that uses filtrated handwashing wastewater to flush a toilet. This could cut more than 400 lb. of weight per flight, or more than 600,000 lb. per year.

to adhere to [in order to] find a new type of agent by 2040."

Meanwhile, last year's tests of the CF3i point to the need for additional work. "We're continuing our learnings," Lutters says, adding that the exercise proved the value of the ecoDemonstrator. "I think it was really good that we tested [the Halon replacement candidate] on the airplane because we test in a real environment rather than in a lab. We are able to see how it actually performs."

The program also will test several flight-deck technologies aimed at improving operational efficiency, including a system developed using Jeppesen airport maps that will enable optimized taxiing operations before takeoff and after landing. The Taxi Time Information and Taxi Clearance applications will be tested with electronic flight bags and use automatic dependent surveillance-broadcast positioning data and aircraft connectivity to estimate required taxi time. "It will give pilots and operations teams an idea of what's really going on so they can choose to be on one engine," Lutters says. It also will let them know that they have time to "spool up that engine before they take off," she notes.

The next phase of ecoDemonstrator tests in 2023 are slated to evaluate a more advanced head-mounted portable enhanced vision system (EVS)—a version of which was initially tested in 2019. Developed by Universal Avionics, the SkyLens head-up display (HUD) system will integrate aircraft data with imagery from a nose-mounted camera. The EVS system is designed to provide improved situational awareness to the flight crew, particularly in low-visibility conditions, while saving the weight and complexity associated with conventional cockpit-mounted HUDs.

Technology tests in the cabin include a "gray" water recycling system that collects and filters washbasin water for later use in flushing toilets. Developed by Diehl Aviation, Boeing says the system has the potential to save around 50 gal. or more than 400 lb. of weight per flight. "This is a really cool concept," Lutters says. "This apparatus will

PAUL WEATHERMAN/BOEING

BIGGER PICTURE

> SAF EMISSIONS TESTED WITH BOEING 777 ecoDEMONSTRATOR

> LOWER-SULFUR JET A FUEL USED FOR BASELINE TRIALS

Guy Norris Seattle

Sustainable aviation fuel is the air transport industry's best bet for achieving near-term decarbonization, but many unknowns remain as plans continue toward its widespread use at 100% rather than blended with current jet fuel.

Emissions characteristics of unblended sustainable aviation fuel (SAF) have not been tested yet across multiple engine types, and there are questions about the potential effect of their particulates and chemistry on contrail formation.

To learn more, researchers from NASA have joined forces with Boeing to measure emissions from SAF-powered aircraft in the manufacturer's most recent ecoDemonstrator technology programs. Tests of a CFM International Leap 1B engine with 100% SAF on a Boeing 737-9 in 2021 showed significantly reduced soot particles, while analysis of recently completed tests on this year's demonstrator—a Rolls-Royce Trent 800-powered 777-200ER—is still underway.

"We're looking at different combustor technologies and using the pure fuel to understand how the emissions change across those engines," says Richard Moore, a physical research scientist from the NASA Langley Research Center in Virginia. Using successive ecoDemonstrators, researchers for the first time measured emissions from SAF burned in the state-of-the-art low-emissions

NASA Langley's mobile lab (bottom left) analyzed emissions collected via a probe from the ecoDemonstrator's No. 2 right-hand engine.

staged-combustion design in the 737's Leap 1B and the contemporary rich-burn/quench/lean-burn (RQL) combustor of the higher-thrust Trent 800.

In addition to releasing CO_2, aircraft engines burning regular fossil-based Jet A-1 emit water vapor and particles composed of volatile components such as sulfates and nitrates as well as nonvolatiles such as carbon and ash. The nonvolatile particles form in the combustor while the volatile emissions

cycle through about every 10 min. during flight tests to represent average passenger use."

Another experimental toilet cubicle developed with interior specialist Jamco and Japan-based All Nippon Airlines incorporates a hands-free door opening-and-latching design, while a third lavatory unit—also developed in collaboration by Boeing and Jamco—will be used to evaluate an automated ultraviolet (UV) disinfecting system. UV irradiation deactivates viruses and kills bacterial organisms by destroying their DNA. "The idea is that after someone uses the restroom, they would exit, the door would shut, and a sensor would sense no one was in there," Lutters says. "It would activate the system, go through its cycle, disinfect it, and then be ready for the next person."

Other cabin technology tests include evaluation of UV cabin lights and a new air chiller, in partnership with Collins Aerospace. The UV light, which for the tests is located in the galley of the 777, could be featured in cabin configurations to help disinfect them during turnarounds between flights. The new air chiller uses Opteon R-1234yf, an environmentally preferred refrigerant agent based on hydrofluoroolefin—a molecule that, if accidently released, has an average atmospheric lifetime of 11 days, compared with the roughly 12-year life of a typical hydrofluorocarbon-based refrigerant.

"It literally looks like something you would do in a high school laboratory, but we're collecting data by putting thermocouples in bottled water in different areas [of the galley,]" Lutters says. "We're going to be collecting data over time to see that it performs how we would expect it to and to see if it is similar to the ones that we currently utilize."

Boeing also is using the ecoDemonstrator to test wider applications of additive manufacturing, including a part made from recycled aluminum, a complex engine bracket made from Inconel and an auxiliary power unit duct panel crafted from titanium—the largest Boeing-made additively manufactured part yet built and flown by the company.

emerge in the gas phase at the engine exhaust. At cruise altitudes, the water rapidly condenses onto the particles and under the right conditions can form droplets that grow as the exhaust plume cools. These eventually freeze to form a condensation trail that in certain atmospheric conditions can persist for hours, spreading to form contrail cirrus.

However, SAF differs from conventional jet fuel in both chemical and physical properties, most notably lacking the aromatics and sulfur components that are precursors to the formation of nonvolatile and volatile particulate emissions. To quantify the makeup of the gas and particulates in the exhaust from the engine and fuel effects alone, researchers conducted multiple tests to compare traditional 100% Jet A fuel, 100% HEFA-SPK SAF (synthetic paraffinic kerosene produced via the hydroprocessed esters and fatty acids pathway) and blends of the SAF plus Jet A.

For the 2021 tests, 100% conventional Jet A kerosene was used as the reference fuel against 100% HEFA-SPK SAF and two different types of SAF: 30-70 and 50-50 blends of Seattle-area-refinery-sourced, fossil-based Jet A-1. The 30-70 blend used a commercially available SAF, while the 50-50 blend used SAF specially made for the ecoDemonstrator tests.

For this year's trials, the fuels included a 100% HEFA-SPK SAF, 100% regular Jet A and a low-sulfur Jet A that was evaluated in the engine at 100% and as part of a 50-50 blend with SAF. The use of low-sulfur Jet A is important for establishing the true comparative basis of the emissions from the SAF in lean-burn engines, says Steve Baughcum, Boeing Emissions technical fellow.

"Soot increases if the aromatic content is higher," Baughcum says. "And we also produce aerosols, so one of the questions is: How important is the sulfur content to the aerosols we produce? Particularly the volatile aerosols.

"We're trying to get down into those low sulfur levels and use some of the NASA instrumentation to evaluate that," he adds. "How do soot concentrations and volatiles interact with each other? If I have a lot of soot surface area, then I can deposit those onto the soot, and I don't create new particles."

For the tests, a NASA Langley mobile lab vehicle containing a suite of instruments was parked behind a jet blast deflector located aft of the 777 ecoDemonstrator. Emissions from the exhaust plume of the right (No. 2) engine burning the test fuel were fed to the instruments via a custom-built probe, which projected through the deflector. A set of spectrometers analyzed volatile and nonvolatile particle size and concentrations, while sensors provided by Massachusetts-based Aerodyne Research—including optical monitors based on the cavity-attenuated phase-shift technique—measured particle light-absorption and chemical composition.

"We want to understand how the emissions vary throughout the full range of the aircraft operations: from idling at the gates to taxiing to high thrust for takeoff and midthrust for cruise," Moore says. Unlike flight tests, where only limited data can be collected from chase aircraft, "one of the beauties of doing this work on the ground is that we're not looking at a single thrust data point or one or two points," he adds. "We can fill out the full curve and have information and understand how the engine performs both at idle, which we care about for air quality and what's happening around the airports, as well as the higher thrust that we care about for cruise and contrails.

"The lessons that we learn on the ground are directly translatable to what we get at cruise, and we've seen from past ground tests that the fuel emissions reductions associated with sustainable fuels or fuel blends directly translate to reductions in particle emissions at cruise," Moore continues. The NASA-Boeing work also dovetails with other SAF projects such as the European ECLIF3 study involving Airbus, Rolls-Royce and German aerospace center DLR. In 2021, the project flew an Airbus A350 with both of its Trent XWB engines fueled by 100% SAF produced by Neste.

"We're all looking at each other's data, and we're using the measurements that we made last year to contextualize that single data point that they have and fill in the bigger picture," Moore says. "The hope would be, as the community moves forward, that there'll be an opportunity to extrapolate these measurements we make on the ground up to the cruise condition."

Making the Case for Aviation's Sustainability Options

> CASCADE MODEL STRESSES SAF IMPORTANCE TO SUSTAINABILITY

> LIFE-CYCLE EMISSIONS OF ELECTRICITY AND HYDROGEN MUST BE CONSIDERED

Graham Warwick Washington

Biofuels and e-fuels, electricity and hydrogen, mandates and tax credits—these and other options on the table risk overwhelming policymakers being pressed to provide government support to help aviation become sustainable.

What role should an aircraft manufacturer play in that decision-making melee? For Boeing, one key effort is to model the effects of different options on aviation emissions in a way that helps policymakers and customers assess the outcomes of their choices.

Boeing's model is called Cascade, and the initial results of beta testing are reinforcing what the company is already arguing: Fleet renewal and sustainable aviation fuel (SAF) are the most powerful levers that can be used to improve airline sustainability.

Cascade is suggesting that electric and hydrogen propulsion can help reduce emissions, but perhaps not as much as some hope. The reason is not just the limitations of technology but also the cleanliness of the electrical grid used to recharge batteries or produce green hydrogen.

"There's almost this belief that, when you say 'electricity' or 'hydrogen,' those are already green," says Chris Raymond, Boeing's chief sustainability officer, a position created in 2020. "Whereas if you say 'sustainable aviation fuel,' people say: 'Yes, but there's life-cycle emissions.'"

The concept of total life-cycle emissions is understood for liquid fuels, he says, but not for electricity and hydrogen. "One point we try to illustrate with Cascade is that, if you think electricity or hydrogen is your fuel of the future, you need to take into account the same total life-cycle emissions as we do with liquid fuels."

Take the example of an electric regional aircraft. Assuming a 700-nm-range aircraft that replaces 100% of the current fleet and a 100% clean, renewable-energy grid, Cascade predicts global emissions will drop just 2.5%. "Not a lot, but it helps," Raymond says.

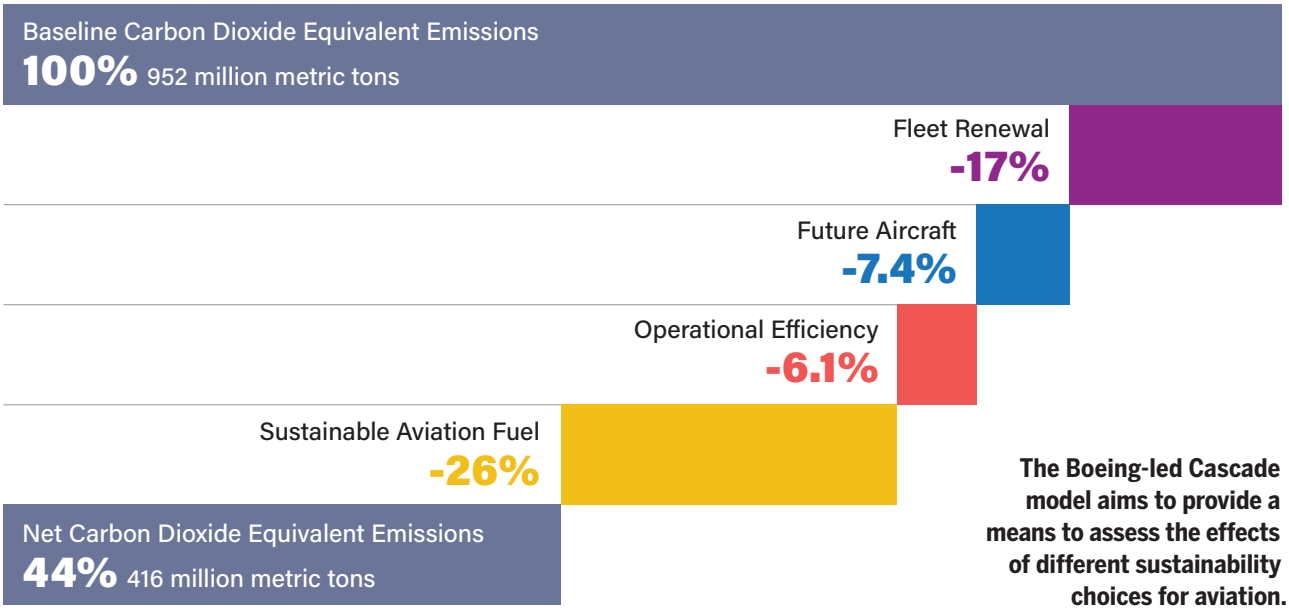
Now assume a hydrogen-powered regional. With today's gray hydrogen, emissions get worse. "What if the hydrogen were blue? There's a crossover point. As it gets closer to cleanly produced green hydrogen, it starts to help," he says.

Initially, Cascade models the global scheduled air traffic system for the yearlong period from February 2021 through February 2022—more than 32 million flights that generated as estimated 952 million metric tons of CO_2.

"One observation is that about 50% of the flights are less than 1,000 km [540 nm], but that's not where the fuel usage is—50% of the fuel is on flights over 2,800 km, but that's only about 20% of the flights," Raymond says. "So we've got to solve this long-range problem eventually."

In a demonstration at Boeing's Washington office, Raymond used Cascade to show that replacing all existing narrowbodies with new Airbus A320neos and Boeing 737 MAXs "at the snap of a finger" would reduce global emissions 17%. Operational efficiencies such as winglet retrofits and air traffic management improvements would buy another 6%. But a 50% SAF blend would provide a 26% benefit.

Modeling Pathways to Net-Zero Emissions



The Boeing-led Cascade model aims to provide a means to assess the effects of different sustainability choices for aviation.

Source: Boeing

"SAF and fleet renewal are the ways the industry can get to net-zero by 2050," he says. "Our view is you're going to need SAF no matter what. So we've developed this expression 'SAF and' because our view is it's going to take SAF and whatever electricity and hydrogen can do. It's not an 'or.'

"We also don't think we should sit around and wait for the perfect SAF. We're going to have to embrace a lot of different pathways for SAF. What is anathema in Europe is acceptable in the U.S. or Brazil—ethanol, for example," Raymond says. "We just need to have some level of sustainability criteria around those feedstocks."

Boeing sees SAF coming in three phases. The first is existing pathways, primarily HEFA (hydroprocessed esters and fatty acids) from fats, oils and greases. "It starts with waste- and biomass-based SAF, but over time people are going to add renewable electricity or green hydrogen to that equation, and those pathways can be made cleaner," Raymond says. "We call that power-and-biomass-to-liquid."

The end state, in Boeing's view, is power-to-liquid SAF, also called synthetic kerosene or e-fuel. This is produced from green hydrogen and captured CO_2 using renewable energy and is more popular in Europe, where it is to be included as part of the EU's upcoming SAF mandate.

"My only dilemma with that is it's going to mean choosing to spend a huge amount of available renewable energy making a fuel," Raymond says. "And if today's SAFs are 2-4 times more expensive [than fossil jet fuel], wait till we see what that might pencil out at. We're working with the Massachusetts Institute of Technology on what we have to solve as we migrate to power-to-liquid."

SAF today is limited to a 50% blend—and in reality to a much lower percentage due to availability—so that the blended fuel can be considered a drop-in replacement for conventional jet fuel. Boeing and Airbus are working to have aircraft compatible with 100% SAF by 2030.

ASTM International has a task group developing a specification for drop-in SAF that can completely replace fossil jet fuel without requiring aircraft or engine modifications. The standards body also has a second task group working on a non-drop-in 100% SAF—a specification for a new, and hopefully better, fuel that each airframe/engine combination would need to be certified to use.

Airbus is chairing the non-drop-in 100% SAF group, but Boeing is also involved, Raymond says. "What we'll be seeing is how far you can push the chemistry of a SAF and still have it considered drop-in. And what would you come up with as a clean-sheet fuel chemistry if you didn't care about making airplanes already in the system adapt to it? And how close can those two things get to a convergence point?"

In effect, industry is working left to right to see how far it can push drop-in SAF chemistry and from right to left to develop a new fuel optimized to reduce all emissions, including soot particles, nitrogen oxides, carbon and contrail formation.

The question that teams on both sides of the work are trying to answer, Raymond says, is: "If I wanted to optimize for all those things, what chemistry would I come up with, and how far away is that from a drop-in chemistry? We need to be figuring that out because we might find an 'aha' in there. I don't know if those two will ever coalesce into one, but I think it's good practice to come at it from both directions."

Meanwhile, Boeing plans to use Cascade to engage government policymakers and encourage them to start with policies and incentives "where technologies are mature and the impact can be felt sooner while we're working on tougher things like electric and hydrogen," he says. The model can be used to show them why policies that will help scale SAF production or incentivize investment can make a difference.

In addition to its SAF subject matter team, Boeing has a dedicated global policy team. "We're trying to share what we are seeing in other jurisdictions," Raymond says. While the EU plans to use the stick of a SAF mandate, the U.S. has enacted the carrot of a blender's tax credit. "What we've said in Europe is it's not for Boeing to say whether someone wants to use a mandate or not, but you pair it with some incentives," he adds.

Boeing has also learned that the book-and-claim system, which allows customers to buy SAF for delivery elsewhere and still get the carbon credit, is important as the industry scales up. The EU does not yet recognize book-and-claim. "That is one thing we've tried to suggest to the EU alongside our European customers," he says. "You don't want people doing stupid things like tankering or road-transporting fuel."

Boeing and its collaborators are now working on a dynamic mode for Cascade to go from modeling a year in the life of the aviation system to projecting the effects of various choices out to 2050. Users of the tool will be able to enter assumptions for traffic growth, fleet renewal percentage and the types of aircraft that enter the system as well as the rate at which their production ramps up to see how close to net-zero emissions they can get.

A Year in the Life of Aviation

32,226,001
flights

3.71 Ltr/100 pkm
operational fuel efficiency

111 gCO_2e/pkm
operational CO_2e Emissions

952 $MtCO_2e$
net CO_2e Emissions

gCO_2e Grams of carbon dioxide equivalent
Ltr Liters
$MtCO_2e$ Million metric tons of carbon dioxide equivalent
pkm Passenger kilometers

Source: Boeing

TECH TAKE

By **Graham Warwick**

For the latest, go to **AVIATIONWEEK.COM**

DARPA Eyes Airborne Wireless Energy Network

DARPA has launched its Persistent Optical Wireless Energy Relay (POWER) program, an effort to demonstrate the long-distance wireless transmission of energy using lasers and uncrewed aircraft as relays.

DARPA

DARPA wants to use UAVs as laser energy relays.

In particular, the research agency wants proposals for developing airborne optical energy relays that would enable a wireless energy network for powering equipment spread out on the battlefield. DARPA plans to host a "Proposers Day" on Oct. 24 for potential participants in the program.

"This is the internet for energy—harnessing resilient, multipath networks to flow energy from abundant sources to energy-starved consumers," says Col. Paul Calhoun, POWER program manager in DARPA's Tactical Technology Office.

"The military faces particularly acute energy challenges, which are driving this innovation," he says. "We often must operate far from established energy infrastructure and rely on liquid fuels that require precarious supply lines."

DARPA notes that military vehicles that have long range, long endurance or substantial weapons delivery requirements must be physically large to carry enough liquid fuel for power. However, if those vehicles could ditch the fuel tank and receive power wirelessly, they might become cheaper and smaller—and have "unlimited range or endurance."

Still, the inefficient process of converting electricity into laser power and then back to electricity at its point of consumption presents challenges. Those challenges are magnified if conversions must be made at each relay in a wireless network.

"The POWER program will develop efficient power-beaming relays that redirect optical energy transmissions while maximizing beam quality at each point along the way, selectively harvesting energy as needed," Calhoun says. "It is a three-phase development effort, culminating in a compelling energy-relay flight demonstration."

DARPA did not enumerate the distance over which it wants to relay energy or the amount of electrical power it wants to receive at the final point of consumption on the ground.

Separately, as part of the Airborne Energy Well program launched in June, DARPA is asking companies to put forward ideas for using inflight refueling tankers as airborne recharging points for networks of electric-powered UAVs. That effort calls for companies that have demonstrated a prototype of a 100-kW continuous-wave laser to submit proposals.

The program envisions tankers, such as the Boeing KC-46, beaming laser energy to UAVs using a wing-mounted laser pod. Several U.S. companies are developing high-power laser weapons for applications such as shooting down drones or missiles.

DARPA says wireless energy could create a military advantage for the U.S. "We believe the next energy revolution will be enabled by the wireless energy web," Calhoun says. "It will dramatically compress transport timelines and resiliently provide distributed energy to consumers in air, on land, on the sea, undersea and in space."

—Garrett Reim in Los Angeles

Xwing Works With NASA on Automation

Xwing has signed a three-year partnership with NASA to study performance, procedures and risks for flight automation. The San Francisco-based startup initially plans to study hazards, performance and safety benefits of its vision-based autoland system. Data and lessons learned will be shared with NASA.

Researchers at NASA will use the information to validate and evaluate safety management systems and algorithms, as well as provide risk analyses and prognostics.

"Emerging aviation relies heavily on advanced automation to ensure safety," says Misty Davies, NASA system-wide safety project manager. "This partnership will help NASA understand the real-world challenges that industry is facing."

Xwing plans to retrofit an undetermined number of its Part 135 commercial cargo fleet of Cessna Caravans with electro-optical and infrared cameras in underwing pods. Computer vision software will use the imagery to identify the runway, centerline, threshold markings and other cues to line up an aircraft for final approach and landing. The sensors will also be used for automated taxiing and detect-and-avoid capabilities.

"It's about supplementing GPS/inertial-based navigation with a separate independent system to validate the position of the aircraft, especially on final [approach]," Xwing CEO Marc Piette says.

Xwing is working to obtain a supplemental type certification (STC) for the sensor pods, which is "in the final phases," he says. Flights with the pods would begin once the STC is obtained.

XWING

Multisensor pods will be mounted under the Caravan's wing.

"This first STC is not going to be integrating with the flight control system, but it acts as a data collection mechanism that we could deploy in the 14 states that we currently fly to today," Piette says. The pods also house radar and lidar sensors.

Data collected from the Part 135 fleet will be used to validate and improve Xwing's algorithms and will supplement and refine work done using Xwing's modified Caravan technology testbed. That aircraft demonstrated autonomous gate-to-gate flight and taxiing last year.

Xwing is competing against startups such as Reliable Robotics and Merlin Labs to automate aircraft flights, including cargo operations. Removing a pilot from cargo flights would significantly reduce costs.

In 2021, Xwing signed a joint development technology agreement with Caravan manufacturer Textron Aviation to accelerate the integration of autoflight technologies into existing and future aircraft. As part of UPS' regional air cargo network, Xwing conducts about 400 flights a week with 35 Caravans to 57 locations across the U.S. to gather hands-on operations experience.

"If you think about deploying this autonomy at scale, it's not just about flying the airplane," says Jesse Kallman, Xwing's vice president of commercialization and strategy. "A lot of it is ground taxi operations, loading and unloading."

Programming aircraft to deal with uncertainties also needs to be figured out. That's especially the case with some of the small, nontowered airports Xwing's pilots fly into today, says Piette, who likens the uncontrolled airspace to the "Wild West."

"You've got crop dusters without radios flying around. You've got skydivers that are jumping close to the pattern. Student pilots are flying around. You've got people landing in both directions on the same runway," he says. "You've got to coordinate all of this.

"People really like to focus on automation of the aircraft and the fact that the aircraft can do a takeoff and landing on its own," Piette says. "That's not where the challenge is. It's being able to handle all of these curveballs that can be thrown at the system and do it gracefully."

—Garrett Reim in Los Angeles

South Korea's First 5G Network for UAM

South Korean telecommunications provider KT has completed the country's first 5G wireless network dedicated to urban air mobility (UAM). The network will support the first phase of South Korea's K-UAM Grand Challenge demonstration project.

The network is designed to provide stable 5G service to support UAM test operations at altitudes of 300-600 m (1,000-2,000 ft.) in corridors and vertiports around the Goheung Aviation Test Center, where the K-UAM Phase 1 trials will be conducted.

Coverage of the 5G network was optimized using 3D design technology, KT says. Unlike ground coverage optimization applied to a flat surface, the design was optimized by modeling the beam pattern in the three-dimensional UAM operating area to ensure there are no coverage holes or interference.

KT also used network slice technology, which guarantees communication service quality by separating special and general purpose traffic. For the 5G air network, slice technology ensures transmission reliability for UAM command-and-control data even under heavy network traffic, KT adds.

The company plans to expand use of the UAM-only 5G network to other manufacturers and operators of small- and medium-size aircraft. Beginning next year, KT plans to apply satellite communication and quantum cryptography to the air network to enhance the security and reliability of communications for UAM operations.

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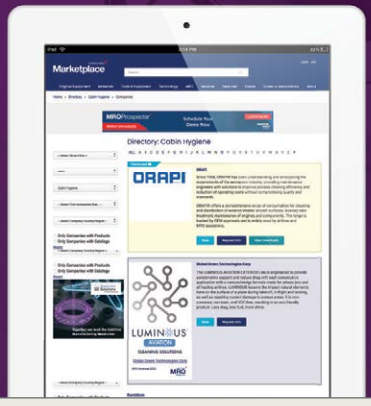

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Aerospace Calendar

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Nov. 1-3—International Air Transport Association (IATA) World Passenger Symposium. Gulf Hotel Bahrain. Manama, Bahrain. See iata.org/en/events/wps

Nov. 2-5—IndoAerospace 2022 Expo & Forum. JIExpo Kemayoran. Jakarta, Indonesia. See indoaerospace.com

Nov. 7-9—Flight Safety Foundation's International Air Safety Summit. Omni Atlanta Hotel at CNN Center. Atlanta. See flightsafety.org/iass2022

Nov. 7-9—Air Traffic Control Association (ATCA) Global Conference and Exposition. Walter E. Washington Convention Center. Washington. See atca.org/global

Nov. 8-9—Hypersonic Defense 2022 Conference. Westin Hotel. Huntsville, Alabama. See intelligence-sec.com/events/hypersonic-defense-2022

Nov. 8-9—IATA Wings of Change Europe. Hilton Bomonti Hotel. Istanbul. See iata.org/en/events/wings-europe

Nov. 9-10—Future Travel Experience Airline Passenger Experience Association (APEX) Asia Expo+. Marina Bay Sands Expo and Convention Center. Singapore. See futuretravelexperience.com/fteasia

Nov. 9-11—Bahrain International Airshow. Sakhir Air Base. Bahrain. See bahraininternationalairshow.com

Nov. 10—Third Spanish Aviation Summit. Virtual event. Madrid. See aeropodium.com/spain

Nov. 15-16—Mexico's Supply Chain Nearshoring Summit. Queretaro Congress Center. Queretaro, Mexico. See mexicoaerospacesummit.com

Nov. 15-17—Space Tech Expo Europe. Messe Bremen. Bremen, Germany. See spacetechexpo.eu

Nov. 15-17—More Electric Aircraft USA Seattle. Venue TBD. Seattle. See iqpc.com/events-more-electric-aircraft-seattle

Nov. 15-18—International Defense Exhibition & Seminar (IDEAS). Karachi Expo Center. Karachi, Pakistan. See ideaspakistan.gov.pk

Nov. 16-17—ISTAT Latin America. Hilton Panama. Panama City. See connect.istat.org/Latin-America

Nov. 16-17—Air and Missile Defence Technology. Hilton London Kensington. London. See smgconferences.com/defence/europe/Air-Missile-Defence

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Nov. 2-4—GAD World. Amsterdam.

Nov. 3—Aviation Week Network's Laureate Awards. Washington.

Nov. 3—20 Twenties. Washington.

Nov. 3-4—CAPA Asia Aviation Summit & Sustainability Awards. Singapore.

Nov. 3-4—Corporate Travel Community (CTC) Asia Corporate Travel Summit & Sustainability Expo. Singapore.

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VIEWPOINT

Supercharging Innovation

By **Michael R. Bloomberg**

The American private sector innovates and produces like no other nation in the world. And with Russia's invasion of Ukraine and the challenges it presents to democracies around the world, there is renewed urgency to find ways to quickly leverage U.S. innovation and ingenuity to defend our values at home and abroad.

At the Pentagon, the challenge of transitioning technology to the battlefield is well known: It's called the "valley of death."

When American startups, often from Silicon Valley, are funded to develop cutting-edge technology demonstrations for our nation's defense, their innovations tend to languish in government bureaucracy, without ever getting integrated into Defense Department operations—and without moving promising technologies from the lab to the battlefield.

This red tape frustrates the Pentagon and Silicon Valley startups alike. But it's also an issue that Defense Department leaders, particularly Secretary Lloyd Austin, are determined to solve.

Success requires funding more venture-backed companies with robust research and development capabilities while also integrating Defense Department experts into the product development phase. Together, they can more rapidly build, fail, learn, build again and continue learning. Trial and error during development is crucial, and both groups—startups and the Defense Department—must collaborate closely to ensure that the insights they gain are used to build a better mousetrap.

Bloomberg (right) spoke with Lanzilotta aboard the USS Ford.

MASS COMMUNICATION SPECIALIST JACKSON ADKINS/U.S. NAVY

"PRIVATE-SECTOR STRATEGIES CAN HELP DEFEND AMERICA."

At Bloomberg LP, rapid technological development is a major reason for our success over more than 40 years. From the start, we've had a relentless focus on the customer. We continually seek their feedback, which our engineers integrate into product development, so we can build, fail, learn, build again and eventually succeed, in the shortest time possible.

Not all operational strategies in the private sector apply to government, especially when agencies rely heavily on outside contractors. But many critical management strategies do apply, including learning from customers, constantly overseeing progress, holding people accountable for staying on time and on budget, breaking big projects into smaller component parts, using data to identify challenges and target resources, incentivizing risk, being willing to accept failure and recognizing when to double down and when to walk away. Integrating these and other practices more deeply into the Defense Department can help bridge the valley of death.

The department has several efforts underway to incorporate the type of rapid development and implementation that can harness U.S. innovation, and these programs are showing early promise. For example: In July 2022, the department announced the first set of projects to receive funding as part of a program that aims to accelerate the procurement and fielding of innovative technologies. One of the recipients, Shield AI, is a venture-backed company working on the next generation of autonomous uncrewed aerial systems that can provide higher-quality weapon-targeting information through artificial intelligence (AI). These systems can operate in high-wind and extreme weather conditions, which are becoming more common due to climate change, and can lower the risk of casualties to service members and civilians.

Weather conditions can be a matter of life or death for pilots. As a licensed airplane and helicopter pilot for three decades, I've seen firsthand how new technologies, including AI, have made flying more safe and reliable. And these technologies have largely been the result of private-sector innovation.

Another new Defense Department program decreases the time between development and deployment of commercial drone systems in the field. It reforms the acquisition process by rapidly vetting and approving uncrewed drone systems so they can be quickly deployed, and it ensures that our forces have the latest uncrewed drone technology at their fingertips.

The program, called Blue sUAS, is designed to help U.S. and allied companies rapidly iterate by working "shoulder-to-shoulder" with soldiers to develop and manufacture small and easy-to-use drones. These drones can provide everything from on-demand intelligence and reconnaissance to routine monitoring of facilities, bases and infrastructure.

This collaboration is a prime example of how the Pentagon can tap into the nation's most dynamic companies and quickly deliver the latest technology to support our men and women in uniform—and I recently saw it in action. In October, I joined Capt. Paul Lanzilotta, commanding officer of the USS Gerald R. Ford, for the carrier's first deployment, where I saw how the department is investing in new technologies that have enormous potential for improving the efficiency and effectiveness of their operations.

These efforts are yielding real results for the U.S. military. By putting more ingenuity to work at the Defense Department, we can help our service members defend America and our values and interests—and help bring more of them home safely.

Michael R. Bloomberg is the founder of Bloomberg LP and Bloomberg Philanthropies as well as chair of the Pentagon's Defense Innovation Board. He served as mayor of New York City from 2002 to 2013. The views in this column are his own.

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