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ANDURIL

**38** *Anduril is testing the production system for a Fury mockup inside the first building opened within its Arsenal-1 defense manufacturing complex.*

### ON THE COVER


ELECTRIC.AERO

*Electra.aero is developing the EL9 Ultra Short, a nine-passenger hybrid-electric regional aircraft designed to take off and land in just 150 ft. not only from runways but also from taxiways, ramps, fields and even vertiports. Electra is aiming for service entry in 2030. Aviation Week was given the opportunity to fly in Electra's EL2 technology demonstrator, and Chief Test Pilot Cody Allee (right) showcased the aircraft's capabilities for Executive Editor for Technology Graham Warwick (left). Warwick's report begins on page 56. Electra.aero photo by Dave Koch.*

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# FEEDBACK

## COOPERATION AND COMPETITION

As Jens Hoeg notes in his letter *("Cooperation Obstacles," Jan. 12-25, p. 5)* in response to my Viewpoint about U.S.-China space cooperation *(Nov. 24-Dec. 7, 2025, p. 53)*, competition has historically been a strong motivator of space program progress that should continue to be harnessed. What he misses is that it is wholly unnecessary and counterproductive to assume "cooperation versus competition" is a binary choice.

While the U.S. and the Soviet Union were partnering on the first great space collaboration between adversaries, the Apollo-Soyuz mission, they were also competing intensely. During this period in the early 1970s, the U.S. had begun the space shuttle program with the intent of leapfrogging the Soviets in space launch. A race to establish crewed space stations was active, first with Salyut and then Skylab. The U.S. intelligence community was revolutionizing reconnaissance with the Hexagon program, and the U.S. Air Force was transforming military communications with the Defense Satellite Communications System. Apollo-Soyuz served as an important symbol of shared destiny and potential, but it did not undermine competitiveness, urgency or the drive to push the envelope.

The U.S. and China should identify opportunities for civil space cooperation, engage in exploratory discussions and take steps forward. Both countries are putting megaconstellations into orbit. They surely will not jointly build a megaconstellation, but they can and should cooperate on conjunction risk and traffic management so that their satellites don't collide. They likely will not perform joint crewed missions any time soon, but they can and should operationalize mutual crew rescue. Over the coming years, both nations will be sending spacecraft into deep space. A modicum of scientific coordination would likely maximize discovery, benefiting the global scientific community.

We can all agree that there are areas in which collaboration would be detrimental to the objectives of both nations. However, if we fail to act on the many opportunities for beneficial collaboration, we will be doing humanity a grave disservice.

*Dan Hart, president of HarTechnologies and senior fellow at the Atlantic Council, Long Beach, California*



## DISCOVERY DUST-UP

It was a busy January in the battle over the proposed relocation of the space shuttle Discovery from the Smithsonian's National Air and Space Museum Steven F. Udvar-Hazy Center in northern Virginia to Houston *("Smithsonian Fights Texas Grab for Space Shuttle Discovery," July 14-27, 2025, p. 21)*.

The 2026 budgets for NASA and the Smithsonian Institution are now official, and while they included $85 million for a spacecraft relocation, they did not provide additional funds necessary to move Discovery. NASA's new administrator, Jared Isaacman, suggested that an alternative spacecraft could be sent to Houston, given budgetary and damage concerns. The alternative could, per Isaacman, be the Artemis II capsule that is set to launch in a few weeks. But the fight for Discovery is not over—Sen. John Cornyn (R-Texas) is pledging to move the shuttle to Houston despite these developments.

*Joe Stief, KeepTheShuttle.org, Washington*

## THE SPIRIT OF FLIGHT

I am writing to you from Lower Austria to express my deepest appreciation for your outstanding publication. I worked as an avionics engineer for 38 years at Austrian Airlines. I have been retired for three years now, and your magazine has brought me right back into the heart of aviation. It makes me feel "live" and part of the action once again.

The cover of the first issue I received this year was particularly meaningful to me. The image of the "golden dome" of the quantum computer was a perfect entry point and truly fascinating.

Thank you for the high-quality journalism and for keeping the spirit of flight alive for veterans like me.

*Hannes Kellner, Mank, Austria*

## WISE INVESTMENT

The success of the Airbus A320neo *("Bittersweet Success," Jan. 12-25, p. 36)* is well noted. It should be remembered that between 1945 and 1980, European manufacturers sold a touch over 2,800 jet airliners. The A320 marked the true breakthrough for the European consortium then known as EADS.

During a fraught campaign in the early 1980s to secure support from the British government to launch the A320, then-Prime Minister Margaret Thatcher reportedly said, "I don't want another Concorde on my hands." History proved that EADS/Airbus made the grade. The returns from the A320 repaid every penny of UK government aid to civil programs launched after 1945—including the Concorde—and with a profit.

*Keith Hayward, London*

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.

# WHO'S WHERE

**Christophe Bruneau** has been named CEO of *ArianeGroup*, effective April 1, succeeding Martin Sion. He was executive vice president and general manager of military engines at Safran Aircraft Engines. Before that, he was CEO of Europrop International and Aerospace Embedded Solutions.

*GE Aerospace* has promoted **Mohamed Ali** to president and CEO of Commercial Engines and Services and **Jason Tonich** to chief commercial sales and customer officer. Ali was chief technology and operations officer, and Tonich was vice president of global sales and marketing.

**Filip Filipov** has been promoted to CEO from chief operating officer at *OAG*, succeeding Phil Callow. His past positions include vice president of strategy at Skyscanner.

*Malaysia Aviation Group* has promoted **Bryan Foong Chee Yeong** to CEO of the airline business from group chief strategy officer. **Low Wen Long** has been promoted to group chief strategy officer from head of corporate strategy.

**Max Kownatzki** has been named CEO of *Eurowings*, succeeding Jens Bischof. He was CEO of SunExpress and previously worked across Lufthansa Group and Jetstar.

Turkish-German carrier *SunExpress* has appointed **Marcus Schnabel** CEO, succeeding Max Kownatzki. He was head of ground operations in Munich for Lufthansa Airlines and has been with the group for more than 20 years.

**Harry Holt** has been named to succeed David Lockwood as *Babcock* group CEO when Lockwood retires at year-end. Holt is CEO of the group's nuclear division and has held executive roles at Vertical Aerospace and Rolls-Royce.

Ahead of a planned merger with Sun Country Airlines, *Allegiant* has appointed **Michael Broderick** as chief integration officer, **Rebecca Aretos** as chief accounting officer and senior vice president of finance, and **Asad Shaikh** as senior vice president of corporate finance and treasurer. Broderick was senior vice president of procurement, financial planning and analysis, and airport affairs, while Aretos has held senior finance positions at the carrier for 18 years. Shaikh was vice president of fleet and corporate finance.

**Shuai Feng** has been named chief technology officer at autonomous air taxi developer *EHang*. He was the compliance officer and has been a member of the founding team since 2014. He is also deputy director of the Tsinghua-EHang Joint Research Institute for Low-Altitude Aviation Technology.

*Vertical Aerospace* has hired **Ollie Roberts** as chief people officer, **Juan Carlos Sacristan** as chief data and information officer and **Richard Moore** as vice president of powertrain. Roberts was chief human resources officer and chief transformation officer at BMI Group, Sacristan was chief digital information officer at Abcam, and Moore was director of propulsion and executive director of engineering at Lotus.

**Scott Humphrys** has been appointed chief operating officer at *Slingshot Aerospace*. He was owner, chief operating officer and executive vice president of Mission Essential and served for 25 years in the U.S. Army.

*HawkEye 360* has hired **Michael Turner** as chief legal officer. He was chief legal and administrative officer at 908 Devices and before that was co-CEO, general counsel and executive director at Allied Minds.

**Brian Wynne** has been named executive director and president of the board of directors for the *National Association of Flight Instructors*. He was president and CEO of the Association for Uncrewed Vehicle Systems International for nine years.

*West Star Aviation* has hired **William Morris** as general counsel. He was general counsel and chief compliance officer at Wencor Group.

*HAECO* has hired **Haijun Jiang** as general manager of composite services and **Tom Owen** as group director of corporate development. Jiang was regional business director for China at Parker Hannifin. Owen was director of cargo at Cathay Cargo and before that was director of people at Cathay Pacific Airways.

**Bill Adkins** has been appointed principal deputy director of the *National Reconnaissance Office*. He was a senior staffer at the U.S. House of Representatives, overseeing legislative duties affecting the National Reconnaissance Office and other intelligence agencies.

**Alex Krutz** has returned to *Patriot Industrial Partners* as managing director following 10 months as deputy assistant secretary for manufacturing at the International Trade Administration in the U.S. Commerce Department. His past employers include P3 Group, GKN Aerospace and Pratt & Whitney.

*Lockheed Martin* has promoted **Dan Tenney** to senior vice president of global business development and strategy. He was vice president of strategy and business development for rotary and mission systems, a title he had held in the space sector. Before joining Lockheed, he was chief financial officer at the University of North Texas System and worked for 27 years at NASA.

**Megan McArthur** has become an astronaut advisor at *Vast*. She had a long career at NASA, most recently as chief science officer at Space Center Houston. Before that, she was deputy division chief of the Astronaut Office, director of flight operations for the International Space Station program and an astronaut, with 213 days logged in space.

*To submit information for the* Who's Where *column, send Word or attached text files (no PDFs) and photos to:* **whoswhere@aviationweek.com** *For additional information on companies and individuals listed in this column, please refer to the* Aviation Week Intelligence Network *at* **AviationWeek.com/awin** *For information on ordering, telephone U.S.: +1 (866) 857-0148 or +1 (515) 237-3682 outside the U.S.*

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- Boeing Defense, Space & Security CEO Steve Parker
- Rafael and Mafat Iron Beam
- Rolls-Royce Orpheus
- Ukraine's Darknode

### SPACE
- Axiom Space Private Astronaut Missions
- Rajeev Badyal, Amazon's Project Kuiper
- Blue Origin New Glenn
- Firefly Aerospace Blue Ghost
- U.S. Air Force Rapid Capabilities Office Boeing X-37B

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- Pete Bunce, GAMA
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# FIRST TAKE

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## AWARDED

A pair of Aviation Week editors have been recognized for their industry-leading coverage of air transport in the Asia-Pacific. **Adrian Schofield** (left), who writes for Aviation Week and CAPA – Centre for Aviation, won Best Commercial Aviation Submission at the 2026 Aerospace Media Asia Awards for a feature he wrote for *AW&ST* on Vietnam's fast-growing commercial air transport sector. And **Chen Chuanren** was presented with the Outstanding Achievement Award for his overall work for *Air Transport World* and Aviation Week. The awards were announced at a Feb. 2 gala in Singapore.


AVIATION WEEK

## DEFENSE

**The Royal Australian Air Force has** received its first MC-55A Peregrine intelligence, surveillance, reconnaissance and electronic warfare platform, a Gulfstream G550 modified by L3Harris Technologies.

**SpaceX has introduced a temporary** speed limit for Starlink receivers operating in Ukraine in an attempt to prevent Russia from using the satellite communications system to control attack drones.

**L3Harris Technologies will launch** production of Red Wolf low-cost strike missiles and Green Wolf electronic attack munitions for U.S. Marine Corps Bell AH-1Z helicopters under an $86.2 million contract.

**South Korea has begun the air-to-**ground testing of the Hanwha Systems active, electronically scanned array radar on the Korea Aerospace Industries KF-21 fighter.

**Uncrewed aircraft were used by Ukraine** to strike more than 800,000 Russian targets in 2025. Drones were used against 80% of personnel, equipment and vehicles targeted.

**Boeing has reported a fourth-quarter** 2025 charge on its U.S. Air Force KC-46 tanker program of $565 million, bringing the total cost overrun on the fixed-price contract to $9.55 billion (page 33).

**Lockheed Martin plans to spend $1 billion** to stockpile spare parts for the F-35, making up for a shortfall the company says was caused by government underfunding.

**The UK Defense Ministry has shortlisted** seven bidders in its hunt for an autonomous collaborative platform to operate alongside Boeing Apache attack helicopters in the 2030s.

## COMMERCIAL AVIATION

**The NTSB probe into the January 2025** midair collision of a regional jet and a U.S. Army helicopter near Ronald Reagan Washington National Airport has resulted in recommendations for sweeping systemic changes at the FAA (page 22).

VIEW FROM LONDON

# Trump's Bombardier Threat Unlikely To Materialize

Chances of U.S. President Donald Trump being able to decertify Bombardier's Global Express and all Canadian-made aircraft are fairly low, experts say. But his threat to impose a 50% tariff is a wild card.

The threats, should they come to fruition, would hurt not only Bombardier, but also U.S. consumers, suppliers and employees, experts said at the Corporate Jet Investor conference in London on Feb. 2.

In a Jan. 29 social media post, Trump accused Canada of "wrongfully, illegally and steadfastly" refusing to certify Gulfstream's G500, G600, G700 and G800, prohibiting their sale into Canada. Trump said he was decertifying Canadian-built aircraft in return. The White House later clarified it would not affect Bombardier-built aircraft currently in service.

Canada has done nothing wrong or illegal in not approving the Gulfstream aircraft. "They have a right . . . to certify products," said David Hernandez, a shareholder at law firm Vedder. "It's part of a very fundamental process."

A bilateral aviation safety agreement between the U.S. and Canada outlines each country's right to certify its own products. In addition, the U.S. does not certify Canadian products; it validates Canadian certification, and vice versa.

"Even if there were some action, it would have to come from the FAA, which has very limited authority to act in these types of situations," he said. "There has to be a safety reason to challenge the certification validation."

Jim Bell, a partner at WFW London, said Trump tends to argue that he holds power unilaterally and could assert that his power exceeds the FAA's.

Trump's post raises the question of why Transport Canada is slow in certifying aircraft. "They're incredibly slow," said Ehsam Monfared, an attorney with the Toronto-based YYZlaw. "Thank you, President Trump, for trying to light the fire."

There is an unwritten rule, however, that they do not start the certification process until there is actual demand for the product, Monfared said. The number of Gulfstreams operating in Canada is low because the overall market is small.

**Just weeks after signing a widebody** order with Boeing, Delta Air Lines has agreed to purchase 16 Airbus A330-900s and 15 A350-900s.

**Embraer and Adani Defense and Aero-**space have signed a memorandum of understanding to build an E-Jet E2 final assembly line in India and collaborate on advancing India's regional aircraft sector (page 25).

**Russia's United Aircraft Corp. has final-**ized plans to assemble Yakovlev SJ-100 regional jets in India with Hindustan Aeronautics Ltd. and partnered with Indian startup Flaming Aerospace on the Ilyushin Il-114-300 turboprop.

**Air India bolstered its narrowbody order** backlog with commitments for 30 Boeing 737 MAXs and 15 Airbus A321X-LRs, continuing its fleet transformation.

**Boeing is reviewing a potential durability** issue with GE Aerospace GE9X engines powering the 777X but does not expect the problem to impact certification or expected deliveries in 2027 (page 24).

**Singapore is to be the first airport test-**bed for the real-world evaluation of open fan powerplants developed under CFM International's RISE technology demonstration.

**Electra.aero has received its first deposit-**backed commitment to buy its EL9 Ultra Short aircraft, signing predelivery payment agreement for five aircraft with Bristow Group (page 56).

**Ultra-low-cost carrier Wizz Air's UK unit** has formally applied to the U.S. Transportation Department for authority to operate flights between the UK and U.S.

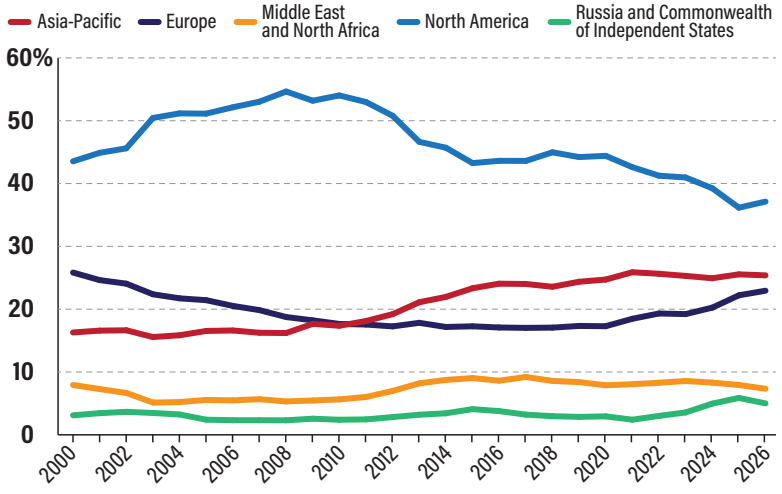
## SPACE

**A SpaceX Falcon 9 launched the ninth of** 10 Lockheed Martin-built GPS III navigation satellites for the U.S. Space Force on Jan. 27 from Cape Canaveral SFS.

**Finland's Iceye is pushing Europe to** build an autonomous satellite intelligence system, proposing a 1,000-spacecraft construct called Constellation Europe (page 20).

**Military satellite startup York Space** Systems listed publicly on Jan. 29 with a $629 million initial public offering that valued the company at $4.4 billion.

## U.S. Share of Defense Spending Shrinks




*Source: Aviation Week Defense Market Analyzer*

The U.S. share of global defense expenditures hit its lowest level since World War II in 2025, dropping from 50% as recently as 2011 to about 36% last year, data from Aviation Week's Defense Market Analyzer shows. While American defense spending has been largely flat in real terms since 2008, funding in the rest of the world was up 90%, driven by rapid growth in Asian budgets and Europe's response to Russia's 2022 invasion of Ukraine. But the U.S. decline is likely at its nadir, notes Craig Caffrey, Aviation Week's head of defense and data analysis, as Washington's military spending looks set to rise by 10% in real terms in 2026 and further in 2027.

*Find out more about our AWIN defense data & market intelligence, including the Defense Market Analyzer, at* **AviationWeek.com/awin-defense-data**

## 50 YEARS AGO IN AVIATION WEEK

**Concorde Commercial Service Begins**

By Herbert J. Coleman

Bahrain—British and French Concorde supersonic transports last week opened international fare-paying passenger services with British Airways' Concorde landing here 18 min. ahead of schedule and Air France arriving at Rio de Janeiro 42 min. behind schedule on Jan. 21, after simultaneous takeoffs from Europe.

The Air France and British Airways Concordes took off from Paris' Charles de Gaulle and London Heathrow airports at 12:40 p.m. GMT after a 3½-second countdown by both pilots.

At zero count, Capt. Norman Todd and Capt. Pierre Chaminet both released brakes for a 37-sec. takeoff run for rotation at Mach 0.37.

Block time from London to Bahrain's Muharraq airport was 4 hr. 6 min. Actual flying time from takeoff to touchdown was 3 hr. 37 min. Aircraft was met here by the Ruler of Bahrain, Shaikh Isa bin Salman al-Khalifa.

On board was Sir George Edwards, retired chairman of British Aircraft Corp., who left a suitcase to make the journey. He said Concorde's only main problem now was to gain acceptance in the U.S. and said "we will keep on fighting until that happens."

British Concorde schedule will be to depart London and Washington, D.C., at 10:45 a. m. GMT, arriving at Bahrain at 6 p. m. local time, a scheduled elapsed time of 4 hr. 15 min. It returns to London Tuesday and Thursday, leaving Bahrain at 10 a. m. local time and arriving at Heathrow at 11:30 a. m. GMT.

Gordon Davidson, Concorde general manager for British Airways, said that the airline will supply a British Aircraft Corp. Super VC-10 jet transport, in all-first-class configuration, as a standby in case Concorde flights are canceled for technical reasons.

Concorde is getting maximum support from the Bahrain ruler and his cabinet, since the Shaikh considers selection of his country as Concorde's first service a singular honor. The airport is being modernized and is considered an excellent connecting point for Middle East points and on to the Far East and Australia.

Concorde received in-overflying rights from Lebanon, Syria and Saudi Arabia prior to the departure, and the diplomatic approval allowed British Airways to finally begin a promotion campaign that will cost about $2 million.

As Henry Marking, British airports managing director pointed out: "Without the rights we would hardly advertise a service that did not exist."

The flight became the world's first supersonic fare-paying passenger service shortly after the Concorde passed over Venice, Italy, at 25,000 ft. Flying at Mach 0.93 at that point, Italian air traffic control cleared Todd to a transonic climb at Mach 1.3 to 53,000 ft. down the Adriatic Sea.

The climb climaxed a flight that took 30 fare-paying passengers and 70 invited guests to Bahrain. In the cockpit jump seat was Brian Trubshaw, BAC chief test pilot.

Concorde climbed out from Heathrow to the west at Mach 0.44 at an angle of about 15 deg., which caused chief stewardess Francine Curvilla, walking to the aft section, to exclaim: "He like coming down a ski slope."

Concorde crossed the French coast at 23,000 ft., about 18 min. after takeoff, and Todd and Air France's Dodal compared notes as the French Concorde flew toward Dakar, its fuel stop.

Todd said the Concorde had a "flawless flight" and favorable winds at 53,000 ft. helped to gain time over the planned schedule. Concorde flew down the coast of Greece slightly under 2 hr. after takeoff, and 10 min. later overflew Crete.

Concorde flew over the northern section of Lebanon for 1 min. 30 sec., where it checked in with Beirut control, which was still operating despite the civil war, for clearance. Concorde also was cleared by Damascus air traffic control, to overfly Syria prior to letdown for Bahrain.

Concorde landed at 687 temperatures after a long final approach. Todd used in-flight thrust reversing three times on the letdown to establish the approach pattern.

Bahrain airport does not yet have a special Concorde departure and arrivals facility. In London, a special checking area, with its own security forces and hardware, opened with the first fare-paying flight. The Bahrain passenger lounge is keyed to businessmen, and is equipped with desks, teletypewriter machines, refreshments and bar services.

Once airborne, Concorde's narrow aisle became a motte as stewards and stewardesses tried to serve drinks and food, while reporters and television teams conducted interviews. Opinion of the flight was summed up by Lord Lambton, a director of the National Westminster Bank, who reserved the first Concorde ticket 12 years ago and paid for it last November. He was also on the first flight of the de Havilland Comet and British Airways' first Boeing 747. He said: "It was fantastic, and doubly so because the flight was so uneventful."

Engine performance was monitored at various times on the flight here by Sir Stanley Hooker, technical director of Rolls-Royce, Ltd., and senior engineer on the Rolls-Royce/Snecma Olympus 593 engine. He said the engines performed "beyond our expectations." Two spares had been shipped previously to Bahrain, where British Airways has set up a Concorde maintenance depot.

**Festivities, Inlet, Fueling Cause Delays**

Paris—Air France Concorde making its first paying flight was the 14th production aircraft of 19 currently scheduled to be built by Aerospatiale and British Aircraft Corp. It carried a full payload of 100 passengers and was piloted by Air France Capt. Pierre Chanoine, with Capt. Pierre Dudal, chief pilot for Concorde operations at Air France, acting as co-pilot. Flight systems engineer was Andre Blanc.

The aircraft landed 3 hr. 43 min. after takeoff at Dakar, Senegal, for a scheduled 55-min. refueling stop. Airport festivities, a speech by Senegal President Leopold Senghor, and a passenger who returned to the aircraft after the doors had been closed for departure, extended the stopover by an extra 22 min. This was compounded after takeoff by a malfunctioning air inlet on the No. 2 engine, which delayed acceleration to supersonic speed for several more minutes.

As a result, the aircraft landed at Rio de Janeiro, its destination, at 4:05 p.m. (local time) and shut down two minutes later. Elapsed block time from Paris to Rio was 7 hr. 42 min. compared to the scheduled 7 hr.

Return flight left Rio for Paris about 4 hr. later, at 8:04 p.m., arriving in Paris at 7:45 a.m. (local time) Jan. 22. That flight also lost time in Dakar when the fuel meter on the tank truck refueling the Concorde malfunctioned. This necessitated a manual calibration of the fuel taken on board at Dakar, based on the amount of fuel on board when the aircraft landed. Total of 36 min. was lost in that operation.

Air France estimates that about 44% of the passengers booked for the first two months of Concorde operations are French. About 25% are from the rest of Europe, 28% from South America, 5% from North America, and 2% from the Far East. About 10 Americans were on board the first commercial flight from Paris to Rio.

Oldest passenger on the first flight was an 80-year-old French woman.

Return flight from Rio to Paris carried a dog belonging to one of the passengers on board. The dog's fare was $240. It was carried in the cabin.

editors must have felt the same way. The inauguration of Concorde service did not make the cover, meriting only a single page of coverage without any photos.

*Subscribers can log in to access every edition of Aviation Week back to 1916 at:* **archive.aviationweek.com**

UP FRONT

# ANTHONY L. VELOCCI, JR.

## A Work in Process

### Boeing's turnaround will not hinge on a single airplane, program or team

**IN AN *AW&ST* VIEWPOINT TWO** years ago, I stated that Boeing was on course to become one of America's greatest industrial tragedies (Feb. 12-25, 2024, p. 11). That assessment may have struck some readers as overly stark, but events soon rendered it conservative. By early 2024, Boeing exhibited classic signs associated with large-scale industrial failures, such as rampant production problems and quality lapses. The company's governance failures had hardened into a pattern that raised a previously unthinkable question: Does Boeing possess the institutional capacity to reverse its organizational free fall?

Today, the company deserves credit for regaining its footing. Boeing recently reported its first full-year net profit since 2018, and 2025 commercial aircraft deliveries were up sharply year over year. A change in top leadership in August 2024, a broader reset of senior operating roles and a more candid acknowledgment of systemic breakdown marked a clear departure from years of defensiveness. Factories have stabilized, and the tone toward regulators has shifted from brittle to sober.

JENNIFER BUCHANAN/AFP/GETTY IMAGES

Indeed, the rebound thus far has been nothing short of remarkable. But that is not the same as a turnaround. While the earnings report was encouraging, think of it more as a milepost in a long journey that has barely gotten started. "The company is on the right track, but it's still very much a work in process," a retired senior executive close to Boeing told me.

The challenge confronting Boeing is not the aftermath of a single crisis but the accumulated consequences of decisions made over decades—decisions that steadily subordinated engineering judgment to financial cadence. This was never just about airplanes or programs. It was about incentives, authority and a culture that too often treated technical dissent as little more than friction.

What gives the current effort credibility is its emphasis on the unglamorous work: slowing production to regain control, rebuilding quality systems, reinserting engineering authority into day-to-day decision-making and engaging regulators with a degree of transparency that would have been unimaginable a few years ago. These are not headline-grabbing moves; they are the necessary preconditions for restoring trust.

Still, the most dangerous phase of any corporate recovery comes after the company resets. For example, General Electric repeatedly declared itself "fixed" long before its underlying industrial and financial weaknesses were addressed, only to see new crises emerge. Management mistook stabilization for success and underestimated how quickly old habits can return once pressure eases.

That risk now confronts Boeing.

The test will come not when production flows smoothly but when suppliers stumble, schedules slip and the temptation to explain away inconvenient data resurfaces. Culture is revealed under stress. Whether Boeing's reboot endures will depend on its willingness to protect dissent and accept short-term pain in service of long-term credibility. "Long-term success will only come from adhering to the back-to-basics strategy to which Kelly Ortberg and his team appear to be committed," the retired executive said.

There are profound lessons here for the broader aerospace and defense community. Regulators are not obstacles to be managed but guardrails to be respected. Safety and quality must be enterprise-level priorities, not departmental concerns. Reputational capital, once spent, can be rebuilt only through consistency over time. And cultural drift can accumulate unnoticed for years; when crisis hits, leadership replacement is the precondition to cultural change, not the solution itself.

Which brings us back to Boeing. The company is no longer an industrial tragedy in the making, but neither has it convincingly escaped the forces that once put it on that path. Boeing has demonstrated that decline is not inevitable when accountability replaces denial, when top management truly believes transparency beats damage control and when engineering fully regains its voice. Change at Boeing's scale is slow, uneven and unforgiving of complacency and hubris.

Boeing's level of success five years from now will not hinge on a single airplane, program or leadership team. It will turn on something less visible and more consequential—whether engineering authority remains central when schedules tighten, quality metrics are protected when cash pressures return and bad news travels upward without penalty.

If those conditions hold, Boeing's recovery will be remembered as one of the most difficult—and instructive—industrial resets in decades. If they do not, today's progress will be seen not as a turning point but as an interlude.

*Anthony L. Velocci, Jr., was editor-in-chief of Aviation Week & Space Technology from 2003 to 2012.*

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## QUANTUM LEAP
# GARRETT REIM

**THERE WAS A TIME WHEN BOEING** aircraft were designed in giant rooms filled with rows and rows of draftsmen and drafting tables. Over the years, pencil, paper and T squares gave way to computers—and computer-aided design.

By the 1990s, Boeing was boasting that the 777 widebody had become the first clean-sheet commercial airliner to be designed entirely with computer-aided design (CAD) software, Dassault Systemes' CATIA.

Going from paper to computers made Boeing engineers more efficient, but it also made some skills obsolete. That process of inventing new tools while making old skills no longer relevant is known as creative destruction—and it is as old as time.

Since humans went from digging in the dirt with their hands to using shovels for thousands of years and then to mechanical excavators roughly 190 years ago, creative destruction has brought increased productivity, greater economic prosperity and job cuts.

Now the aerospace industry is facing a new force in creative destruction: artificial intelligence (AI). Early demonstrations of the technology promise to shrink multiple jobs into one while working several times faster and engineering parts many times stronger than humans can. Some futuristic programs, such as NASA's Text-to-Spaceship, aim to replace entire engineering teams with AI agents directed by a few humans typing commands into a chat box.

The Society of Professional Engineering Employees in Aerospace (SPEEA), representing more than 17,000 engineers, technical workers and pilots employed by Boeing, mostly in the Puget Sound area of Washington, has not taken an official position on the use of AI. But the union's leadership expects the technology to be a likely topic at contract negotiations in the fall.

"I think that we're likely to see AI-assisted tools used by our members long before we see our members replaced by AI," SPEEA Executive Director Ray Goforth tells Aviation Week. "But if Boeing could replace our members with software, it would certainly do it. My expectation is that this will be a subject of discussion in upcoming collective bargaining."

Boeing declined to comment on union contract negotiations, but its chief engineer, Howard McKenzie, wrote in a LinkedIn post in January that AI is "to enhance human capability, not replace it."

As SPEEA grapples with the potential of AI to replace workers, software developers at nearby leading technology companies in the Seattle area, such as Amazon and Microsoft, already feel the pain. In the past year, executives at those corporations have laid off thousands, citing productivity gains from automated code-writing programs.

However, engineers at Boeing have job protections that their neighboring software developers do not: They work in a highly regulated industry focused on passenger safety; aircraft development is a decadal process, not a weekly sprint; and building a flying machine is far more complex (and consequential to humans) than a mobile phone app.

Yet AI-powered engineering is not a question of if, but when, Goforth says. "If you ask me, 'Will AI be designing major components of aircraft 20 years from now?' I'd probably say, 'Yeah,'" he says. "Two years from now? 'No.'"

SPEEA, founded in 1947, has not opposed technology adoption historically, Goforth says, noting the use of CAD. Typically, the union acknowledges the productivity gains brought by new technology but seeks to benefit as well, advocating for higher wages and retraining.

The union has been critical of Boeing's previous attempts to substitute human engineers with slick software, Goforth says. For example, the company's overreliance on digital engineering for the development and manufacturing of the Boeing 787 backfired spectacularly, he says. "I would expect the company to be real hesitant about betting its future on another set of magic beans," Goforth says.

Still, the question remains: Is this time different?

If you listen to the AI crowd, we are on the verge of "artificial general intelligence"—a promise recently inflated to "superintelligence." Mass unemployment and the end of the market economy as we know it would follow. But talk to the people trying to automate tasks in their line of work and you will find that AI, while sometimes impressive, does not live up to the dystopian hype.

"For every 10 hr. of efficiency gained through AI, nearly 4 hr. are lost to fixing its output," states a recent report by Workday, a human resources software developer. Moreover, skilled human workers are critical to making AI work well. Employees who had the highest AI productivity gains were two times as likely to have received substantial skills training from their employers compared with struggling users, Workday's report said.

In other words, AI looks a lot like every other technology—something Boeing should keep in mind during upcoming contract negotiations.

## Negotiating AI

Artificial intelligence is likely to figure in **Boeing engineer union contract talks**

CYRIL MATLAND/DAILY EXPRESS/GETTY IMAGES

**SPEEA has represented Boeing engineers since the days of pencil, paper and T squares.**

## LEADING EDGE
## GRAHAM WARWICK

# Leveling the Field

### Replacing humans as the **infrastructure for programs**

**THE U.S. AIR FORCE HAS LAUNCHED** an initiative called Industry One to establish a "level digital playing field" and evaluate its ability to provide all participants in a program access to the latest information at the appropriate classification level.

The service is working with startup Istari Digital, better known for its Flyer One program with the Air Force Research Laboratory and Lockheed Martin Skunk Works, to flight-certify a version of the X-56A X-plane (pictured) entirely digitally.

The problem to be solved is that engineers and managers "spend nearly a third of their time just being certain that what they're working on is the actual source of truth," Istari CEO Will Roper told the American Institute of Aeronautics and Astronautics' SciTech Forum in Orlando, Florida, on Jan. 13. "There should be zero time spent trying to figure out, 'Are you working in a source of truth?' There should be zero time spent wondering, 'Is this the correct version?' "


LOCKHEED MARTIN

Roper, a former Air Force acquisition chief, outlined the role infrastructure has played over history in leveling the playing field for society: Roman aqueducts and roads, railroads, the telegraph, the shipping container—all the way up to the internet and cloud.

"And this is the point in history at which . . . the digital playing field starts getting a little bit of a slope," because the sharing of data that works for individuals does not work for enterprises, Roper said.

Engineers and managers on aerospace and defense programs are mostly working with tools that are not interoperable, he said. "People are having to be the translator, sending emails and copies and versions to everyone that is collaborating," Roper noted.

Almost no one is working with a source of truth, and copying those sources of truth is the problem that needs a solution, he said. "We're the infrastructure—humans," Roper added. "We're the translators; we're the transport layer, using email and Dropbox, and we are doomed to repeat this again every time something changes.

"How do we fix it? We need an infrastructure that is built for aerospace," he said. "Not one that is built outside and thrust upon us, that does not consider our reality." Istari's solution to leveling the digital playing field has three parts: a data plane, a control plane and a provenance plane.

In a major weapon system program with a few thousand suppliers working for an OEM, there a few thousand sources of truth, each with a tool.

"The first thing we are going to do to change the paradigm is not have the human as the translator," Roper said. "We are going to replace them with a software agent that is taking the data inside their tool and translating it into an open, vendor-neutral copy on the outside that speaks the language of interoperability. We add this to each one of our sources of truth."

Data then must be orchestrated. "You can protect data, but every time it was attempted, the control plane—which is supposed to determine who gets access—got tainted by the data," he said. This means all data inherited the classification of the most sensitive information, restricting access for everyone.

In Istari's system, the control plane routes access to data and remains nonsensitive. "User X is allowed to have data Y for purpose Z," Roper said. "This is authorized and published to a control point so that when a separate data plane makes that valid request, the control plane can authenticate. The two data planes can interact via a one-time ticket to that data. We have not tainted the control plane."

This is enabled by the third part of the system, the provenance plane that automatically assigns a unique identifier to every piece of data to control access using cryptographic hashing. "If you give every piece of information a unique ID, locally generated, 36 characters gives you a one in 340 trillion trillion trillion probability that you will ever be the same," he said. "But the probability that AI would ever hallucinate one of these strings of characters is equally improbable.

"We give the control plane only the IDs," Roper said. "The IDs are locally generated. Who are they valuable to? They are only valuable if you sit where the data is located."

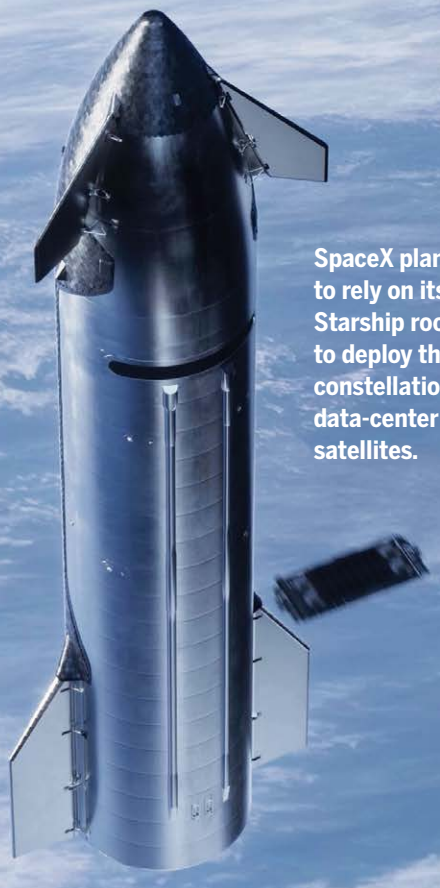
Blue Origin has employed Istari's infrastructure to develop a space-qualified lunar regolith battery using artificial intelligence (AI). "The AI designing something 75% faster and 40% better is amazing," Roper said. "But what made it qualifiable is that this ID system, the provenance plane, was used to create guardrails for nearly everything that would keep you up at night in an enterprise."

# Becoming SpAIceX

- SPACEX MAKES A BIG BET ON AI FOR SPACE
- AN IPO WILL BRING MORE INVESTOR SCRUTINY TO SPACEX
- A MANEUVERING SPACECRAFT MENACED A STARLINK SATELLITE

**Robert Wall** London

SpaceX is going all in on artificial intelligence, combining two of the hottest investor topics as the space company prepares for its initial public offering.



SpaceX plans to rely on its Starship rocket to deploy the constellation of data-center satellites.

SPACEX IMAGES

Elon Musk's spacecraft business may have made its name as the premier launch service provider, but it is now looking to demonstrate that it is so much more before undertaking what could be the most expensive initial public offering (IPO) this year—and certainly the largest ever for an aerospace company.

Since CEO Musk suggested on social media in December that a public listing was in the offing, SpaceX has received the go-ahead to expand its Starlink broadband constellation vastly. In January, the company said it is getting into the space traffic management business and plans to deploy a huge network of data-center satellites in low Earth orbit (LEO). To top it off, Musk has now combined investor hunger for space and artificial intelligence (AI), disclosing Feb. 2 that SpaceX has acquired his xAI business.

The IPO plan reflects a shift in Musk's thinking about the future of the company. Although he had said more than a decade ago that SpaceX would list at some point, he more recently signaled the Starlink communications business would go public first and separate from the space transportation operation. Musk has indicated in the past a reluctance to expose SpaceX to the vagaries of the public market while the company still pursues the goal to reach Mars.

Going public is likely to boost the personal wealth of Musk, who is already the world's richest person. But it also comes with risks. At Tesla, he has bristled at the quarterly analyst scrutiny that public companies receive, and he has been at war with short sellers that probably will circle SpaceX as well.

SpaceX's eventual stock pricing will likely surpass typical valuation criteria based on earnings multiples, said Chris Quilty, president of research consultancy Quilty Space. "Investors will always give SpaceX credit for the X factor," he noted.

Timing for the listing is somewhat inauspicious, since China is ramping up its launch and satellite ambitions now. Chinese company BYD displaced Tesla as the world's best-selling electric-vehicle-maker last year, showing that competitive threats loom.

SpaceX would likely use the IPO to raise tens of billions of dollars to help finance industrial expansion of its Starship program and its effort to put data centers in space. The competition for deploying space-based data centers is heating up. Google parent Alphabet last year mapped out a plan to deploy its first test satellites within two years.

SpaceX stated in a Jan. 30 regulatory filing that it would deploy as many as 1 million satellites into LEO as part of its project. The actual constellation would likely be much smaller. The satellites would operate at altitudes of 500 km (310 mi.) and 2,000 km, the company said. The spacecraft would come in different versions for best performance depending on the orbital shells.

The move comes as growing use of AI has companies looking for better ways to provide processing power, since current methods require massive energy and cooling needs.

Musk has long been focused on AI and its potential. He backed OpenAI a decade ago, before leaving the company amid a rift with its management. He founded xAI in 2023 in part to take on OpenAI and others, such as Microsoft.

SpaceX did not disclose what it paid for xAI. The deal, Musk wrote in

a blog post, is intended to create "the most ambitious, vertically integrated innovation engine on (and off) Earth, with AI, rockets, space-based internet, direct-to-mobile device communications" and more.

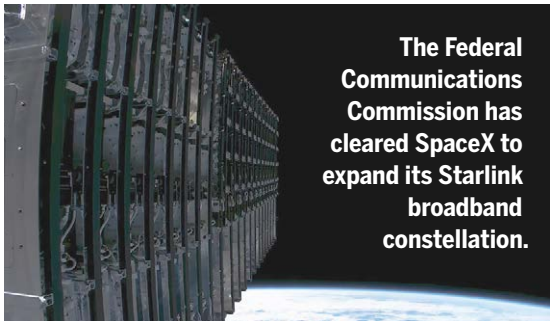
"By directly harnessing near-constant solar power with little operating or maintenance costs, these satellites will achieve transformative cost and energy efficiency while significantly reducing the environmental impact associated with terrestrial data centers," SpaceX stated in the regulatory filing. "Orbital data centers are the most efficient way to meet the accelerating demand for AI computing power."

Musk added in the blog post that he estimates AI computations from space will be cheaper than through terrestrial data centers within 2-3 years.

The deployment request that still needs approval came only a few days after the U.S. Federal Communications Commission gave SpaceX the green light to deploy and operate 7,500 more Starlink Gen2 satellites. That will allow SpaceX to operate a constellation of 15,000 Starlink satellites, the regulator said in a Jan. 9 statement.

The company has said it plans to begin deploying third-generation Starlink satellites this year to deliver more than 1,000 Gbps in downlink and 200 Gbps in uplink capacity. With each Starship launch of V3 satellites, the company will add more than 20 times the capacity to the constellation as the current Falcon launches of the V2 Starlink satellites, Musk said.

With all those satellites in orbit, SpaceX has become vocal in its concerns about near-collisions. In late January, the company unveiled its Stargaze system, which tracks other objects and can alert users about collision risks.



**The Federal Communications Commission has cleared SpaceX to expand its Starlink broadband constellation.**

Stargaze pulls data from the almost 30,000 star-trackers on Starlink broadband satellites. The trackers help orient the LEO spacecraft that are constantly observing nearby objects, allowing them to detect 30 million transits daily, the company said. Information on the detected objects is then used to predict their paths and is fed into a space traffic management system.

The Stargaze system then assesses the risk of a conjunction—when two objects are at risk of collision or passing each other at an unsafe distance—and, if necessary, generates Conjunction Data Messages to provide collision warnings. SpaceX said it would share that data at no cost with others via its traffic management system.

SpaceX says it has worked with more than a dozen satellite operators to develop and test the system.

Companies that provide trajectory data to the system on their own spacecraft will in return receive such information involving the satellites from other participants. They will also benefit from receiving collision alerts.

In its announcement, SpaceX detailed a late 2025 event during which a Starlink satellite was closely approached by what it called a third-party maneuvering satellite whose operator did not share trajectory data. SpaceX said the two spacecraft were on track to pass at a range of about 9 km until about 5 hr. before their expected encounter. The other satellite then began maneuvering, which changed its trajectory and reduced the miss distance to about 60 m, causing Stargaze to trigger the Starlink satellite to move out of the way.

"With so little time to react, this would not have been possible by relying on legacy radar systems or high-latency conjunction screening processes," SpaceX asserted.

# NASA Retargets Artemis II for March

> A LEAK HALTED THE PRACTICE COUNTDOWN EARLY

> THE NEXT LAUNCH WINDOW OPENS MARCH 6

**Irene Klotz** Cape Canaveral

Compared with the launch campaign ahead of NASA's Space Launch System's debut, the Jan. 31-Feb. 3 wet dress rehearsal for the rocket's second flight was a promising start, with a full load of propellants aboard and being replenished in its core and upper stages.

It took four wet dress rehearsal tanking tests to hit that mark before the first Space Launch System (SLS) rocket lifted off Nov. 16, 2022, for the uncrewed Artemis I flight test. Pending the results of the practice launch countdown, NASA was prepared to conduct Artemis II—a crewed flight test of the Orion deep-space capsule—in February.

But with 5 min. 15 sec. left on the clock, the automated ground launch sequencer, which had been in control since the 10-min. terminal phase of the countdown began, halted operations due to a spike in the concentration of liquid hydrogen in the interface of the tail service mast umbilical (TSMU). The TSMU is a ground-side umbilical tower that connects the SLS mobile launcher to the rocket's core stage engine section for propellant loading and other prelaunch servicing. It features quick-disconnect cryogenic fluid lines that attach to interface plates on the core stage.

During Artemis I wet dress rehearsals, engineers wrestled with hydrogen leaks in a purge area around the TSMU's quick-disconnect interface, an enclosed area that is purged with an inert gas to prevent accumulation of combustible hydrogen/air mixtures.

For the Artemis II wet dress rehearsal, which began at 8:13 p.m. EST Jan. 31, the Kennedy Space Center launch team twice paused liquid hydrogen loading due to leaks that approached concentration limits of 16%. Both times, engineers used procedures developed during the Artemis I campaign to return hydrogen concentrations to acceptable levels. The techniques included stopping the flow of liquid hydrogen into the core stage, allowing the interface to warm up and reseat its seals, and adjusting propellant flow rates.

"The fact that we got to full tanking on the first try was a tremendous success," Lori Glaze, acting associate administrator for NASA's Exploration Systems Development Mission Directorate, told reporters Feb. 3. "We gathered an enormous amount of data on the processes and how we want to go forward with that in the future."

There were no workarounds, however, once the core stage tank was pressurized, a milestone that occurred as the countdown clock ticked down inside the T-minus-6 min. mark early Feb. 3.

"As we began that pressurization, we did see that the leak within the cavity came up pretty quick," Artemis II Launch Director Charlie Blackwell-Thompson told reporters. "We did a cutoff, which is a normal safety activity for us."

JOHN KRAUS/NASA

**The Artemis II Moon mission will have to wait until at least March 6 following the results of a Jan. 31-Feb. 3 wet dress rehearsal at Kennedy Space Center.**

NASA had hoped to count down to T minus 33 sec.

"This one caught us off guard," SLS Program Manager John Honeycutt added. "We try to test like we fly. . . . But this is a very complex interface and hydrogen is a very small molecule."

Initial indications point to a seal misalignment, deformation or debris, Honeycutt noted.

Repairs are expected to be conducted while the SLS remains at Kennedy Space Center Launch Complex 39B. NASA would then perform a second wet dress rehearsal, possibly paving the way for a launch attempt March 6-11.

"We had wanted to get inside of terminal count," Blackwell-Thompson said, referring to the final 10 min. of the countdown. "We wanted to verify our 3-min.-hold capability, which is when you have all of your cryo prop systems in a launch-ready state, and you can hold them there for up to 3 min.

"We wanted to demonstrate that capability, and we wanted to demonstrate a recycle—when we go down, have a planned cutoff in the countdown, come back and retarget a new T-0 within the launch window," she said. "We didn't get a chance to do that."

If launch is delayed past March, the SLS would likely need to be returned to the Vehicle Assembly Building for battery servicing of the rocket's interim cryogenic propulsion module—an upper stage provided by United Launch Alliance and Boeing that is based on the now-retired Delta IV Heavy second stage—and other components.

Artemis II is intended to test the Orion capsule with a four-member crew ahead of the Artemis III lunar landing mission this decade. Commander Reid Wiseman, Pilot Victor Glover, Mission Specialist Christina Koch and Canadian Space Agency astronaut Jeremy Hansen are expected to spend 10 days on what will be the first crewed flight in deep space since Apollo 17 in 1972.

"Safety remains our top priority for our astronauts, our workforce, our systems and the public," NASA Administrator Jared Isaacman said in a statement after the practice run. "We will only launch when we believe we are ready to undertake this historic mission."

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# Space Debris Drives Change in Spacecraft Operations

> SPACEX EXECUTIVE BEMOANS A "LACK OF COORDINATION" AMONG COUNTRIES

> CHINA TO ADD MORE THAN 200,000 SATELLITES

**Robert Wall** London and **Garrett Reim** Seattle

The return of the Chinese Shenzhou-20 crew capsule did not unfold as planned. When it touched down in northern China on Jan. 19, it was late, without its three taikonauts and with a cracked window repaired in orbit—another casualty of space debris.

The Chinese taikonauts had returned to Earth in November in another capsule, temporarily leaving the three remaining crew without an emergency escape vehicle. The incident is part of a growing trend that is putting space collisions in the spotlight.

Among other events in recent months: the rare failure of a SpaceX Starlink satellite; the loss of the 7-m (23-ft.), 6-metric-ton (13,200-lb.) SpainSat NG-II military communications satellite while en route to its intended orbital slot; and a near-collision between at least two other spacecraft.

Rafal Modrzewski, CEO of radar satellite operator Iceye, said that on-orbit maneuvers to dodge other objects are happening "more and more frequently." The company has automated the process for its satellites to detect objects and take evasive action if needed, he said Jan. 21 at the World Economic Forum in Davos, Switzerland.

"You need space traffic management and [to] really understand what is happening where with very high accuracy and very high confidence," European Space Agency (ESA) Director General Josef Aschbacher added. That requires policies at a global level and, in some cases, debris removal, he said.

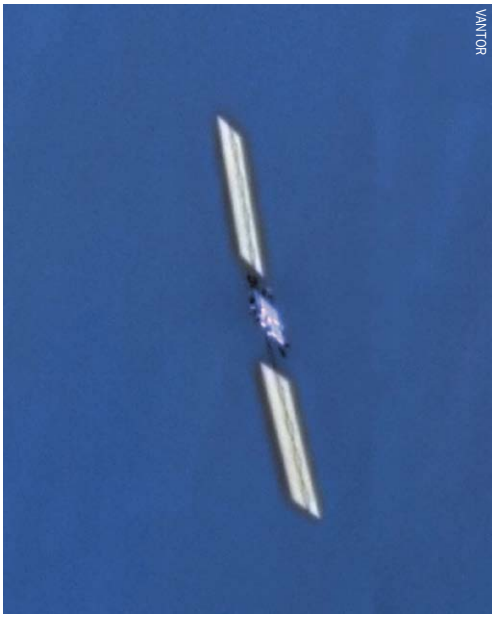
Space debris comes in many guises and sizes. Some is in the form of naturally occurring micrometeorites, but other potential hazards are the result of human activities. In 2024 alone, 3,000 new fragments were cataloged and linked to design issues with spacecraft instead of collisions, according to an ESA report.

The big concern about space debris has long been the Kessler Syndrome, named after a NASA space debris expert. The theory posits that a high density of space debris could set off a chain reaction of collisions, effectively contaminating the environment near Earth.

Space debris events have garnered increased focus not because their scale has changed but because of a growing awareness and an enhanced ability to spot the problem, says Holger Krag, the head of ESA's Space Debris Office. Still, he added, the trends around debris are concerning.

"We are about to enter, or have already entered, into the runaway situation," Krag said, explaining that substantial collisions that occur about every 5-6 years will increase to annual events. The development may unfold over 100 years, but the point of no return may already have been crossed, he suggested.

SpaceX, which operates the largest satellite constellation by far, with more than 9,000 Starlink spacecraft in orbit, has faced collision risks. Michael Nicolls, vice president of Starlink engineering, said on Dec. 13 that a deployment of nine Chinese satellites resulted in one of them coming within 200 m of a SpaceX bird. "Most of the risk of operating in space comes from the lack of coordination between satellite operators—this needs to change," Nicolls added.




**Vantor used its WorldView-2 satellite from 150 mi. to image the Starlink spacecraft that experienced an anomaly on Dec. 17.**

Days after the Dec. 13 incident but unrelated to it, a Starlink satellite failed, leading to what SpaceX called "a small number of trackable low-relative-velocity objects." The satellite should be decommissioned and deorbited soon, the company added.

Subsequently, SpaceX disclosed plans to adjust the orbital parameters of more than 4,000 satellites over the course of the year in a move that the company says is aimed at reducing the risk of creating orbital debris. It would shift operations of about 4,400 of the broadband satellites to an orbital altitude of around 480 km (300 mi.) from around 550 km.

Nicolls' statement about Chinese satellite deployments came just before companies in China unveiled plans to launch more than 200,000 satellites collectively. China's previously unheard of Institute of Radio Spectrum Utilization and Technological Innovation filed two applications in the final days of 2025 to launch two constellations comprising 96,714 satellites each. Those plans add to multiple Chinese satellite constellations that are in different stages of development; at least three entities are intending to operate more than 10,000 satellites each.

SpaceX filed paperwork on Jan. 30 with the Federal Communications Commission to launch as many as 1 million satellites to be used as orbiting data centers.

*China Daily*, an English-language publication owned and operated by the Central Propaganda Department of the Chinese Communist Party, said there was "nothing untoward" about China's latest constellation plan, defending it as necessary to grab limited orbital slots. It also took aim at SpaceX. "China's space station has already carried out orbital maneuvers to avoid potential collisions with Starlink satellites," the party outlet stated.

The *China Daily* commentary advocated for enhanced international coordination and transparency without putting forward any concrete proposals.

China is a signatory to the 1967 Outer Space Treaty, the leading international law governing space debris. More than 100 states are party to that treaty, but the document lacks

details about how to deal with potential collisions and space debris, says Ely Sandler, a research fellow at the Belfer Center's Science, Technology, and Public Policy Program within Harvard University's Kennedy School.

The rules of the road for what a satellite operator must do to avoid collisions are not defined, Sandler says. "It's a much more fundamental problem than not having teeth," he adds.

Exchanging real-time trajectory data on spacecraft with China is a big gap, Alvin Drew, director for space sustainability at NASA, said in October at the International Astronautical Congress in Sydney.

"For years, for political and legal reasons, our ability to communicate with the Chinese national space agency has been extremely crude: emails and Dropboxes," he said, noting that the Chinese occasionally replied.

"We would send a note to the Chinese, saying: 'We think we're going to run into you. You hold still; we'll maneuver around you,'" Drew said. "Often we would not get a reply. In one case, we did maneuver both at the same time and fortunately missed."

However, NASA is seeing signs that Beijing may be changing its stance. The Chinese National Space Administration sent a message in September saying it would maneuver a spacecraft to avoid a potential collision and advising the U.S. to hold still. It was a moment of celebration at NASA, Drew said.

"Holy cow," Drew remarked. "How long have we been operating in space? And this is the first time we have been getting two-way communication between two of the more prolific space operators out there."

# U.S. Space Development Agency Explores On-Demand Deorbiting

> STARFISH COULD DEORBIT SATELLITES UNDER SDA CONTRACT

> TECHNOLOGY COULD ALSO BE USED FOR WARFIGHTING IN SPACE

**Vivienne Machi** Los Angeles

As the number of satellite constellations in low Earth orbit continues to swell, managing the end of the operational lives of the spacecraft has become a growing concern. The U.S. Space Development Agency is moving early on the problem, planning for the assisted removal of certain satellites as part of routine constellation management rather than as an afterthought.

STARFISH SPACE

Starfish Space envisions a tow-truck-like service to deorbit satellites from LEO.

In a step that could effectively put a tow truck on call in orbit, the Space Development Agency (SDA) awarded a contract to Tukwila, Washington-based startup Starfish Space to deorbit at least one of the agency's satellites in a mission targeted for 2027. Under the $52.5 million contract, Starfish is to build, launch and operate the Otter, a small servicing vehicle, to perform "an initial deorbit" of an SDA satellite, the company announced Jan. 21. The award follows a 2024 call to industry in which the SDA awarded six study contracts to companies exploring on-orbit servicing, including Starfish.

While the base award covers one satellite deorbit, the SDA can exercise options to remove additional satellites using the same Otter.

Starfish designed the spacecraft to conduct multiple disposals on a single mission and to service satellites that were not built with cooperative interfaces, cofounder Trevor Bennett tells Aviation Week. That flexibility is particularly relevant for the SDA, which flies satellite buses from multiple vendors.

To date, the agency has deployed nearly 70 satellites to low Earth orbit (LEO) as part of its Proliferated Warfighter Space Architecture (PWSA), a planned constellation of hundreds of spacecraft linked by optical intersatellite connections to provide continuous data transport and missile warning and tracking. The first 27 satellites were launched in 2023-24, another 42 were launched last fall, and more are on the way this year.

The SDA has not disclosed which satellite would be removed or the rationale for that selection; a spokesperson tells Aviation Week a decision has not yet been made. The systems are designed with a five-year operational life span to encourage rapid technology updates and replenishment.

Bennett hopes the SDA mission will validate a commercial "deorbit-as-a-service" model for managing end-of-life disposal in LEO. The company ultimately envisions an on-demand service that could support multiple customers.

The award aligns with other government-backed debris removal demonstrations, such as Japan's with Astroscale and the UK's with Clearspace UK. Astroscale and Starfish are also partnering with the U.S. Space Force to perform demonstra-

tions of on-orbit docking and refueling this year.

But unlike those efforts, the SDA contract is not framed solely as a technology demonstration but as an operational capability.

SDA satellites are designed to deorbit themselves naturally in compliance with U.S. Orbital Debris Mitigation Standard Practices. Still, the agency wants commercially available "assisted disposal options" in case of a contingency, as on-orbit anomalies remain a persistent risk, the spokesperson says.

"As we developed the PWSA, we recognized that our risk posture and the imperative to deliver capabilities to the warfighter at speed might result in some satellites being unable to deorbit themselves," the spokesperson says, noting that the SDA expects to use future deorbit awards "as needed" to supplement built-in disposal capabilities.

Concerns about congestion and collision risks are rising as LEO constellations multiply. For years, operators viewed debris removal as risky and expensive, limiting market growth. But with roughly 300 new constellations operating or in development, such services may begin to look like indispensable insurance, Analysys Mason Principal Analyst Dallas Kasaboski says.

Government contracts remain critical for jump-starting emerging markets, and the SDA's willingness to move quickly could help normalize in-space servicing, Kasaboski says.

Operators are increasingly focused on protecting their own orbital neighborhoods, Bennett notes. Deorbit-as-a-service allows constellation owners to remove failed satellites, preserve long-term system health and, in some cases, relocate spacecraft while conserving onboard fuel.

As the U.S. and other countries increasingly view space as a warfighting domain, the technology for in-space servicing also can be used for counterspace activities. Analysts and commercial trackers have observed Chinese satellites grappling and relocating other spacecraft, blurring the line between servicing and interference.

Bennett declines to address potential military applications for Starfish's technology but notes that the company sees building the fundamental technologies to do rendezvous and proximity operations, docking and interfacing with satellites as "the first steppingstone" of many in the startup's journey.

# Europe Seeks Unity of Purpose as Space Projects Mushroom

> A VIRTUAL SPACE COMMAND COULD BE COMING SOON TO EUROPE

> EU SEEKS FASTER IRIS$^2$ DEPLOYMENT

**Robert Wall** Brussels

Europe has a new space challenge on its hands: keeping a multitude of military initiatives working in tandem.

The latest joke among European space officials is that they have gone from having too little money but plenty of time to having plenty of money but not enough time—all because of the threat from Russia and concerns about the U.S. Now there is a new twist: Europe may have gone from too few programs to too many.

Iceye is promoting the idea of Europe deploying a 1,000-multisensor-satellite constellation.

ICEYE

Germany, for instance, plans to deploy a low-Earth-orbit (LEO) military constellation of over 100 satellites, even as the European Union works on the roughly 300-satellite, secure multi-orbit IRIS$^2$ system. Other countries across the region are buying spy satellites while the EU prepares its Earth Observation Governmental Service (EOGS) system. Underpinning the moves is a desire by states to wean themselves off dependence on the U.S.

"From one side, it's good," European Defense and Space Commissioner Andrius Kubilius said. "We individually are becoming stronger in space. But on the other hand, we risk also becoming more fragmented."

These systems need to be able to work together from the get-go, he urged during his opening address at the annual European Space Conference on Jan. 26 in Brussels. He had a blunt message for the audience in the EU's capital: "No single member state is stronger than Russia. If you protect only your own country, your own army, we shall not learn to fight as Europe. We will not deter Putin."

Others echoed that message. "Despite intense geopolitical and economic pressure, Europe does not always act together through unified programs," European Space Agency (ESA) Director General Josef Aschbacher told the gathering on Jan. 27. "Too often, we do the opposite, fragmenting and renationalizing our efforts. This weakens us."

The leader of Germany's Space Command, Maj. Gen. Michael Traut, said the country's national LEO broad-

band constellation would be interoperable with the EU's. "This increases our deterrent value," he noted, because if one system is attacked, partners can help backfill capacity.

To help ensure that happens, the EU is planning the European Space Shield. That is one of the flagship initiatives Brussels unveiled in late 2025 to ensure harmonization between member states and the EU in certain defense and space programs. The plan, due in the spring, would cover secure and more resilient position, navigation and timing; communications; Earth observation; space surveillance; detection of radio-frequency interference and other activities.

"National sensors alone are insufficient," Italian Air Force Chief Lt. Gen. Antonio Conserva said. "We need a federated European sensor network capable of eliminating blind spots." He called space "one of the most advanced laboratories for the ambition of common European defense."

Kubilius said he would like Europe to establish a virtual space command, where member states can mobilize and coordinate efforts during a crisis or conflict.

Data sharing can be a problem because of security considerations, which is why Germany is pushing a European initiative to allow the classified exchange of satellite imagery among all EU member states, German Defense Ministry State Secretary Jens Plötner said at the gathering. "Pooling and sharing must be our guiding principle," he said.

The deliberations are unfolding as Europe works to finalize plans for two of the big programs at the heart of the coordination effort: the IRIS$^2$ system and the EOGS. The EU hopes to conclude a go/no-go review in April on the IRIS$^2$ project, including a move to accelerate the effort.

"I have asked all partners to step up and speed up on IRIS$^2$, and I'm confident we can deploy initial services by 2029," Kubilius said.

To keep to the accelerated timeline, program officials are looking to field an initial batch of satellites that address some IRIS$^2$ requirements in 2029 and field the final standard around 2031, said Jérémie Godet, the European Commission's head of secure connectivity.

The EU is deploying its effort to achieve secure, autonomous space capabilities through multiple steps. The first major milestone occurred in late January, when the Govsatcom program came online. Member states pool services over eight satellites from five countries through Govsatcom. Ukraine may be given access to the capacity, Kubilius said. That service should expand next year with added commercial capacity, he said, before the dedicated satellites come online.

The EU also plans to finalize requirements for the EOGS in the next few months. The requirements document will take another 2-3 months to finalize, said Mauro Facchini, head of Earth observation programs with the European Commission, noting that they are awaiting input from the European Defense Agency on member state needs. EU members late last year asked the commission to seek that input before finalizing the specifications.

"Creating an independent, sovereign European intelligence capability is the right starting place for us to ensure that we have the means **to know what's happening around us."**

The European Commission hopes to have the first elements of the EOGS program ready in 2028, leveraging systems or service contracts provided by member states. The first dedicated satellites are expected to come online in 2030 or slightly later. The goal is to field a secure, autonomous system with higher resolution and revisit rates than current European Earth observation systems.

To speed up the program, Europe is developing invitations for industry to help develop the project. ESA will serve as the program architect through its European Resilience from Space-Earth Observation program. The studies, due to be launched soon, follow those conducted by OHB and Telespazio, which were awarded in 2024 and concluded late last year.

The agency secured €167 million ($200 million) for the program during last year's ministerial meeting and is hoping to boost that to around €350 million by keeping the government subscription window open until November, longer than usual. ESA has been working with draft requirements to develop program plans, said Simonetta Cheli, the agency's director of Earth observation. An invitation to tender for the architecture study is due to be issued in late February; contracts would be due before June.

A second effort will simulate the optimal data distribution approach, Cheli said. The bidding documents for that effort are also due in late February. Another round of invitations to tender will go out to support about four in-orbit demonstration/validation activities.

Cheli said those have not been finalized but are likely to look at issues such as electro-optical imaging in low light conditions, multi-imaging on a single pass and data downloading.

European radar satellite provider Iceye used the forum to unveil its Constellation Europe concept. The proposed 1,000-spacecraft system would comprise synthetic aperture radar, electro-optical spacecraft and signals intelligence satellites, with a communications layer connecting the assets and other features, CEO Rafal Modrzewski told reporters.

"Creating an independent, sovereign European intelligence capability is the right starting place for us to ensure that we have the means to know what's happening around us," Modrzewski said, citing recent political developments, including around Greenland, as shaping his thinking.

The system could come online in 2028 and deliver world-leading service in 2030, he said.

Although Europe's willingness to invest in space has increased dramatically over the past two years, Aschbacher noted that the region still risks falling behind. "To keep pace with international competitors, Europe must step up its efforts," he said.

The U.S. spends six times more than all European actors combined, and China outspends Europe by 50%, Aschbacher said. Europe's global share declined 50% in relative terms in 2019-24, he added.

Aschbacher celebrated that ESA has recently secured a record €22.1 billion in funding for 2026-28. "We are moving in the right direction, but others are moving just as fast, if not faster," he added.

# DCA Probe Prompts NTSB Push To Improve Pilot Situational Awareness

- THE BOARD IS CALLING FOR COMPREHENSIVE CHANGE IN AVIATION SYSTEMS
- MANDATED ADS-B IN EQUIPAGE TOPS THE LIST OF RECOMMENDED ACTIONS

**Sean Broderick** Washington

The NTSB's investigation into last year's midair collision near Washington was expeditious, wrapping up in less than 12 months. If investigators have their way, the efficient yet thorough probe and resulting recommendations will serve as catalysts for the most sweeping changes U.S. aviation has seen in decades.

NTSB staff and three participating board members agree multiple factors caused the Jan. 29, 2025, collision of PSA Airlines Flight 5342, a Bombardier CRJ700 regional jet, and a U.S. Army-operated Sikorsky UH-60L Black Hawk helicopter just east of Ronald Reagan Washington National Airport (DCA).

NTSB

Topping the list was the FAA's placement of a designated helicopter path, Route 4, in close proximity to DCA's Runway 33 approach. The aircraft collided at the intersection of the two air routes as the CRJ, cleared to land on Runway 33, was nearing its touchdown point. That mistaken placement was one of the nine issues in the NTSB's probable cause statement, which continued with a list of five contributing factors.

The draft final report's list of 74 findings and 50 new recommendations hammers home the accident's complexity and the magnitude of the challenges ahead for industry stakeholders that have the power to drive systemic changes.

Some of the most obvious steps have been taken, including Route 4's closure. While the recommendations target half a dozen issues at six organizations, the most significant call for new technology that improves pilot situational awareness.

The board, which adopted its final report on the accident during a Jan. 27 board meeting, amplified its longstanding call to expand Automatic Dependent Surveillance-Broadcast (ADS-B) usage requirements. An FAA mandate that went into effect in 2020 requires ADS-B Out—the automated broadcasting of an aircraft's identification, location, altitude and speed—in most controlled airspace. The technology is replacing radar as the primary way aircraft are tracked.

While the FAA saw equipping aircraft with ADS-B Out as essential, the agency did not mandate ADS-B In, citing high costs. The technology enables reception of nearby aircraft information and, with some avionics upgrades, displays it to pilots. FAA-backed trials at American Airlines have demonstrated ADS-B In's benefits in real-world environments (*AW&ST* March 11-24, 2024, p. 31).

The NTSB's updated recommendation calls for ADS-B In on any aircraft required to use ADS-B Out under the FAA's 2020 rule. Those upgrades should incorporate traffic display and aural alerting, the board added.

The Black Hawk was equipped with ADS-B Out, but it was not activated, which is common for military operations, and training flights in particular. The Army crew was training when the accident took place. Investigators determined ADS-B usage played no role in the collision, primarily because the CRJ was not equipped with ADS-B In, and controllers tracked the helicopter on radar.

Also high on the NTSB's recommendations list: a push to improve onboard collision avoidance technologies.

Investigators determined that the CRJ and Black Hawk collided at 278 ft. above the Potomac River. The altitude is well below the level at which current traffic collision and avoidance systems

**The NTSB is seeking changes that would further automate airborne collision avoidance systems.**

(TCAS), which are based on decades-old technology, provide conflict resolution advisories with recommended evasive maneuvers. TCAS and its current iteration, TCAS II, rely on more precise vertical guidance when issuing conflict resolution advisories, which override any air traffic control (ATC) instructions. Ordering a low-flying aircraft to descend rapidly introduces risk.

Around busy airports—especially those with considerable transient helicopter traffic like DCA—conflict resolution advisories and the less urgent traffic advisories are common enough to be considered nuisance alerts. This is one reason the systems are inhibited below certain altitudes. Investigators are confident that the next generation of airborne collision avoidance systems, ACAS X, can narrow this gap.

"Although the airplane's traffic alert and collision avoidance system operated as designed, it was ineffective in preventing the collision because of current activation criteria and resolution advisory inhibit altitudes," the NTSB found. "Technological advances since the development of [TCAS II] operating standards may allow [ACAS X] with reduced inhibit altitudes to have an expanded alerting envelope while reducing nuisance alerts," another finding states.

Among the board's recommendations is a call to evaluate whether advanced versions of ACAS X can be used closer to the ground. A joint RTCA/Eurocae committee that developed baseline ACAS X standards has been evaluating the issue and plans to have initial recommendations this year. The NTSB also wants the new standard to be retrofitted on all aircraft required to carry TCAS and a rotorcraft-specific version on all helicopters that operate in Class B airspace, found above the busiest airports.

ADS-B In and upgraded TCAS mandates—which would take years to develop and implement—together would affect more than 170,000 U.S.-registered aircraft, including the entire commercial fleet.

NTSB Board Member Michael Graham underscored that equipage is only part of the answer, particularly with expanded ADS-B. "I'm a believer in ADS-B In, but I'm only a believer if we do it right," Graham said during the board meeting, citing cockpit integration, led by effective visual and aural pilot cues, as the key factor. "Just to have it in [aircraft] is worthless."

The largest subgroup of recommendations targets changes to ATC staffing, training and procedures, both in general and for handling helicopters near major airports. Controllers need more training on identifying and mitigating risk, especially in high-workload environments where threats are nearly constant.

In addition, the NTSB called for improving controllers' conflict alert system to help ensure serious threats are more easily recognized and not mistaken for nuisance alerts. "Providing controllers with additional salient cues regarding the perceived severity of a potential conflict would reduce controller cognitive load and would likely improve reaction time to the most critical conflict alerts," the board states.

Further, the NTSB urged the FAA to make better use of safety data it gathers (*AW&ST* March 25-April 6, 2025, p. 41). The board's probe found the agency neither analyzes its data effectively enough to mitigate risk consistently nor shares it adequately enough for other stakeholders, including the NTSB, to fill those gaps.

"Multiple data sources provided evidence of midair collision risk between fixed-wing aircraft and helicopters at [DCA], including on approach to Runway 33, before this accident," one finding states. "However, the limited access to and use of available objective and subjective proximity data hindered industry and government stakeholders' ability to identify hazards and mitigate risk."

Recommendations to the U.S. Army and Defense Department focus on improving pilot training and safety data analysis as well as ensuring that military aircraft use ADS-B (*AW&ST* Aug. 11-31, 2025, p. 22).

"The Army's safety reporting systems for pilots were not well utilized and did not provide the organization with information about close encounters between Army helicopters and other aircraft that were later found to have occurred frequently," the NTSB found. "The Army's process for allocating resources to aviation safety management did not ensure the development of a robust safety management system for helicopter operations in the Washington, D.C., area."

While such major changes as aircraft equipage mandates will not come quickly, the FAA has taken steps in response to the avoidable disaster that killed all 67 passengers and crew on both aircraft.

The agency has reversed its years-long opposition to mandating ADS-B In—a step that Congress might order. Just before the board meeting, the FAA announced a reorganization that seems at least partially influenced by the DCA accident. The new structure introduces an Aviation Safety Management System (SMS) Organization that centralizes SMS activity previously fell within five different business lines.

An ineffective SMS process, particularly within the Air Traffic Organization, helped set the stage for the midair collision because it did not flag the helicopter routes or safety reports about them as significant risks. Controllers also raised concerns, as did a helicopter operations group that recommended changing or shuttering some routes. But the FAA did not act until compelled to react.

"The data was there," NTSB Chair Jennifer Homendy said. "This was 100% preventable."

## New NTSB Recommendations

| Topic | Number |
|---|---|
| **FAA** | |
| ATC staffing, training, procedural changes | 12 |
| Technology improvements, including ADS-B In and collision avoidance | 8 |
| Helicopter route management* | 5 |
| ATC traffic management | 3 |
| FAA safety data sharing | 3 |
| ATC incident response | 2 |
| **Total** | **33** |
| **U.S. Army** | |
| Safety data reporting improvements | 4 |
| Pilot training and procedural changes | 3 |
| Aircraft inspections | 1 |
| **Total** | **8** |
| **Defense Department** | |
| Technology improvements, including ADS-B In and radio communications | 5 |
| **Total** | **5** |
| **Transportation Department** | |
| ATC incident response | 1 |
| ATC safety culture review | 1 |
| **Total** | **2** |
| **Transportation Department Inspector General** | |
| Review ATC safety culture | 1 |
| **Total** | **1** |
| **RTCA** | |
| Collision avoidance technology standards | 1 |
| **Total** | **1** |

*Excludes two helicopter route management recommendations issued in March 2025.

*Source: NTSB*

# Chasing Volume

> AIRBUS NEARS BIG DECISION ON WIDEBODY RATES, A350 STRETCH

> THE MOVES COULD TRIGGER CHANGES TO INDUSTRIAL FOOTPRINTS

**Jens Flottau** and **Guy Norris** Singapore

Airbus has a long-established lead on Boeing in the global market for narrowbodies, but the airframer is still trailing its U.S. competitor in the widebody field. The new CEO of Airbus' commercial aircraft division, Lars Wagner, is determined to change that.

"The focus was on single-aisle on both sides of the Atlantic, but I'm seeing the same momentum on a smaller scale coming up [for widebodies], and there is no single day on which I don't talk about a widebody rate increase," Wagner said days before the Singapore Airshow.

"I believe the rate that we are planning right now is by far not enough," he added. "We see further momentum, so I need to think about how to serve our customers." Demand for widebodies is driven to a large extent by airlines in the Asia-Pacific region.

Airbus is targeting a rate of 12 A350s by 2028 to cater to the surge in widebody demand. The manufacturer delivered 57 A350s in 2025, a year in which it was heavily affected by supply chain constraints at Spirit AeroSystems and other companies. Boeing plans to increase the 787 production rate to 10 per month this year and is looking at further big production growth. The future 777X production rate is not clear yet, but Darren Hulst, vice president of marketing for Boeing Commercial Aircraft, indicated during a briefing at the Singapore Airshow that the monthly rate could ultimately exceed seven aircraft.

JENS FLOTTAU/AW&ST


**Airbus displayed a Starlux A350-1000 at the Singapore Airshow, demonstrating its widebody ambitions in the Asia-Pacific region.**

It is not clear what A350 production rate Airbus is considering, but it could ultimately exceed 20 per month, an unheard-of volume for widebodies. The rate increase will depend on two factors: a decision on a possible stretch of the aircraft and the results of a study into industrial capabilities of Airbus and its suppliers. The A330neo, by contrast, will remain relatively close to current rates and is unlikely to exceed five per month for the foreseeable future, industry sources say.

A decision about launching the A350-2000 is expected soon, possibly even this year. That would put the program, which has been under consideration for some time, on a timeline for service entry in the early 2030s. The aircraft's market positioning is still being evaluated, and it has gained importance as Emirates presses Boeing to launch a larger version of the 777X, dubbed the 777-10. While no Boeing moves are imminent, Airbus will have to keep in mind the possibility of a larger Boeing 777 at some point.

Previous studies into the A350-2000 have assumed the addition of 3-4 seat rows, which would bring the aircraft more or less in line with Boeing 777-9 capacity. Making the -2000 even larger, possibly between the size of the 777-9 and a future -10, would enhance the A350-2000's competitiveness and distance the model further from the A350-1000. Airbus must consider potential market cannibalization between the two Airbus models.

A stretched A350 would require a more powerful engine, too. The A350-1000 is equipped with the Rolls-Royce Trent XWB-97.

Expanding A350 production considerably would also likely exceed the limits of current industrial setups at Airbus and its key suppliers. Eliminating bottlenecks is an essential prerequisite for building up production volume. One bottleneck is cabin outfitting: Because many parts are arriving so late, Airbus has temporarily added so-called Station 20s—where cabins are typically installed—downstream of final assembly completion. It is an inefficient and expensive move that Airbus deems necessary to avoid clogging the final assembly line for the time being.

Airbus also could use the A350 growth plans to expand its industrial footprint to new sites, should it conclude that current bases, such as Toulouse, will not be able to cope or that moving some production elsewhere, potentially to high-growth markets in Asia, makes sense.

For its part, Boeing insists the long-delayed 777-9 remains on track for initial deliveries in 2027 despite the recent revelation of a newly discovered "potential durability issue" with the aircraft's GE Aerospace GE9X engine.

News of the GE9X issue emerged during Boeing's fourth-quarter earnings call on Jan. 27, when President and CEO Kelly Ortberg said the airframer was "working with GE to better understand that issue and finalize root cause and corrective action.

"Importantly, as we work through this issue, we continue our certification flight testing, and we don't expect this to impact our delivery in 2027,"

Ortberg added. As if to underscore this, Boeing has continued to conduct 777-9 test flights, and insiders say work under the latest phase of FAA Type Inspection Authorization (TIA-3) might wrap up in the fourth quarter.

GE Aerospace, meanwhile, remains tight-lipped about the ongoing investigation, which seems to be focused on the durability of an unspecified seal assembly within the engine. "We have an on-wing inspection program in place to support Boeing while we analyze the issue and define the corrective action, guided by our safety and quality systems," a GE spokesperson says. GE also continues to conduct long-running endurance tests of the GE9X in the run-up to the 777X's service entry.

Despite the engine durability issue, Ortberg said "the aircraft and engine continue to perform well." Under TIA-3, for which Boeing received approval in the fourth quarter, the company is focusing on tests of avionics, environmental control systems and the auxiliary power unit.

While 777-9 production slowly ramps up in anticipation of certification, Boeing is awaiting U.S. Transportation Department approval to extend the 777F freighter assembly line beyond Jan. 1, 2028, which it requested in late December. Boeing is asking for an exemption from compliance with International Civil Aviation Organization (ICAO) emissions regulations that would render the older GE90-powered model no longer eligible for FAA airworthiness certificates after Dec. 31, 2027.

Boeing has asked to build another 35 777F aircraft to cover a gap in new widebody freighter production capacity that opened up last year with the announcement of additional delays to the 777X program and the 777-8F cargo derivative.

Under Boeing's original plan, production of the "metal wing" 777F version was scheduled to finish in late 2027 as production of the follow-on replacement 777-8F accelerated. Powered by more modern GE Aerospace GE9X engines, the 777-8F will comply with the ICAO emissions regulations. Production of the 767-300F freighter is also due to cease at the end of 2027 to comply with the ICAO regulations.

Airbus says production of the first A350F freighter, MSN700, remains on track, with first flight expected around midyear and service entry scheduled for the second half of 2027. The heavily modified A350-1000 derivative, designed to carry payloads of 111 tons across ranges up to 4,700 nm, has so far attracted orders for 81 aircraft, 35 of which were placed in 2025.

Production of theA350F's main cargo door—at more than 14 ft. wide, the largest of its type—is underway at Airbus' composites production facility in Illescas, Spain. The door is expected to be completed and integrated into the aircraft in the second quarter. Assembly of the second A350F, MSN701, is also underway, Airbus says.

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# Embraer's India Move: Strategically Obvious, But Difficult To Implement

> EMBRAER EXPLORES PARTNERSHIP FOR E-JET FINAL ASSEMBLY

> A FACILITY IS SLATED TO BE SET UP WITHIN FIVE YEARS

**Jens Flottau** Singapore

Embraer's decision to explore a final assembly line for its E-Jets in India has been both a poorly kept secret and a move that most in the industry consider a logical step, given the rapid growth of air transport in the country. But the preliminary deal with joint venture partner Adani Defense and Aerospace still faces many hurdles and may not be the no-brainer that many might expect.

Embraer's step should be viewed in two separate but related contexts. The Brazilian manufacturer is seeking new markets for its E-Jets, particularly the E2, given that U.S. scope clauses are preventing widespread introduction of the aircraft into the U.S. market. The company has focused its attention on Asia, with a particular emphasis on India. Embraer is betting that, sooner or later, India's largest airlines—after expanding mainline routes and adding or starting long-haul capacity—will have both the management capacity and the desire to move some of their strategic attention to developing secondary and tertiary markets.

In the longer term, Embraer may seek to work with India's industry to develop the company's next and potentially larger commercial jet, should it decide to launch one, providing easier access to an even larger market expected to emerge in the 2030s.

Embraer's commercial strategy dovetails with a long effort to gain a foothold in India's growing defense market, which includes the possibility of a local final assembly line for Embraer's C-390 Millennium tanker-transport. The airframer sees a market for up to 80 C-390s in India alone and more than 180 in the Asia-Pacific.

India's government has clear ambitions to develop both regional aviation and a local aerospace industry. Development of regional networks is supported by the government-subsidized UDAN scheme, India's version of public service obligation routes. "UDAN" is a Hindi acronym for a phrase that translates roughly as "let ordinary people fly."

Star Air, operating a fleet of Embraer 175s, benefits from the scheme, as does IndiGo, with its ATR 72 fleet. Government-owned Alliance Air has a fleet of 20 ATRs, but only eight are in service, according to the Aviation Week Fleet Discovery database. Other players like SpiceJet and Akasa are focusing on narrowbody fleets—both have placed very large orders for Boeing 737 MAXs.

An interesting aspect of the preliminary agreement between India and Embraer is what it may mean for the country's regional transport aircraft (RTA) program. India has been trying to kick off the development of its indigenous regional aircraft for more

than 20 years. The program's targeted outcome was a large turboprop that could compete with the ATR, for which India remains a hugely important market. At one point, the Indian government requested consideration of a regional jet rather than a turboprop, but the focus has shifted back to turboprops.

Embraer's agreement with Adani Defense and Aerospace says the two want to "advance" the RTA program. The exact implications remain unclear, but the ill-fated initiative now appears to be evolving into a far less ambitious collaborative agreement with a Western aircraft manufacturer—an outcome that India had previously sought to avoid.

EMBRAER


**Regional airline Star Air operates eight Embraer 175s on domestic routes in India.**

Most details of the Embraer and Adani agreement have to be worked out.

"This potential partnership will leverage Embraer's deep engineering and aircraft manufacturing expertise alongside Adani's aviation value-chain footprint, which includes airport infrastructure, aerospace manufacturing, [maintenance, repair and overhaul] services and pilot training," the agreement stated.

Embraer Commercial Aviation CEO Arjan Meijer said the aim is to set up an assembly line within the next five years, but he added that he expects the process to be "quicker than that."

It is not clear whether Embraer plans to assemble the E175-E1, the last in-production model of the first-generation E-Jets, or the larger E190-E2 or E195-E2, in India or where an assembly line would be located. The RTA framing and the current state of development of India's regional airline sector would seem to indicate that the E175-E1 is likely to be the first step, potentially followed by the larger E2 models at a later stage.

India's only Embraer commercial jet operator, Star Air, flies eight E175-E1s, which are between five and 13 years old, according to Aviation Week's Fleet Discovery. Thirty-two E-Jets and ERJ145s are in service in different roles in the country, many of them with government agencies.

The main trigger that could start Embraer's move into India in earnest would be local airline orders large enough to justify investment in a second final assembly line beyond the current one in Sao Jose dos Campos. In one scenario, Embraer could focus E2 production at its headquarters in Brazil and move E1 production to the new site in India.

But it is not clear when the main airlines, Air India and IndiGo, would be ready to order Embraer aircraft. Both have placed huge narrowbody and widebody orders with Airbus and Boeing. IndiGo is also branching out into long-haul flying.

While the development of regional airports in the country is progressing as part of the government's investment and conversion programs, the airlines may lack management bandwidth to deal with another major project—at least in the short term.

Management attention or corporate strategy might not be the only—or biggest—issues the Embraer-Adani initiative faces before a formal launch. India's domestic air transport system suffers from high levels of taxation, regulatory burdens and high fuel costs, among other things, which strains the profitability of regional routes in particular. In such a high-cost environment, there is an incentive for airlines to operate larger aircraft in order to distribute costs across more seats.

The UDAN scheme provides financial support for regional operations, but only for three years. The plan subsidizes routes up to a cap of 40 seats, and the remainder of the capacity is flown at the airline's own risk, which is another factor that favors smaller regional jets over larger ones.

Many UDAN routes are abandoned shortly after the support ends because they become economically unviable without the subsidies, according to an Indian aviation industry executive. Aircraft are then transferred to other routes to which the UDAN scheme applies.

The UDAN scheme was launched in 2016 for a 10-year period. If Embraer's venture is to succeed, the scheme would need to be extended by another 10 years. Meijer noted that he would like the scheme to be extended and to incorporate a higher cap.

India would not be the first place Embraer has established a final assembly line abroad. The airframer opened a plant in Harbin, China, for the ERJ145 in 2004, but production ceased after an overall unsuccessful 12 years, in which the facility delivered only 41 aircraft.

Boeing and Airbus have established significant footprints in India, and they should take particular interest in the fact that Embraer has opted not to collaborate with any of their current partners—such as Tata, Mahindra, Dynamatic Technologies or Hindustan Aeronautics Ltd.—but instead with a company that is not working with them.

There are no overall exclusivity deals in place, so Embraer could have tried to make arrangements with an Indian player that works on large Western aircraft programs. But the entry of Embraer as an additional foreign partner might have raised questions about such a company's ability to take on more work for Airbus and Boeing programs, an ambition that is within the realm of possibilities, as the two airframers are seeking more supplier capacity and redundancy globally.

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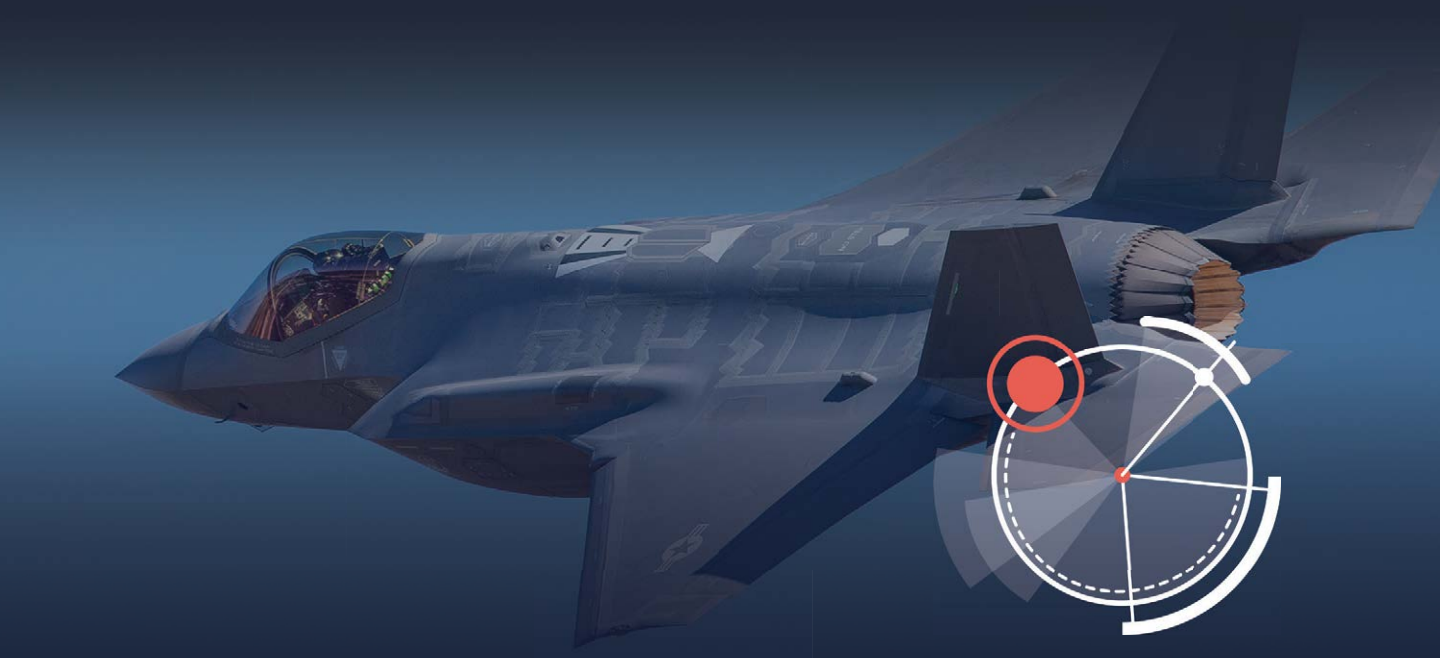

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# Trump's Strategic Defense Pivot Pressures U.S. Suppliers

> INDONESIA STEPS AWAY FROM THE BOEING F-15EX

> AIRBUS AND SAAB HIGHLIGHT INCREASED OPPORTUNITIES

**Brian Everstine** Singapore

An uncertain trade policy from the White House reverberated around the world to the Singapore Airshow, where European and Asian companies said they have seen increased interest in their products and U.S. officials sought to ensure the desire to buy American will remain.

Individual announcements made both before and at the show reflected the ramifications of the uncertain trade policy under President Donald Trump. Boeing, for example, announced on Feb. 3 that it will no longer pursue the sale of Boeing F-15EXs to Indonesia.


A Boeing KC-46 was displayed near an Airbus A400M (background) at the Singapore Airshow as both companies pitched their aircraft to global buyers.

BRIAN EVERSTINE/AW&ST

Jakarta subsequently announced a plan to buy Leonardo M-346Fs.

In a briefing that included talk of increased interest in the new Airbus A330 Multi-Role Tanker Transport Plus after Thailand's order, announced in September, Airbus leaders said they have seen an "uptick" in inquiries due to both American leadership and a push to diversify suppliers.

"I think that countries not only in this region but other regions as well [are looking] at diversifying the choices that they make to ensure they have sustainability, dependability, reliability as well," said Zakir Hamid, head of the Asia-Pacific region for Airbus Defense and Space. "So yes, diversification is something that is of interest in looking for . . . defense capabilities."

Mikael Franzén, Saab's chief marketing officer for the Gripen fighter, said the momentum of nations increasing defense spending, bolstered by concerns about Russia's 2022 invasion of Ukraine, has led to a specific interest in fighter aircraft. Canada, for example, recently raised the possibility of buying the Gripen and decreasing its purchase of Lockheed Martin F-35s.

"The demand and the interest and the urgency in the questions has increased a lot," Franzén said.

At the air show, host nation Singapore made a surprise announcement that it will buy used Lockheed Martin C-130Hs to replace its four oldest C-130Bs instead of purchasing new C-130Js. The move is a deferral of full recapitalization and appears to indicate that the Republic of Singapore Air Force is considering procurement of the Airbus A400M and/or the Embraer C-390.

Some at the show and in Washington raised concerns about the American ability to deliver products or be a reliable supporter. During a Feb. 3 Senate Foreign Relations Committee hearing, for instance, Sen. Jeanne Shaheen (D-N.H.) highlighted an Algerian plan to buy Russian-made fighters instead of U.S. ones, although Algeria had not announced publicly an intent to purchase U.S. aircraft.

"Public reporting currently suggests that the Algerian government has purchased Russian fighter aircraft, and it's in talks to purchase even more, because it would take too long to get American planes delivered," Shaheen said.

The urgency can be seen within the American aerospace and defense industry's top lobbying and advocacy group, the Aerospace Industries Association. The group's president and CEO, Eric Fanning, told Aviation Week that he still sees a lot of desire to partner with the U.S. despite the uncertain trade policy and the new National Defense Strategy that shifts the Pentagon's defense focus toward homeland defense in the Western Hemisphere and away from competition with China.

While there is intense frustration in Europe, bolstered by threats from Trump to take Greenland and comments downplaying the contributions of NATO forces in Afghanistan, allies and partners in the Asia-Pacific region remain interested in maintaining business relations with the U.S.

"Their alternative is China," Fanning said of Asia-Pacific nations looking to buy. "And they want to counter that and not be dependent on China, not be under the thumb of China. And we still make the best stuff."

Trump announced a new trade deal with India on Feb. 3, the day the air show kicked off, which included a reduction in tariffs on Indian goods once that nation agreed to stop purchasing Russian oil. Fanning said this is an example of America keeping the Asia-Pacific region as a priority.

"There is optimism the U.S. will remain focused on this region and a lot of desire from these countries to continue partnering," Fanning said. "This region is going to demand our attention, whether we want it to or not."

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# Geopolitics Cement Launcher Proliferation

> "NORMAL MARKET DYNAMICS" NO LONGER APPLY

> EUROPE EXPLORES LAUNCHER BLOCK BUYS

**Robert Wall** Singapore and Brussels

Conventional wisdom has held that the emergence of near-innumerable launch startups around the world would trigger a period of sharp consolidation. Geopolitics may prove conventional wisdom wrong: Political tensions are driving countries to seek independent space access, industry and government officials say.

"Each country will have a launch company in 2030," said Yoon Shin, CEO of South Korean startup Perigee Aerospace, which is targeting a first suborbital launch by year-end before scaling up for orbital operations and additional rocket component reusability.

South Korea is investing heavily in military space and looking for domestic launch options, worried that shipping satellites abroad for a ride on foreign rockets would allow others to glean sensitive information on system capabilities, Shin said Feb. 2 at Space Summit 2026, held on the eve of the Singapore Airshow.

Karishma Maharaj, a business development official for Spanish rocket startup PLD Space, says the company sees similar dynamics at play. "Given the geopolitical climate, everyone wants their own sovereign-to-space access," she said on the sidelines of Space Summit 2026. "Normal market dynamics do not apply anymore."

PLD Space, which aims to conduct the first launch of its Miura 5 rocket from the European spaceport in Kourou, French Guiana, in the third quarter, is seeing some of those market dynamics play out firsthand. Around half of the demand for its rockets over the next decade is expected to come from European government customers, Maharaj said.

The rocket startup also is looking to leverage its position as a Spanish company to help secure business abroad, Maharaj added, suggesting that the location makes it a neutral player, which could be attractive to prospective customers.

The extent to which politics are shaping the launcher market is apparent in the takeover talks between European space startup The Exploration Company and British launch newcomer Orbex. In announcing the potential acquisition in mid-January, The Exploration Company founder Hélène Huby said the company assured the British government that the merger would align with national launch goals.

More launch startups aspire to emulate companies such as Rocket Lab that have shown there is room for more service providers. German startup Isar Aerospace intends to conduct the first orbital launch of its Spectrum rocket in March, after a failure during the inaugural flight last year, and Isar's local rival Rocket Factory Augsburg aims to fly its RFA One rocket in the second half of the year. EU Defense and Space Commissioner Andrius Kubilius has championed diversification of European launch services since he took office little more than a year ago. "We need to take our launch capacity to the next level," he said Jan. 27 at the European Space Conference in Brussels.

Skyroot Aerospace, an Indian startup, has its eye on flying the four-stage Vikram-1 in March, Ashwin Mahavadi, senior vice president for business development, said in an interview at Space Summit 2026. The rocket can loft 480 kg (1,058 lb.) of payload into low Earth orbit and will carry five small satellites. The higher-capacity Vikram-2 could follow next year, he added.

Singaporean-based startup Equatorial Space is looking to fly its next suborbital launcher in March, too, and plans to have an orbital rocket in a few years, company officials said.


PERIGEE AEROSPACE

**Perigee Aerospace is working on methane engine technology to support South Korea's reusable space launch vehicle ambition.**

Traditional launch providers also are leaning into national sentiments to foster their growth. Europe should embrace launch policies like those of the U.S. government to strengthen its own industrial base, executives from leading European space launch companies argue.

The two main approaches they want Europe to adopt are preference for local providers and the kind of multiyear launch commitments the Pentagon makes in the National Security Space Launch initiative, the executives say.

Arianespace is ramping up but also has launch slots available in a few years; they are being kept open for European demand, said David Cavaillolès, CEO of Ariane 6 operator Arianespace. Some of those contracts are slow to materialize, he added, noting that the company and suppliers are starting to make parts for launchers in 3-5 years. "We need contracts" to give suppliers certainty, he said.

Giulio Ranzo, CEO of Vega-C maker Avio, said that the U.S. sometimes procures 20 launches at a time, far more than are approved in Europe. Europe's diverse customer base makes industrial planning much harder, he added. SpaceX has program stability because of consistent in-house Starlink launch demand and U.S. government missions, which are lacking in Europe. That needs to change if Europe wants to catch up, Ranzo said.

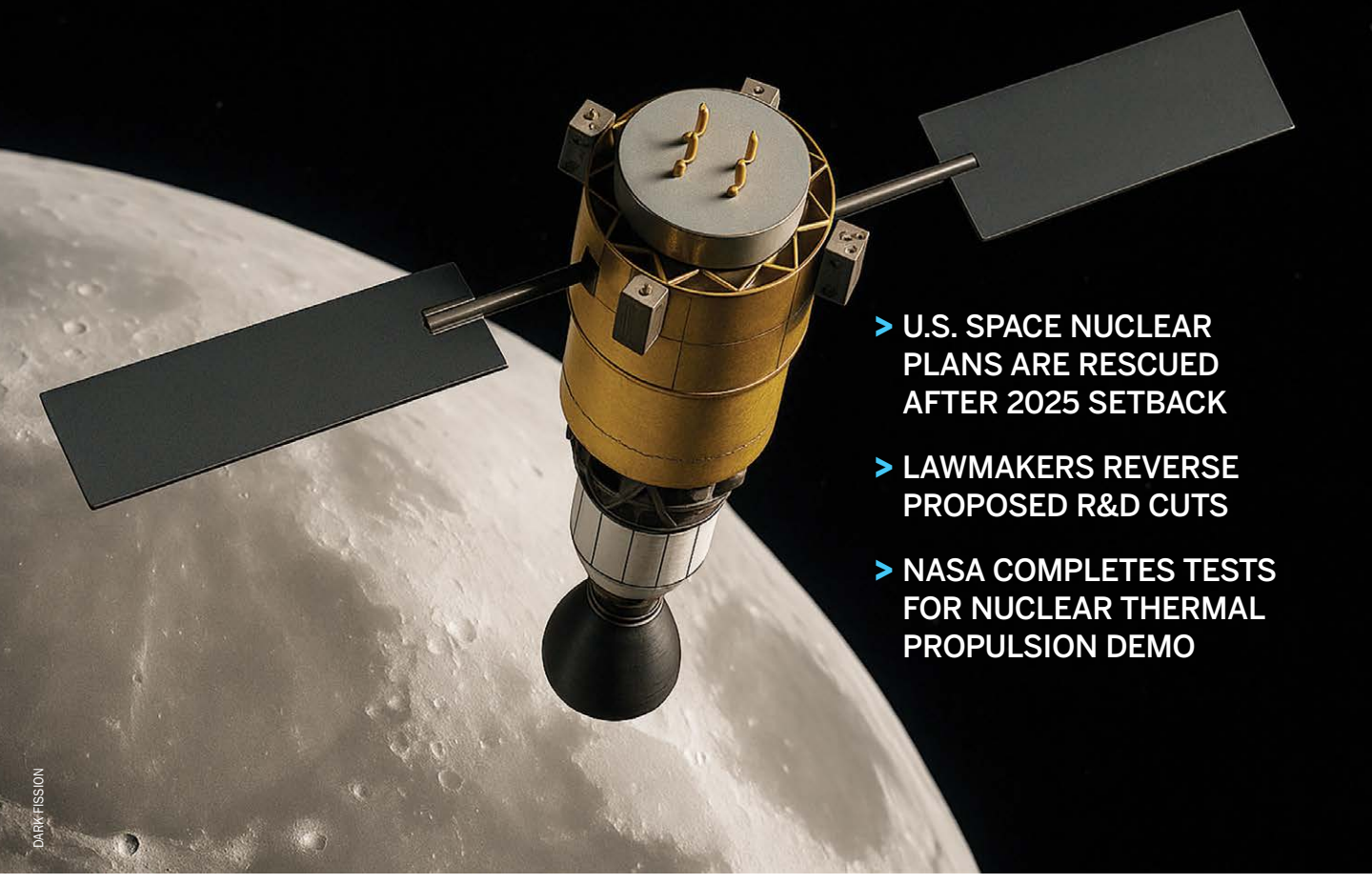
European officials are assessing how they can coordinate launch demand, said Toni Tolker-Nielsen, the European Space Agency's head of space transportation. But how to deliver block buys still needs to be worked out, he added.

Ranzo said that the local preference for which European providers are asking is no different from what takes place elsewhere. The U.S., China, Russia and India all opt for domestic service providers, he pointed out.

"We are not asking for a favor," Cavaillolès said.

MILITARY SPACE > Taking nuclear power to the Moon p. 32

# NUCLEAR REVIVAL



- U.S. SPACE NUCLEAR PLANS ARE RESCUED AFTER 2025 SETBACK
- LAWMAKERS REVERSE PROPOSED R&D CUTS
- NASA COMPLETES TESTS FOR NUCLEAR THERMAL PROPULSION DEMO

DARK FISSION

**Vivienne Machi** Los Angeles

After a bruising 2025, nuclear propulsion for space may be back in favor as the U.S. seeks technology to power vehicles going to Mars and beyond.

The nuclear thermal propulsion (NTP) and nuclear electric propulsion (NEP) community was rattled last year when NASA canceled a critical demonstration program with DARPA and then zeroed out funding for fiscal 2026 as part of a proposed pivot to nearer-term alternatives.

Now the pendulum is swinging back. Congress injected $110-120 million for NASA to further NTP research and development and $50 million for NEP efforts under the recently passed appropriations bill. New NASA Administrator Jared Isaacman has embraced nuclear propulsion and fission surface power as core to the agency's mission. During a December hearing, he told lawmakers that such technologies fit squarely within its role to tackle "the near-impossible." Meanwhile, the Pentagon has sharpened its rhetoric about on-orbit competition with China.

Since the Nuclear Engine for Rocket Vehicle Application (NERVA) program ended in 1973, investment in nuclear propulsion writ large has remained low, largely because "there was not a driver, which we absolutely see today," says Robert O'Brien, director of the Center for Space Nuclear Research in Idaho Falls, Idaho.

NASA's cancellation of the Demonstration Rocket for Agile Cislunar Operations (DRACO) last year dealt a blow to space nuclear propulsion efforts. The joint NASA-DARPA program was intended to demonstrate an NTP system powered by a high-assay, low-enriched-uranium reactor, on-orbit tests of which were targeted for 2027. Before NASA halted work last summer, the Lockheed Martin-BWX Technologies team had cleared subsystem preliminary design reviews, begun propulsion reactor testing and started the interagency nuclear launch safety process, says Kerry Timmons, strategy lead for nuclear and power infrastructure at Lockheed.

**Dark Fission aims to launch a prototype nuclear-powered spacecraft by 2029 using public and private funds.**

But NASA has quietly preserved momentum on NTP even after DRACO's formal shutdown. The agency's Space Nuclear Propulsion Office completed more than 100 cold-flow and flow-induced vibration tests last year on a full-scale reactor engineering development unit built by BWX Technologies. Those tests, announced in January, marked the first evaluation of a flight-

like space reactor design since the 1960s. The agency has also continued work on developing NEP thruster and power conversion technologies over the past year, a spokesperson says.

Advocates say nuclear propulsion will unlock faster, safer and more capable missions to Mars and the outer Solar System and provide higher power for onboard instruments and communications systems. A 2022 study led by the University of Alabama in Huntsville found that NTP could cut transit times to the gas giants dramatically, allowing a spacecraft to reach Jupiter in just over two years and Saturn in under five, compared with 5-7 years for past missions with chemical propulsion.

While the preferred use cases for nuclear propulsion are still being worked out, NTP research and development work is more mature, observers note. Thanks to the progress on programs like NERVA and DRACO, "as soon as the word comes from [Washington], the team is ready to go toward an [NTP] demonstration flight," says L. Dale Thomas, deputy director of the Propulsion Research Center at the University of Alabama in Huntsville.

Testing infrastructure has emerged as a choke point to fielding nuclear propulsion systems, as national labs face oversubscription driven by small modular reactor programs and rising demand for space systems testing, Thomas says. The Propulsion Research Center is surveying the unfinished Bellefonte Nuclear Plant outside of Huntsville as a potential ground test site for NASA to hone space nuclear propulsion, Thomas says. The preliminary results show promise that the Bellefonte site could be test-ready "much sooner than building a facility from scratch," he says.

Stakeholders see this year as a launchpad for nuclear propulsion efforts. The fiscal 2026 appropriations for NTP can mature reactor hardware, support subscale ground tests and put key technologies into orbit if NASA resists spreading the money too thin, says Fred Kennedy, a former director of DARPA's Tactical Technology Office who helped to launch the early nuclear propulsion effort that became DRACO.

Fielding an NTP-powered spacecraft will take a mix of NASA-sponsored programs and privately funded ventures, says Kennedy, who is now cofounder and CEO of Dark Fission Space Systems. His company is planning a stepped approach to mitigate operational, regulatory and technology risks via several on-orbit demonstrations: a low-cost pathfinder in 2027, orbital transfer vehicle prototype by 2029 and full-scale demonstrator by 2030.

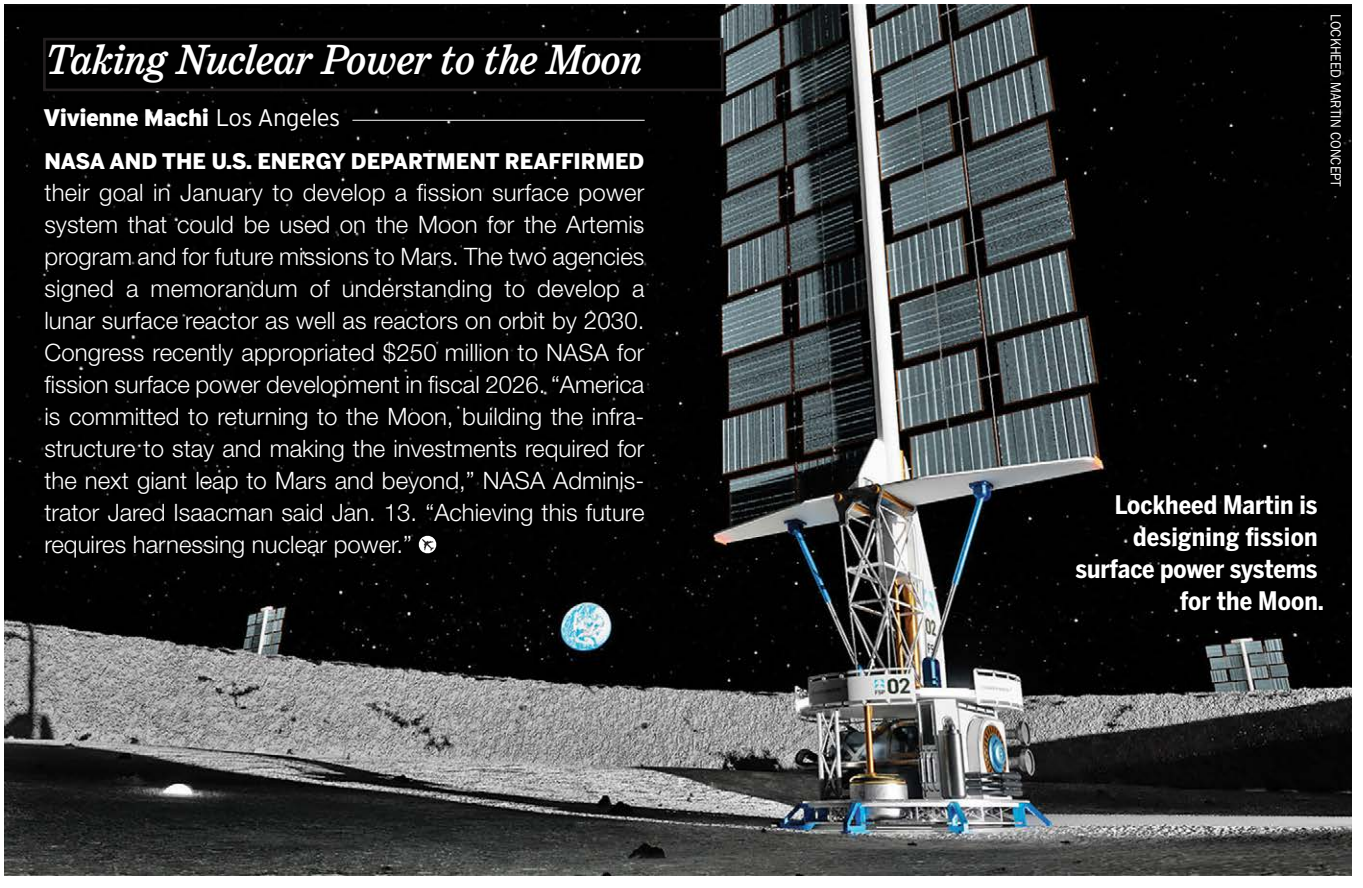
Others warn that current funding levels, while enough to make meaningful gains, only open the door. Sustaining progress toward an operational capability by the 2040s will require annual NTP budgets closer to $500 million, O'Brien says.

Defense interest has added urgency. The U.S. Space Force is pursuing maneuverability and high delta-v beyond low Earth orbit, and DARPA is exploring scalable, cost-effective on-orbit nuclear reactors rather than one-off demonstrations. "A one-two punch of support out of NASA and [the Defense Department] would go a long way toward getting NTP on orbit," Kennedy says.

## *Taking Nuclear Power to the Moon*

**Vivienne Machi** Los Angeles

**NASA AND THE U.S. ENERGY DEPARTMENT REAFFIRMED** their goal in January to develop a fission surface power system that could be used on the Moon for the Artemis program and for future missions to Mars. The two agencies signed a memorandum of understanding to develop a lunar surface reactor as well as reactors on orbit by 2030. Congress recently appropriated $250 million to NASA for fission surface power development in fiscal 2026. "America is committed to returning to the Moon, building the infrastructure to stay and making the investments required for the next giant leap to Mars and beyond," NASA Administrator Jared Isaacman said Jan. 13. "Achieving this future requires harnessing nuclear power."



LOCKHEED MARTIN CONCEPT

**Lockheed Martin is designing fission surface power systems for the Moon.**

# U.S. Defense CEOs Promise More Investment and Shareholder Returns

> LOCKHEED COULD QUADRUPLE PRODUCTION OF HIGH-ALTITUDE INTERCEPTORS

> ANALYSTS SENSE SHAREHOLDER REWARDS WILL BE DEFENDED

**Michael Bruno, Matthew Fulco** and **Steve Trimble** Washington

U.S. defense primes are pledging to invest more of their own money in production capacity and support for the major weapon systems they provide to the Pentagon. But they have also signaled they will continue to reward shareholders with payouts despite President Donald Trump's attack on the practice.

As companies reported fourth-quarter 2025 results and year-ahead 2026 projections in late January, several executives acknowledged Trump's pressure to accelerate delivery of warfighting capabilities. Collectively, they asserted that they will invest billions of dollars over the long term to do so.

Only one prime, Northrop Grumman, indicated that it would forgo share buybacks immediately yet continue with dividends. Primes that reported earnings through January included Boeing, GE Aerospace, General Dynamics, L3Harris Technologies, Lockheed Martin and Northrop Grumman.

Asked on a Jan. 29 teleconference with analysts about shareholder returns, Lockheed Chairman, CEO and President Jim Taiclet sidestepped a direct answer. "We're going to continue to use a disciplined and dynamic capital allocation process that we've been using for years," Taiclet said. Analysts later stated in notes to investors that Lockheed outlined no changes to its traditional goal of returning 100% free cash flow to shareholders.

At RTX, Chris Calio went a step further. The chairman and CEO said Jan. 27 that RTX's shareholders have come to expect dividends and that the company remains committed to offering them.

"That said, again, we're comfortable we can accommodate both that and the investment needs that come with delivering the current backlog and the potential future volumes on key programs," Calio said.

To be sure, RTX feels "the responsibility and urgency to deliver more and to deliver it faster," he told analysts. The earnings call was Calio's first public appearance after Trump's Jan. 7-8 social media posts and executive order criticizing defense contractors for slow deliveries (*AW&ST* Jan. 26-Feb. 8, p. 42).

LOCKHEED MARTIN

**Large primes are promising to invest more money in conjunction with major new missile deals and other U.S. military spending increases.**

In a Jan. 8 Truth Social post, Trump called Raytheon "the least responsive to the needs" of the Pentagon, "slowest in increasing their volume" and "the most aggressive" in terms of share buybacks. He then threatened to cut ties.

"Candidly, we understand the frustration," Calio said.

Supply chain bottlenecks have hampered Raytheon's delivery of SM-6 missiles to the U.S. Navy, mainly due to limited availability of solid rocket motors produced by L3Harris-owned Aerojet Rocketdyne. As of late 2025, only about 500 of 625 contracted missiles had been delivered. Production times for the missiles have been averaging 33-36 months.

"We understand that our products are critical to national security and the security of our partners and allies," Calio said. He noted that Raytheon increased production 20% on several critical programs last year and expects to boost output significantly again in 2026, buoyed by increased capital expenditures.

In a Jan. 27 client note, RBC Capital Markets Managing Director Ken Herbert said RTX's capital expenditure guide is $500 million more in 2026 than it was in 2025—$3.1 billion versus $2.6 billion—but still in line with prior investor expectations.

For its part, Lockheed could quadruple production of high-altitude interceptors after signing a framework for a future agreement with the U.S. military, the company said Jan. 29. The deal, if finalized by the Pentagon and approved by Congress, would expand production capacity to 400 Terminal High-Altitude Area Defense (THAAD) interceptors a year, far exceeding Lockheed's current annual potential delivery volume of 96.

The deal follows a similar agreement signed earlier in January between the Pentagon and Lockheed to ramp up production capacity of Patriot Advanced Capability (PAC)-3 interceptors to 2,000 annually, or more than triple the current output limit of 600.

Both frameworks include "make-whole" provisions that reduce Lockheed's financial risk if the government decides later to reduce orders

of THAAD missiles, which cost $12-15 million each.

Still, Lockheed plans to spend billions of dollars over the next three years to support the production capacity increase by building and modernizing more than 20 facilities across five states. The company also has begun building a Munitions Acceleration Center in Camden, Arkansas, to train more workers to manufacture THAAD, PAC-3 and other rocket-powered weapons.

At the same time, Lockheed aims to spend $1 billion to stockpile spare parts for the F-35, making up for a shortfall that the company has blamed on government underfunding. Lockheed previously spent more than $1 billion to fill some of the gap, Taiclet said.

"We've also committed to an additional $1 billion of strategic internal investment for the F-35, with an emphasis on the aircraft sustainment system to improve mission-capable rates across the fleet," he added. "This is an absolute priority for us and one we are working closely with the [Defense] Department on."

L3Harris plans to increase capital expenditure this year to $600 million, up 35-40% from 2025. The company sees this as a one-time capital investment to modernize solid rocket motor production.

Not every large prime need worry about running afoul of Trump's new policy to curb shareholder returns. Boeing has not carried out share repurchases or paid dividends since March 2020, as it wrestled with the dual Boeing 737 MAX and COVID-19 pandemic crises.

Determining when the giant commercial airframer and defense prime will resume share repurchases or dividend payments has been a top concern of investors and analysts who tuned into Boeing's Jan. 27 quarterly update. On the call, Chief Financial Officer Jay Malave said the company expects to generate $1-3 billion in free cash flow this year overall, albeit back-half-weighted, as Boeing expects to burn cash in the first half. For all of 2025, the company recorded a cash burn of $1.88 billion, despite positive free cash flow of $375 million in the fourth quarter.

Looking back on the first two weeks of industry earnings reports, analyst Byron Callan of Capital Alpha Partners noted that past results differed from future promises regarding the redirection of free cash flow.

For example, capital expenditures as a percentage of sales for General Dynamics' three defense segments were 2.1% in 2025, compared with 1.9% in 2024 and 2.1% in 2023. In 2021-22, they were 2.6%. Northrop's research and development spending was 2.6% of 2025 sales. That was lower than in 2019-24, when it was 2.8-3.3%. Lockheed's capital expenditure as a percentage of sales was 2.2%—"the same, more or less, as in 2022-24." Research and development increased to 2.7% of sales in 2025 from 2.3% in 2024, but it was 2.6% in 2022.

"Managements noted an increased investment plan, but data for 2025 showed that not a lot had changed," Callan wrote Feb. 1.

# U.S. Army Releases Performance Details as Laser Weapons Enter Service

> THE ARMY PLANS TO BUY 24 E-HEL SYSTEMS THIS YEAR

> LENGTHY COOLDOWN PERIOD LIMITS A LASER'S DUTY CYCLE

**Steve Trimble** Washington

The time has come for high-energy lasers. As the technology is deployed to defend troops and civilians, new details are shedding light, as it were, on what these photon-based defensive weapons can do—and what they cannot.

A month after the first operational Rafael Iron Beam laser system was deployed in northern Israel, the U.S. Army released a draft solicitation on Jan. 21 for the mass-producible Enduring-High Energy Laser (E-HEL). The service plans to buy the first 24 systems by year-end.

The Army's draft solicitation is a rare public description of the capabilities and limits of the state of the art in directed energy technology, as it spells out exactly what the service expects from E-HEL products. Potential suppliers include AeroVironment and Huntington Ingalls Industries (HII).

The E-HEL weapon is intended to be towed by or integrated into the 22,500-lb. Oshkosh M1279 Joint Light Tactical Vehicle, the host for competing Army Multi-Purpose High Energy Laser (AMP-HEL) prototypes. AeroVironment (via acquired subsidiary Blue Halo) and HII delivered 20-kW-class prototypes for Joint Light Tactical Vehicle integration last year under the AMP-HEL program.

High-energy lasers are desired because, unlike kinetic interceptors such as those in the Rafael-Israel Aerospace Industries Iron Dome, they come with an unlimited magazine. In an age of mass attacks by swarms of drones, rockets and mortars, directed energy systems could complement a finite supply of kinetic interceptor rounds.

The draft solicitation, however, highlights the duty cycle limitations of these defensive weapons. The Army expects each E-HEL system to need a 4-min. cooldown period each time it is used almost continuously for up to 1 min. That 4:1 ratio for recovery and operation enables the batteries and other subsystems to cool, but it represents a key limitation of a directed energy weapon. The Army hopes industry can propose E-HEL candidates with better performance. "Greater magazine depth is favorable," the solicitation states.

The system is expensive. The Army expects to spend more than $100 million to acquire all 24 E-HEL systems this year, leading to an average cost of at least $4.17 million each. That represents a substantial premium over the $300,000-400,000 unit cost of the Joint Light Tactical Vehicle the system would defend from attack. Unlike kinetic interceptors, however, each laser "round" is relatively affordable, representing only the cost of the energy required to produce the beam.

The Army document also clarifies what a mass-producible high-energy laser should be able to do in the modern era. The draft solicitation requires that the selected E-HEL be able to shoot down an object with a slant range of up to 4 km (2.5 mi.) away. At that distance, the beam should be powerful enough to deposit 1 kW of photon energy on a spot no greater than 1 $cm^2$ (0.2 $in.^2$) within a 10-cm (3.9 in.) area. That combination of accuracy and energy should be enough to defeat threats weighing up to 1,320 lb., the solicitation document states.

At the same time, the Army's expectations for E-HEL reveal the limits of what are considered mass-producible directed energy weapons. A range limit of 4 km renders E-HEL as a last line of defense against incoming threats in many cases, augmenting a limited supply of kinetic interceptors in the same area. The Army plans to field the E-HEL alongside a high-power microwave system as well as kinetic interceptors, such as the RTX AIM-9X Sidewinder, Lockheed Martin AGM-114 Hellfire, Iron Dome's Tamir missile and a future second interceptor for the Integrated Fires Protection Capability Increment 2.


**The U.S. Army demonstrated a drone kill in 2025 using a laser weapon integrated into a Stryker vehicle at Fort Sill, Oklahoma.**

JIM KENDALL/U.S. ARMY

# UK Defense Planners Face Urgency Amid Budget Uncertainty

> CONTRACT AWARD NEARS FOR BALLISTIC MISSILE PROGRAM TO ARM UKRAINE

> GCAP WORKS AROUND DELAYED CONTRACT GO-AHEAD

**Tony Osborne** and **Robert Wall** London

The UK Defense Ministry has launched several programs over the past year, seeking results on an accelerated time frame to address needs in areas such as deep strike, uncrewed collaborative platforms and support helicopters. That momentum is driven by lessons from conflicts in Ukraine and elsewhere, and the realization that the U.S. may no longer be the close security partner it once was.

UK political and military leaders have been invoking that sense of urgency for months. At the same time, the government is wrestling with balancing security and domestic spending needs amid low growth. That has delayed the release of its Defense Investment Plan—which spells out multiyear financial commitments—and hobbled big modernization projects.

Many programs that received the green light are still in their early phases and so do not require the investment plan signoff. For instance, the UK Defense Ministry on Jan. 24 named seven bidders for Project Nyx to produce an autonomous platform to serve as a loyal wingman to the British Army's Boeing AH-64 Apache attack helicopters in the 2030s.

The platform is intended to perform tasks such as reconnaissance and surveillance, target acquisition, strike and electronic warfare. Anduril, BAE Systems, Leonardo, Lockheed Martin, Syos Aerospace, Tekever and Thales are in the running. The aircraft is expected to have a payload capacity above 200 kg (440 lb.), operate largely autonomously and use artificial intelligence to adjust to complex battlefield situations within set operational boundaries.

Anduril is working with electric air taxi developer Archer Aviation and other UK companies. Anduril and GKN Aerospace released an image in December of a large, single-piece V-tail that will be part of their proposed platform. BAE Systems is teaming with startup Certo Aerospace, the developer of a heavy-lift uncrewed rotorcraft that uses a coaxial main rotor system. Certo's aircraft, called the Capstone, has demonstrated the ability to perform logistics missions and could be easily adapted for other tasks, the company says.

Lockheed Martin hinted in a statement that its Nyx contender builds on its existing product portfolio and could use such technologies as the Matrix autonomous flight system or the Nomad blown-wing vertical-takeoff-and-landing (VTOL) uncrewed aircraft.

Tekever, which produced the Stormshroud, the Royal Air Force's

**Project Nyx aims to equip the British Army's AH-64E Apaches with a loyal wingman-like autonomous collaborative platform to perform scouting, electronic warfare and limited attack tasks.**

BRITISH ARMY

first autonomous combat platform, said its proposal did not detail a configuration. The company largely develops fixed-wing drones but has built electric VTOL systems to equip them. Syos Aerospace, a UK-New Zealand autonomous helicopter startup, has developed an aircraft called the SA200 that uses a conventional single-main-rotor configuration and can carry a 200-kg-payload.

The UK also is looking to develop a low-cost drone interceptor quickly under Project Goshawk. The Defense Ministry said Jan. 23 that the project aims to achieve "a favorable 'cost-exchange ratio' and reliably counter diverse targets at varying speeds, altitudes and trajectories." The government is hoping to conduct trials with up to two bidders within a year.

The extensive use of drones and loitering munitions in Ukraine and elsewhere has driven a surge of interest in these capabilities. The UK says Project Goshawk could lead to a production requirement of 3,000-7,000 interceptors per year.

London also signaled growing concern about technology restrictions, such as those typically associated with U.S. equipment. "Ideally no export controls, but European export control will be acceptable if required," the government said.

Not all these efforts are entirely UK-focused. The government disclosed in January that the effort to develop a conventional ballistic missile under Project Nightfall is aimed at arming Ukraine. The program is working to develop a system capable of striking targets at more than 500 km (310 mi.) that can be delivered in 9-12 months. The UK plans to award £9 million ($12 million) development contracts to three industry teams to design and build an initial three missiles for live-fire testing within 12 months. Contracts are due in March.

Each Project Nightfall launcher should be able to fire more than two missiles, each of which could carry a 200-kg high-explosive payload. Eventual production is planned to reach 10 systems per month, with a ceiling price of £800,000 per missile, the UK Defense Ministry said.

Project Nightfall also will be used to help shape future long-range strike projects, the ministry added.

While these programs are being put on the fast track, the broader effort to spell out a modernization strategy has been languishing. London has been working for months on its far-reaching Defense Investment Plan, which was intended to reflect the new defense review released last summer. The government delayed the investment plan from the fall of 2025 to the end of the year. Industry officials now do not expect it until March or even early May.


CERTO AEROSPACE

**BAE Systems is working with Certo Aerospace on adapting the latter's Capstone co-axial UAS that has been tested for battlefield logistics.**

Without the Defense Investment Plan, major program decisions have failed to materialize. The Strategic Defense Review, for instance, pledged £1 billion for missile defense. But relatively little has happened since then, and UK industry officials are uncertain about where the money will be spent.

The Defense Ministry did launch a search last summer for a lead systems integrator for ground-based air defenses ranging from counterdrone capabilities to short- and medium-range air defenses.

Absent the Defense Investment Plan, one of the UK's highest-profile projects, the trinational Global Combat Air Program (GCAP) to develop a future fighter in partnership with Italy and Japan, remains in limbo. The governments were due to award the Edgewing industrial joint venture of BAE Systems, Leonardo and Japan Aircraft Industrial Enhancement Co. a design and development contract late last year, but paperwork has been stuck, jeopardizing an already ambitious 2035 fielding timeline.

Program work continues despite the uncertainty, an Edgewing spokesperson says. "Both parties have a clear, shared view of the scope of work and are focused on ensuring the right contract is awarded," the spokesperson states.

Speed is crucial to the undertaking, said Richard Berthon, director of Future Combat Air at the UK's Defense Ministry, and Edgewing Chairman Herman Claesen in a guest appearance on a Jan. 22 Council on Geostrategy podcast. Claesen said GCAP is in a crucial period to ensure the system's physical attributes are "future-proof." Despite the unexpected wait for the contract, he stressed that the program is "hitting milestones every week, every month."

As Parliament urges the government to accelerate publication of the investment plans, Prime Minister Keir Starmer is reportedly exploring alternative fiscal approaches to overcome the £28 billion shortfall, potentially including controversial private financing initiatives.

The delays in the investment plan have raised another concern: whether the strategy it is supposed to underpin is still relevant. In the intervening time, industry officials quip, the geopolitical environment has changed so much—particularly given U.S. policy pronouncements hostile to Europe—that a new strategic defense review may be required and in turn a new investment plan.

# FACTORY OF DRE

**Steve Trimble** Ashville, Ohio

Standing on the side of a barren soybean field, Keith Flynn pointed to a speck of a structure lying a few miles away, beyond a line of trees in the distance.

"That is Building 1," said Flynn, a former Tesla and Toyota executive who is now senior vice president of manufacturing for U.S. defense technology company Anduril.

The 365,000-ft.$^2$ empty factory on the edge of Rickenbacker International Airport near Columbus, Ohio, stands alone on Anduril's recently acquired property here, but not for long. On the few miles between Building 1 and the empty field where Flynn stood on a cold December day, Anduril envisions establishing the Arsenal-1 defense manufacturing complex over the next 10 years. The company intends for the massive complex to churn out hundreds of Collaborative Combat Aircraft (CCA), thousands of missiles, tens of thousands of drones and pieces of other major systems in its increasingly diverse product portfolio, including autonomous submarines and spacecraft.

If 9-year-old Anduril realizes its goal of becoming one of the largest defense prime contractors over the next 10 years, the company's $900 million bet to create this site will be the reason.

As of mid-January, that investment depends on Anduril's ability to win future production orders on a large scale, starting with a still-pending U.S. Air Force decision on building the YFQ-44 Fury as the first production CCA.

Anduril also is waiting for the Air Force to award production contracts for the Family of Affordable Mass Munitions (FAMM) program to manufacture a palletized, low-cost cruise missile, possibly in the thousands. The service selected the company's Barracuda system to be one of the bidders for the FAMM production contracts.

Still more opportunities may come with the military's growing interest in hybrid-electric vertical-takeoff-and-landing systems. Anduril has teamed with Archer Aviation to develop a candidate for mobility aircraft programs under consideration by the U.S. Air Force, Army and Marine Corps.

The products of all those programs—and potentially others—will need to be built somewhere. Traditional practice in the defense industry is to wait for production contracts to be awarded, then invest the capital necessary to deliver the systems for which the Pentagon

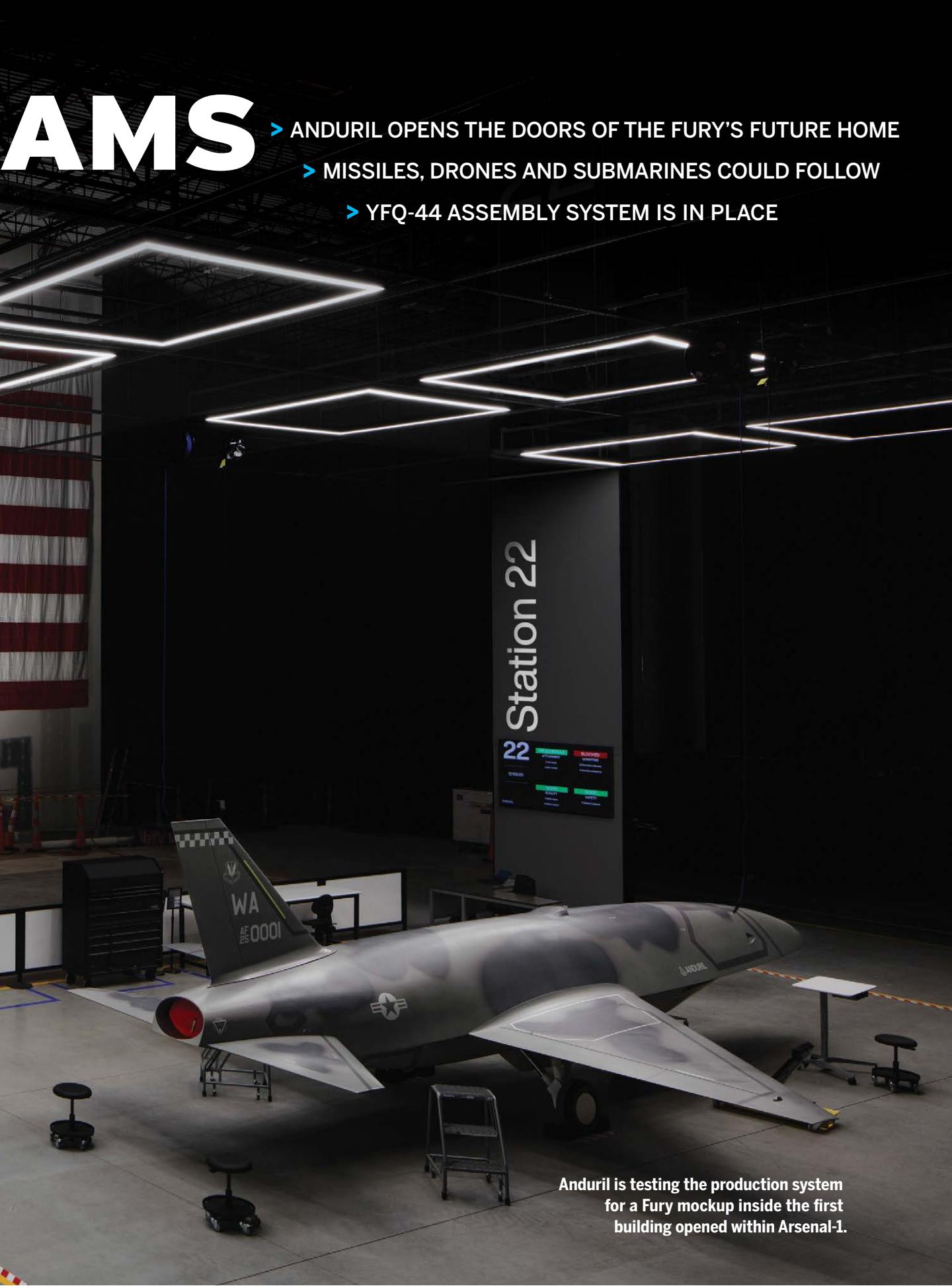
ANDURIL

# AMS

> ANDURIL OPENS THE DOORS OF THE FURY'S FUTURE HOME

> MISSILES, DRONES AND SUBMARINES COULD FOLLOW

> YFQ-44 ASSEMBLY SYSTEM IS IN PLACE




**Anduril is testing the production system for a Fury mockup inside the first building opened within Arsenal-1.**

has already paid. But Anduril is not waiting. As the Pentagon faces urgent pressure to ramp up production capacity, officials have demanded that the defense industry invest in that infrastructure up front and accept the risk that orders may not follow.

"What we want to do is change an acquisition problem of 'how do I get a factory?'" Flynn said. "I have a factory, so what's the proper way to allocate it? Which [product] line is going where and at what time? Developing the Arsenal site allows us to go do that."

Anduril is designing the Arsenal-1 complex to be uniquely interchangeable. The same building that produces missiles can be reconfigured to build drones or parts for submarines. It is an approach that will influence how the company designs products and trains the workers who build them.

According to the company's 2025 application for tax incentives from Arsenal-1 host Pickaway County, Anduril expects Building 1 to open early this year and employ an estimated 301 people by year-end.

Anduril plans to add about 5 million ft.$^2$ of factory floor space across another eight buildings within nine years. The company intends to add 3,707 more employees to the Arsenal-1 payroll by the end of 2035 who would receive about $530 million total in taxable salaries, averaging $132,235 per employee.

For now, visitors see mostly empty fields, although work has started on the exterior walls of two more buildings on the site. "We are at the other corner of the property, so when . . . you try to conceive of 5 million ft.$^2$ under one roof and a property that supports that, it is [this]," Flynn said, gesturing to the rolling, empty fields.

But Arsenal-1 is not completely empty. During the mid-December tour, Building 1 was in the final stages of preparation to become operational.

The first production opportunity for Arsenal-1 illustrates the many challenges Anduril faces as a relatively new defense contractor attempting to break into the exclusive club of makers of large combat aircraft. To be successful, the company has to be ready to scale up production rapidly while navigating the uncertainty built into the Air Force's retooled acquisition plans for the CCA program.

The first hurdle came two years ago, when the service awarded contracts to build CCA Increment 1 prototypes to the Anduril YFQ-44 Fury and the General Atomics Aeronautical Systems Inc. YFQ-42 Gambit, which defeated competing designs offered by defense giants Boeing, Lockheed Martin and Northrop Grumman. That set up Anduril to face a second hurdle. The Air Force plans to select at least one company to launch production for CCA Increment 1 this year. The candidates include at least the YFQ-42 and YFQ-44, and Northrop has not ruled out offering the Talon, a CCA prototype derived from the Model 437 that was unveiled in early December.

**"Quite often, we are trying to actually design products that don't require automation.**

I can always—as the volumes [grow], and it makes sense from a financial standpoint—I can always add automation."

Among those three candidates for CCA Increment 1 production, Anduril stands out as the only one that has not conducted serial manufacturing of a large, jet-powered aircraft. The company has a track record of production in other areas, including small drones, launched effects, missiles and solid rocket motors. But Anduril's experience with fighter-size aircraft is limited to the Fury's first prototypes, which rolled off an interim production line last year in Costa Mesa, California.

Even so, its executives say they are prepared to win the CCA Increment 1 production contract and move immediately into serial production. The first Ohio-based employees are undergoing training in Costa Mesa to build the Increment 1 prototypes, and they will move back to Arsenal-1 to build production versions of the YFQ-44 if the type wins the contract.

Moreover, Anduril is confident in its new production system, which combines features of Industry 4.0 manufacturing techniques with what it considers more practical and conventional methods.

Among the advanced features of the production system, Building 1 lacks fixed tooling monuments, including overhead cranes usually found in factories that produce aircraft weighing thousands of pounds. That absence is intentional. It leaves Anduril with total flexibility to reconfigure the space, allowing manufacturing managers to account for shifts in production volumes or product mix.

At the same time, the approach influences the design of Anduril's production system. In the absence of cranes, the Fury is guided through the first 13 stations of final assembly on specially made wheeled cradles. Landing gear and wheels would be installed on the Fury in Station 14, allowing workers to usher the aircraft through the next eight stages without cradles.

The production system is focused on keeping things simple. Automation is increasingly common among aerospace companies using smart manufacturing techniques, but Anduril plans to keep the Fury as manually built as possible as it attempts to scale up production, assuming it wins the contract.

"The fact is, it is generally easier if you train a human to go do something than to make the investment in facilities and equipment and everything for automation," Flynn said. "And so, quite often, we are trying to actually design products that don't require automation. I can always—as the volumes [grow], and it makes sense from a financial standpoint—I can always add automation."

In some cases, Anduril's production system adopts a measured approach to using new manufacturing tools. Full-size determinant assembly (FSDA) revolutionized automotive manufacturing with predrilling holes at the component level, which saves time in final assembly with the installation of fasteners. Aerospace manufacturers have adopted the practice widely on commercial and military aircraft, with mixed results. In some cases, struggles to implement the FSDA method on an aircraft's more advanced shapes and materials caused schedule delays and cost overruns.

By contrast, Anduril plans to take a slow approach to introducing FSDA techniques on the assembly line. Roughly one-third of the holes in the first lot of Fury aircraft would be predrilled, Flynn said. Application of the FSDA method could be expanded from there, starting with the simplest shapes in the structure and proceeding to more complex areas later.

# Europe Weighs Civilian Airlift Reserve To Speed Military Deployments

> EU DEFENSE AGENCY WILL LAUNCH AIRLIFT RESERVE STUDY IN MAY

> AIRLINES WOULD COMPLEMENT MILITARY AIRLIFT DURING CRISES

**Tony Osborne** London

Russian aggression and escalating global crises are prompting Europe to assess how it can react and deploy its military forces more rapidly.

Organic military transport fleets alone are no longer sufficient. The number of transport aircraft available to European air forces has declined since the end of the Cold War, and those that remain are in constant demand. As a result, European defense planners are considering whether the continent's many commercial airlines could help fill the gap.


Europe seeks its own version of the U.S. Civil Reserve Air Fleet so that it can respond more quickly to regional and international crises.

TECH. SGT. DONALD BARNEC/U.S. AIR FORCE

Inspired by the U.S. Civil Reserve Air Fleet (CRAF)—a voluntary program run by the U.S. Defense and Transportation departments that provides commercial aircraft during crises—the proposed EU Strategic Airlift Reserve would aim to bolster rapid deployment capabilities by supplementing existing and future military airlift assets with additional surge capacity.

Under the concept, European airlines would provide aircraft and crew for rapid airlift missions, reducing the need for governments to invest in more transport aircraft. This initiative is necessary because Europe faces a "strategic airlift gap," Michael Sylla, the European Defense Agency's (EDA) project officer for air transport, tells Aviation Week.

Europe's militaries already routinely charter civilian airlines to carry military personnel, but this approach can face "regulatory and availability hurdles," Sylla notes.

CRAF's last major activation was in 2021, when it helped evacuate U.S. and Afghan personnel and their families to the U.S. after the Taliban regained control of the country during the withdrawal of NATO forces. CRAF aircraft did not operate in Kabul but instead transported evacuees from interim staging bases after U.S. military aircraft had initially airlifted them out.

At the time, European countries were also able to charter civilian aircraft for evacuation flights, leveraging surplus airline capacity during the COVID-19 recovery period. Such availability, however, cannot be assumed in future crises. If there were a sudden deployment coinciding with the peak European summer travel season, for example, heavily utilized commercial aircraft could be less readily available for military charter.

The airlift reserve concept emerged in proposals for a military mobility initiative published in November by the European Commission as part of a wider series of proposals that aims to streamline the transport of military equipment and personnel across Europe.

European officials describe the mobility initiative as a "military Schengen." They assert that just as people can cross the open borders within the European Schengen Zone, EU militaries ought to be able to do the same, particularly if the need should arise to reinforce Eastern Europe.

Sylla says the initiative could "improve strategic airlift responsiveness across the EU [and] support rapid and scalable deployments, strengthening European resilience and coordination."

The EDA is preparing to launch a nine-month study in May to assess operational demand and identify capability gaps, Sylla says. It will also map industry interest and evaluate feasibility by consulting with airlines, cargo operators and leasing companies.

A key focus of the study will be to identify how to encourage airlines to take part; Sylla says incentives could include "contractual agreements, predictable activation procedures and potential financial or operational support." The U.S. CRAF program, for example, offers volunteering airlines preferential access to commercial peacetime cargo and passenger traffic contracts for the Defense Department.

The European airlift reserve would likely rely on a mix of civilian aircraft, including freighters and passenger aircraft capable of dual-use deployment.

When CRAF is activated, the fleets are coordinated by U.S. Transportation Command. With many more countries involved in Europe, command-and-control mechanisms have yet to be worked out, but this will be part of the study. Activating and coordinating the airlift fleet would follow established military mobility frameworks, Sylla says. One option could be to use European Air Transport Command, the Netherlands-based planning cell that has operational control over the air transport and aerial-refueling aircraft of seven European air forces, he suggests.

No timeline for the airlift reserve's formation has been set yet, but the study should provide a foundation for pilot testing and its implementation, Sylla says.

# American and United Prepare for Showdown in Chicago

> UNITED TO REACH 750 DAILY FLIGHTS FROM O'HARE THIS SUMMER

> AMERICAN IS RAMPING UP ITS OWN FLYING AT THE HUB, WITH NEW GATES IN HAND

**Lori Ranson** Washington and **Christine Boynton** Boston

American Airlines has marked the start of its centennial year by engaging in a high-stakes battle with United Airlines in the city where its first flight took off, Chicago.

"We've been flying to Chicago for 100 years . . . and it's going to be part of our system for the next 100 years," American CEO Robert Isom said during a Jan. 27 earnings call.

Fort Worth-based American "lost $500 million, even though [it] didn't start that really until May," United CEO Scott Kirby told investors on a Jan. 21 earnings call. "American—and we're pretty good at estimating this—is likely to push to about a billion dollars of losses in Chicago."

The comments come as American eyes a return to pre-COVID-19 pandemic levels of flying in Chicago, determined to regain a firmer foothold at the strategically important central hub. Despite the rhetoric from its rival, American is confident that the growth will pay off.

"It's going to be our third-largest hub," Isom said, noting a 20% increase in local customer mix and branded credit acquisitions. "We fully expect that Chicago will return to the profitability levels that we had been at prior to the pandemic. . . . We're doing all the right things."

Isom did not offer a time by when Chicago would return to profitability.

In 2024, American's capacity at O'Hare was down 25% compared with pre-pandemic levels, executives noted. Going forward, the carrier plans to achieve growth through new routes and extra frequencies—and with two new gates in hand, acquired from restructuring ultra-low-cost carrier Spirit Airlines late last year.

"American isn't likely to throw in the towel in Chicago anytime soon . . . if ever," JP Morgan analysts Jamie Baker and Mark Streeter wrote in a Jan. 21 investor note to clients. The analysis pointed to "offsetting and outsized" profit streams as supporting factors, including from American's other major hubs and lucrative loyalty programs.

BRIAN CASSELLA/CHICAGO TRIBUNE/ZUMA PRESS WIRE/ALAMY STOCK PHOTO

**Total departing system frequencies from Chicago's O'Hare International Airport are projected to increase nearly 17% year over year as of early July, CAPA data shows.**

But Chicago-headquartered United also has big plans for 2026. During the summer, the airline intends to operate up to 750 daily flights from its hub at O'Hare International Airport, surpassing American's plans to offer 500-550 in the same time frame.

American kicked off its expansion at O'Hare last summer, offering 20% more flights and 22% more seats—competitive activity United said cost its operation roughly $100 million in 2025.

While American prepares to ramp up in Chicago, United is ready to play both offense and defense.

"There's another wave of growth coming for that competitor," Kirby said. "[Later this year], they're going to win three gates back at our expense."

But in 2026, United is "drawing a line in the sand," he added. "We're not trying to win gates—we're going to add as many flights as are required to

make sure that we keep our gate count the same in Chicago."

However, United's expansion may indeed include new gates at O'Hare, since Spirit moved to divest two to the mainline carrier for $30.2 million. The transaction, announced Feb. 3, is still subject to approval from a bankruptcy court. United's growth will otherwise feature new service to small and medium-size cities as well as capacity increases to existing destinations big and small, said Patrick Quayle, senior vice president of global network planning and alliances.

"We're now reaching our highest-ever overall market share," Quayle said during a recent media briefing. "We have a 19-point advantage on Chicago-based customers." He also cited a 38-point advantage "versus our big competitor in corporate share."

With all the new capacity being deployed from O'Hare, an obvious question looms: Is there a risk of oversupply? CAPA – Centre for Aviation statistics show departing frequencies from the airport for the week of July 6 are projected to increase nearly 17% year over year.

"It's been a long time since we have witnessed a good, old-fashioned food fight like we are watching in Chicago," writes William Swelbar, chief industry analyst at the Swelbar Zhong Consultancy. "In some ways it is nonsensical—but the picture is bigger than Chicago, American and United. It is also about continuing to marginalize service from the value airline sector."

The battle for supremacy in Chicago "will result in some service that cannot be sustained," he adds. "But it will work to define one airline's comparative advantage in the nation's third-largest metro [area]" and place a direct shot at value airlines choosing nonhub airports "to serve a region in the name of serving an airport pair with no nonstop service."

In the mature U.S. domestic market, "every airport pair has competition—some direct, some indirect—and all have multiple connecting options for customers in all market areas to consider," Swelbar notes.

Against that backdrop, the domestic competitive marketplace is only becoming more difficult as the network airlines "fight for supremacy in larger markets that are necessary to make the value airline model work," Swelbar adds, "unless you are Allegiant and Sun Country."

# NOTCHING NICHES

> U.S. REGIONALS LOOK FOR OPPORTUNITIES IN A CHANGING LANDSCAPE

> AGING 50-SEATERS PRESENT A CHALLENGE TO GROWTH

> JSX'S PREMIUM TURBOPROP SERVICE LAUNCH WILL BE CLOSELY WATCHED

**Christine Boynton** Boston and **Lori Ranson** Washington

One of the most challenging corners of the U.S. airline industry—the regional sector—finds itself smaller and determined to prepare for what comes next at this midpoint in the 2020s.

The sector's large and small players alike face formidable hurdles: structurally higher costs, labor challenges and, at the very top, the lack of a near-term replacement for aging 50-seat regional jets. In addition to demand shifts in the wake of the COVID-19 pandemic, the general move to larger aircraft has made some routes unviable. Regional airlines took varying steps to react and adjust in 2025.

Preparing for the 50-seater replacement problem, SkyWest announced an equity stake in Maeve Aerospace, claiming exclusive launch customer rights for its planned hybrid-electric regional aircraft. To build scale, Republic Airways and Mesa Air Group merged, condensing an already narrowing field into fewer brands. For others, headwinds have proved too strong. After ending a capacity purchase agreement (CPA) with American Airlines last year, Air Wisconsin attempted a strategy shift but entered 2026 sold off to new ownership.

Today, the remaining smaller players are looking to carve out new opportunities. CommuteAir is a case in point. Founded in 1989, the carrier attributes its resilience and profitability first and foremost to an ongoing partnership with United Airlines, which owns 40% of the smaller airline. Beyond the flying it conducts exclusively as United Express, CommuteAir is evaluating what the future may hold—including potential for its own branded service.

"Overall, our strategy has been to really develop the business on behalf of United, but that has now allowed us to think beyond just one single source of revenue so that we can continue to develop," CEO Rick Hoefling tells Aviation Week. "There is a lot of ideation going on—a lot."

Hoefling notes that the company "has never been in better shape" financially. CommuteAir carries no substantial debt and can generate cash, he says, a firm footing that supports exploring future opportunities. "From an operational performance, it's just stellar," Hoefling adds. "If you look at United versus its competitors, CommuteAir has certainly helped carry some wind in that sail. We've been fortunate to be one of the top performers for United."

After transitioning to an all-jet fleet


**CommuteAir flies Embraer 145s for partner United Airlines and offers charter flying with one E170.**

in 2017, CommuteAir now operates 59 50-seat Embraer 145s for United. The carrier also boasts one E170 for charter service—a long-term investment as it considers operations for its mainline partner in the 2030s. Operating a new type enables it to develop capabilities and achieve necessary training and certifications for possible future scheduled service. While CommuteAir still anticipates "a long runway" for the aging E145s, "we're not going to wait and react," Hoefling says. "We want to be ahead of the curve . . . so we're thinking about what we want to do two, three, five, 10 years from now."

Beyond the one E170 operating charter service today, a recent agreement with Air Partner calls for up to six aircraft, and CommuteAir is looking at sourcing additional E170/E175s, Hoefling explains. The airline is also exploring providing third-party maintenance services to other carriers as it brings more capabilities in-house.

"One of the things I always worry about as a company is a single source of revenue, which is very good if it's under a CPA in the regional business," Hoefling says. "But the more things we can do in improving our revenue, [achieving] different vectors of income, I think that's a healthy thing for us to do. And by the way, it expands our capabilities, which can then be brought back into the United CPA to lower costs for the future."

Overall, CommuteAir aims to think more broadly about how it wants to position its business for the future. That may involve looking back to some of its past. Although demand has shifted toward larger jets, the former De Havilland Canada Dash 8 operator sees potential for reintroducing turboprops in the U.S. regional space.

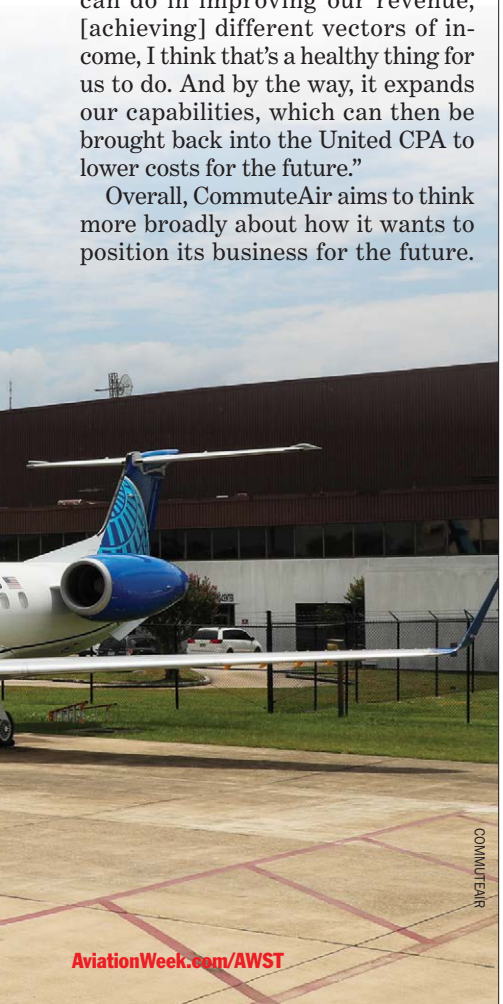
Inspiring this line of thinking is ATR's new 50-seat configuration. Tailored to the U.S. market, the layout features a triple-class cabin, a front passenger door compatible with airbridges and ample space for carry-on baggage. The turboprop airframer has been pushing to reenter the region, achieving a first step with the January launch of ATR 42-600 service by public charter operator JSX. The Part 135 carrier sees considerable potential for the offering to bring new routes within its scope (*AW&ST* Sept. 29-Oct. 12, 2025, p. 46).

CommuteAir also sees potential to support Part 121 operations, "which opens up more opportunities for either prorate service or codeshare, or things of that nature," Hoefling says. "Here in the U.S., we want jet service between small cities, but the reality is you can't do it with [Airbus] A220s, [Embraer] E195s or scope-limited 76-seaters. . . . I think props inevitably will have to come back into the space here in the U.S."

As CommuteAir looks to the future, it has hired revenue managers and network planners from several major U.S. airlines and continues analyzing network and fleet data. A shrinking regional airline industry creates more demand and more opportunity, Hoefling explains. Any evolution would likely start on a smaller scale as the carrier looks to create value but also manage risk, he adds.

One thing CommuteAir does not want is to do "what everybody else is doing," the CEO says. "We don't want to, for example, ever become a low-cost carrier and try to swim in that space" or operate larger aircraft like E195s or A220s. CommuteAir is exploring options with different airframers and seat manufacturers, Hoefling notes, and whatever the next step may be, premium will play a role.

"We don't have to have grandiose ideas to grow to 400 airplanes in a couple years, like some of these low-cost carrier aspirations," he says. "We can go in and do it at a slow pace, test markets, test capabilities, test aircraft and see how it goes. . . . [This year] is, I think, going to be a pivotal year for us, because it's going to help frame what's next for us in a more formal way."


COMMUTEAIR

## A PREMIUM TURN

GoJet Airlines is another smaller regional carrier has carved out a niche for itself. The airline operates premium Bombardier CRJ550s as United Express. United takes a slightly different approach with its regional partners than rivals American and Delta Air Lines, which both work with independent operators and have wholly owned regional subsidiaries. In addition to its 40% in CommuteAir, United purchased a small stake in Republic after it acquired Mesa last year.

"We've never been the largest carrier out there," GoJet CEO Rick Leach said at the RAA Leaders conference in September in Washington. But the airline "has always earned our . . . spot and seat at the table," he emphasized.

Leach, a U.S. regional airline industry veteran, explained that GoJet's major focus is executing its mission for United through operating the three-class CRJ550—a CRJ700 configured with 50 seats, including a first-class offering, 20 seats in Economy Plus and 10 in Economy. When United and GoJet debuted the aircraft in 2019, United CEO Scott Kirby declared that the "CRJ550 is going to give us a unique ability to compete for premium demand that none of our competitors have."

Rival Delta introduced the CRJ550 in 2024 with SkyWest, which now also operates the jets for United. GoJet, meanwhile, plans to expand its fleet of 58 CRJ550s this year and into early 2027, Leach said.

"The importance of the premium product and the experience of the customer is everything in our business today," he stated.

The CRJ700 airframes used for the premium CRJ550 aircraft are starting to approach their midlife, Leach said. He also noted that it is worthwhile to invest in the aircraft at this point to give them 30,000-40,000 more cycles.

While GoJet's immediate focus is sating United's "appetite for [the CRJ550]," the company is also engaging manufacturers on future aircraft technologies. "We've got to figure out how to solve for the retiring 50-seat fleet that has a major risk factor to reduce and possibly eliminate . . . access to air travel in a lot of communities around the country," Leach said. New equipment is needed to fill the void, but "the problem is some of

that is far into the future," he noted.

For now, ATR has the only product to address the gap, Leach said, adding that aircraft capable of rivaling turboprops are likely at least a decade away. But replacing a regional jet with a turboprop is not an apples-to-apples comparison, he explained, given aircraft range and the role of regional jets in airport banking structures. Additionally, Leach pointed out the predisposition to turboprop avoidance in the U.S. and that the ATR's sweet spot is 200-400-mi. stage lengths.

Largely, U.S. customers have known only "what we've conditioned them to know," he stated, which is the "regional jet experience connected with the mainline experience, at the end of the day. . . . I think we just need [customers] to experience the product, and then I think it will multiply."

The big test case for ATR is JSX's launch of premium service. The move is just in its initial stages, but JSX has a letter of intent to take up to 25 aircraft and plans to have four ATR 42s in service in the first quarter of this year.

Leach expects those operations will be watched closely, even though JSX's routes are point-to-point rather than part of a larger network. He said that the feedback from JSX's customers will be important.

Regional airlines need to work with their major partners in considering new aircraft technologies, he added. "They do guide us a little more than one would think," Leach stated. "Yes, we are individual companies, but they decide the demand and what's going to best meet their network needs."


# Regional Air Carriers Struggle To Keep Their Role in Europe

> COMPETITION FROM GROWING LOW-COST CARRIERS HAS STRONG CONSEQUENCES FOR THIN REGIONAL ROUTES

> AIR TRAFFIC CONTROL DELAYS HAVE DISPROPORTIONATE EFFECT

**Thierry Dubois** Lyon and **Helen Massy-Beresford** Paris

Regional air carriers in Europe face multiple challenges that collectively jeopardize the relevance of the segment.

The commercial air transport industry regularly must cope with problems that hamper demand or impede traffic. For regionals, competition from low-cost carriers (LCC) could be the tipping point, compounding existing issues, such as disproportionate air traffic control (ATC) delays and their consequences for regional operators.

Even before the COVID-19 pandemic and ensuing downturn, stagnating sales at the only remaining regional aircraft manufacturer in the 50-80-seat segment, Toulouse-based ATR, might have been a harbinger of decline. Recently, the predicament of regional carriers has been showing in languishing traffic and mushrooming business failures.

LCCs have long been the main driver of traffic growth in Europe, and they took the lead in the number of flights in

**European aircraft traffic grew 4.1% overall in 2025, but regional traffic declined 0.7%.**

2025, accounting for 35.4% of Eurocontrol-managed flights, compared with 34.7% for mainline carriers and 12% for regional operators. The regionals confirmed their predominance with expansion in central Europe and the Balkans.

Despite overall traffic growth in Europe, as the 4.1% increase to 11.1 million flights indicated in 2025, regional operators are seeing a discouraging evolution in their market segment. They recorded a 0.7% decline in traffic in 2025, European Regions Airline Association (ERA) Director General Montserrat Barriga said on Jan. 21 during a webinar organized by Eurocontrol.

The change in passenger types has been a factor. As remote working has spread, business travelers who used to fly frequently to company sites now often rely on video conferencing and need to make fewer trips. Moreover, their employers must set carbon reduction targets, which leaves less room for air travel. Regional carriers have found the recasting unfavorable: Business travelers typically pay higher fares because they value flexibility.

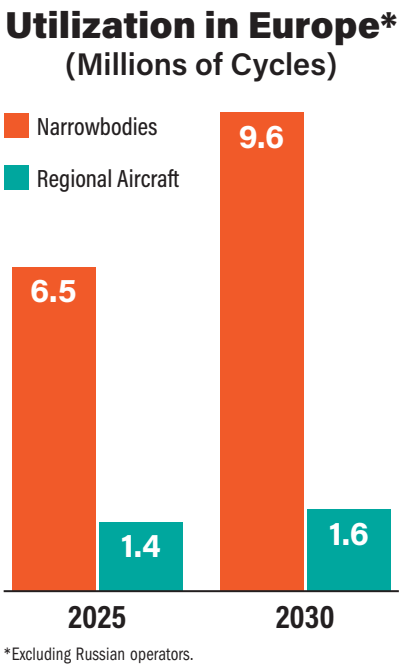
The growth in other passenger types—such as those traveling for leisure or visiting friends and families (VFR)—may offset the business travelers' decline in gross numbers, but it also introduces a vulnerability. When an LCC creates a new route between two European cities, it may be content with a frequency of twice a week. A regional carrier's preexisting daily link may remain relevant in theory, but it

may not survive the LCC's lower prices.

For example, leisure and VFR passengers usually are happy to trade greater choice for cheaper flights and therefore opt for the LCC instead of the regional carrier, Altair Advisory Managing Director Patrick Edmond says. Moreover, the number of passengers ready to pay more for a daily flight has been decreasing with the number of business travelers, he stresses. That scissors effect quickly jeopardizes the regional carrier's business case on the route.

As regionals operate more flights but fewer that are connecting, the ERA is not admitting defeat. "We need to investigate further into why," Barriga said. "Some Eurocontrol member states introduced national taxes, that is key, and [now they may get] the message they should not do that on thin routes." The decline is affecting connectivity for those living in remote regions that have no other viable transport, she emphasized.

The ERA also has been vocal about the effect of ATC delays. The lobbying group saw improvements in 2025, especially in ATC capacity planning in southwest Europe. Nevertheless, ATC delays decreased only 1% for regional traffic, a frustrating number compared with a 14% improvement on average. Regional carriers often serve major hubs, meaning they are more exposed to delays, Edmond says.



*Excluding Russian operators.

*Source: Aviation Week Fleet Discovery*

Delays have a deeply negative effect on regional operations. The duration of a regional flight is shorter, and a crew flies up to six sectors per duty period, so a 20-min. delay can cause a flight cancellation, Barriga explained. "We want our members to be able to operate at full capacity in the peak season," she said.

As a result, the regional industry is seeing more insolvencies than other segments in the European commercial air transport industry. For instance, two regional airlines in the UK, Blue Islands and Eastern Airways, ceased operations late last year, prompting the head of Glasgow-based regional airline Loganair to warn that the cost of some UK domestic flights is nearing the point where passengers will find them unaffordable.

"There's a price point that people aren't prepared to pay for UK domestic flights," but unfortunately, tickets seem destined to become more expensive, Loganair CEO Luke Farajallah said Dec. 10 at the Aviation Club UK luncheon. Higher expenses, such as bureaucratic costs, have a harsher effect on regional companies due to their smaller size.

A case in point is struggling Greek airline Lumiwings, which ceased operations in October following a court case that ordered its sole operational aircraft, an Embraer 195, to be returned to lessor Azorra.

SUSTAINABILITY

# Research Highlights Important Efficiency Role in Decarbonization

> STUDY HIGHLIGHTS EASY WAYS TO CUT AIRCRAFT EMISSIONS

> ALL-ECONOMY LAYOUTS, GREATER PASSENGER LOADS COULD HELP

**Helen Massy-Beresford** Paris

**FOCUSING ON POLICIES** that drive efficiency in the world of aviation could reduce fuel use without limiting air transport capacity, researchers at the University of Oxford say—but airlines do not agree with all of their efficiency-boosting suggestions.

"Efficiency-focused policy could swiftly reduce fuel use without limiting air transport capacity," states a new research paper on global aviation emissions coauthored by researchers at the University of Oxford.

When it comes to improving airspace management in Europe, airlines are sure to agree—for many years now, they have been calling for far-reaching reforms to airspace management. Reforming European airspace for more efficiency could lead to fuel savings of around 10%, they assert, but while reform plans have been edging forward, airlines say progress is not fast enough.

Some of the efficiency-boosting scenarios outlined in the paper, published Jan. 7 in *Nature Communications Earth & Environment*, are likely to be less appealing to an industry struggling with historically thin margins and already concerned about the additional costs of decarbonization on profitability—not to mention its vociferous condemnation of any new attempt to tax the sector.

The research found that global aviation emissions could be reduced by 50-75% through combining three strategies to boost efficiency: flying only the most fuel-efficient aircraft, switching to all-economy-class layouts and increasing passenger loads.

"While technological advances attract attention, operational efficiency across aircraft, airlines, airports, city pairs and regions remains underexplored," the researchers write.

The paper assessed carbon dioxide ($CO_2$) efficiency for 27.5 million flights between 26,156 city pairs in 2023, using data from Airline Data, the International Civil Aviation Organization and the International Air Transport Association (IATA). The results showed wide variation: 32-890 grams (1.2-31.4 oz.) of $CO_2$ per revenue passenger kilometer across routes and 60-360 grams

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

of $CO_2$ per revenue passenger kilometer across aircraft models.

Globally, average aviation emissions were 84.4 grams of $CO_2$ per kilometer for each paying passenger in 2023. The study identifies three practical levers to reduce this figure: operating only the most fuel-efficient aircraft, removing premium-class seating to carry more passengers and raising passenger loads.

Aircraft model alone was found to make a substantial difference. According to the analysis, replacing all aircraft with the most efficient models—the Boeing 787-9 for long-haul operations and the Airbus A321neo for short- and medium-haul trips—would result in fuel savings of 25-28%, the researchers write.

IMAGEBROKER.COM/ALAMY STOCK PHOTO

European airlines see a need for more efficient airspace.

The paper's findings show that increasing passenger numbers to the maximum seating configuration for the most efficient aircraft would reduce emissions 22-57%. Increasing average occupancy to 95% would further reduce emissions by 16%, the researchers add.

If these three measures were applied globally, emissions could be reduced 50-75%, the report states. That would require systemic changes, but airlines could reduce emissions about 11% right now by flying their most efficient aircraft on routes where they already operate, the authors add.

"Efficiency-based policies have a great potential to curb aviation emissions and can be in airlines' own economic interest," Stefan Gössling, lead author of the study and a professor of tourism research at Linnaeus University in Sweden, said in statement that coincided with the report's publishing. "But the reality is that many airlines continue to fly with old aircraft, low passenger occupancies and growing proportions of premium-class seating."

Many airlines hold up their fleet renewal programs as a big part of the answer to reducing their environmental impact—like Air France, whose current fleet comprises 45% new-generation aircraft, with a target of 80% by 2030.

But the all-economy layouts proposed by the researchers—who note that business- and first-class seats can generate up to five times as much $CO_2$ as economy seats—are unlikely to be something airlines will welcome. Many are prioritizing boosting premium revenue as a key part of their strategy—airlines such as Air France, which last year began rolling out its revamped first-class product, or United Airlines, whose new Boeing 787-9s will feature 99 premium seats, about 45% of the total seating capacity.

At an Air France-KLM event in Paris on Jan. 21, KLM CEO Marjan Rintel also spoke out against moves to impose more taxes on the sector. "Dutch-only measures, such as reducing [Amsterdam Airport Schiphol's] capacity, higher aviation taxes and increased airport fees, put our competitive position at risk," Rintel said.

"Research shows that when prices rise, people simply shift to other airports in other countries across the borders, undermining our connectivity and hurting the Dutch economy," she said. "There is little value in having the cleanest and quietest aviation if passengers no longer choose or cannot afford to fly with us."

However, some countries are actively supporting efforts to impose higher taxes on aviation, with a particular emphasis on premium travel.

Last year, a group of countries formed the Premium Flyers Solidarity Coalition to push for taxation for premium flights. Barbados, Djibouti, France, Kenya and Spain are among members of the coalition, and while the idea seemed to be gaining some momentum last year—especially when French President Emmanuel Macron spoke about it at the COP30 climate conference in Brazil—airlines are predictably opposed.

"In practice, these levies don't directly lead to emission reductions, and [they] risk counterproductive effects for developing economies and small island states," IATA said in November. "Increased taxation on air travel threatens connectivity, distorts competition and ultimately undermines social and economic development in the regions most reliant on aviation as a lifeline."

Air France, which is rolling out its La Premiere first-class product on a growing number of routes—with services to Tokyo and Abidjan, Ivory Coast, set to be next—sees premiumization as an important tool in its strategy.

Governments seeking to introduce a premium flight tax will face fierce opposition from airlines, which would argue that such measures could undermine their capacity to invest in newer, more efficient aircraft and jeopardize connectivity and economic growth.

But the authors of the study are clear: With sustainable aviation fuel still scarce or too expensive, e-fuel not yet a reality and hydrogen-based research slipping in manufacturers' timelines, "efficiency gains will be an important pillar of any decarbonization strategy for the sector."

Milan Klöwer, a coauthor of the report and research fellow at the University of Oxford, said: "Our results clearly show that efficiency-focused policy could swiftly reduce aviation emissions by more than half, without reducing flight numbers or waiting for future fuels. These are tools that we can use right now."

The researchers suggest that efficiency improvements could be promoted using policy tools and market-based measures, such as emission ratings for airlines, adjusted landing fees based on aircraft performance and carbon intensity caps.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# Flow Control

- NEW NASA DESIGN METHOD COULD FINALLY UNLOCK LAMINAR FLOW POTENTIAL
- TEST CAMPAIGN INCLUDES EIGHT DATA-COLLECTING FLIGHTS
- REDESIGNED CONFIGURATION SHIFTS WING PRESSURE DISTRIBUTION


CHRISTOPHER LC CLARK/NASA

**Guy Norris** Colorado Springs

The untapped efficiency benefit of maintaining smooth natural laminar flow over the swept wings of jet airliners has been known for decades, but a practical breakthrough toward achieving this goal has been elusive.

A recent NASA-developed design method, dubbed CatNLF, for crossflow attenuated natural laminar flow (NLF), could be a major step forward. The agency is starting flight tests of a representative stub wing section designed using CatNLF that, if successful, could help unlock fuel-burn savings of 10% or more on large transport aircraft.

NLF can reduce aerodynamic skin-friction drag, the biggest source of drag on an aircraft, by up to 50% on wing and tail surfaces. An associated reduction in profile drag could add further efficiency gains.

But without complex, heavy flow-control systems, laminar flow is challenging to implement on swept wing airliners primarily because the spanwise airflow along the wing leading edge destabilizes the thin boundary layer near the wing surface and triggers turbulent flow.

To combat this effect, known as crossflow transition, the CatNLF design method changes the shape of the airfoil to delay the transition to turbulent flow. The revised geometry alters the pressure distribution around the leading-edge region to dampen crossflow instabilities while maintaining the required aerodynamic performance.

This concept was developed computationally in the 2010s at NASA Langley Research Center, and it was evaluated in 2018 on the 5.2%-scale semi-span Common Research Model (CRM) in the National Transonic Facility wind tunnel. Tests validated the CatNLF method and showed laminar flow on 56% of the upper-wing surface at Mach 0.86, yielding a 7% drag reduction compared with the baseline turbulent CRM.

The Langley tests showed laminar flow extents nearly double the historic maximum for comparable wing sweeps in the high 30-deg. range. Researchers expected further improvements in flight tests, in which higher Reynolds numbers could be achieved than in wind tunnels. The Reynolds number predicts flow patterns and determines whether a fluid flow—in this case, air—is laminar or turbulent.

**High-speed taxi tests with the CatNLF wing were completed on Jan. 12.**

The test campaign at NASA's Armstrong Flight Research Center (AFRC) is the culmination of the program that included preparatory flight tests of an improved laminar flow detection system in 2019 and flow environment experiments beneath a NASA Boeing F-15B research aircraft in 2023.

For the final phase, the stub wing test article is mounted directly beneath an F-15B. With a root chord of 73.4 in., a tip chord of 60.9 in. and a span of 40 in., the test article has a planform area of 19.7 ft.$^2$ and a leading edge sweep angle of 35 deg.

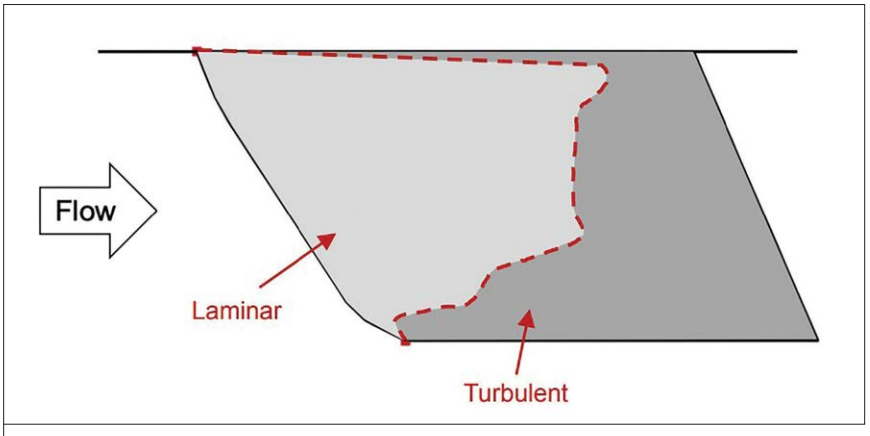
Since the test article represents a wing, the unit is mounted on the centerline instrument panel (CLIP) of the F-15 at an incidence angle of 8.5 deg. to provide a lift coefficient of about 0.5. "The test article has about 1 deg. of twist variation between the root and the tip [approximately 7.5 deg. at the tip] to smoothly reduce the sectional loading toward the tip," Mike Frederick, CatNLF coprincipal investigator at AFRC, says.

Predicted to support laminar flow

on approximately 53% of the suction side of the wing in flight, the "airfoil sections feature a smaller leading edge radius to provide a rapid acceleration of the flow for crossflow attenuation while also keeping the attachment line Reynolds number within established limits to maintain a laminar attachment line," Frederick says.

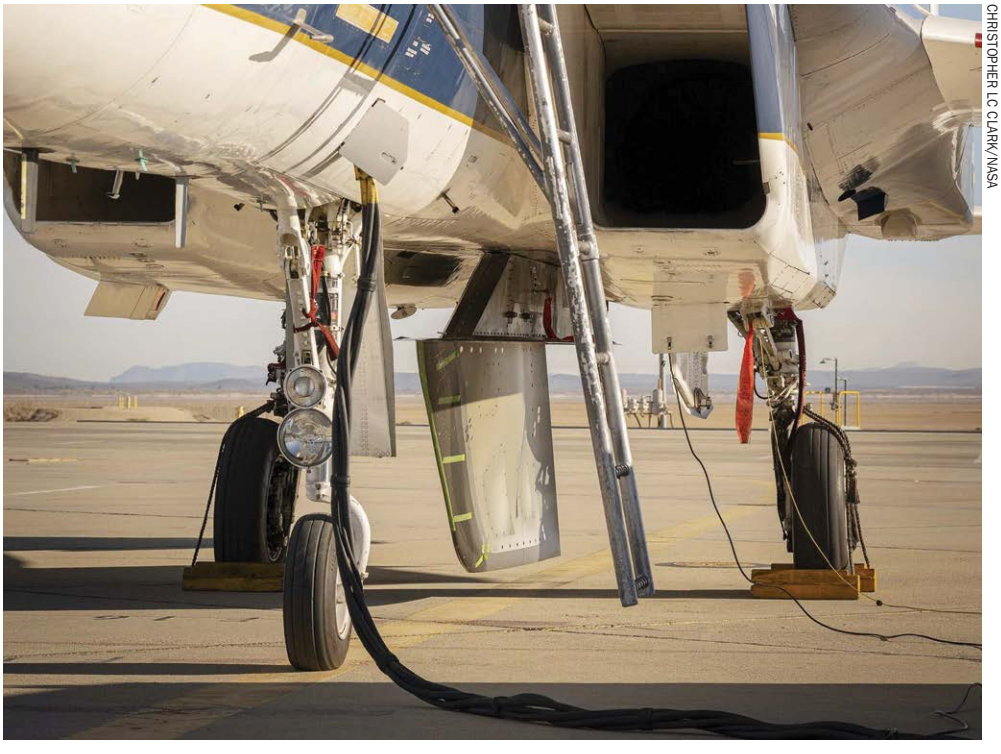
Although the inboard airfoil section is designed to maximize laminar flow extent to where it would naturally transition to turbulent flow due to the shock, Frederick says the outer portion of the span is shaped to demonstrate how CatNLF might control the development of Tollmien-Schlichting (T-S) waves. These are streamwise instability waves caused by adverse pressure gradients that trigger a transition from laminar to turbulent flow around mid-chord.

The test section also incorporates a reduced leading edge sweep at the root where it attaches to the CLIP beneath the F-15B. "This is used to relaminarize the turbulent attachment line coming from the turbulent boundary layer on the underside of the CLIP [to prevent] a turbulent boundary layer on the test article from the get-go," Frederick adds.



NASA

**The stub wing is predicted to support laminar flow on approximately 53% of the suction-side surface area in flight under the F-15B.**


CHRISTOPHER LC CLARK/NASA

**The experimental stub wing section is mounted at a slight angle on the F-15B's centerline instrument platform.**

Even if laminarity can be achieved, it is notoriously hard to sustain. "We plan to explore how off-design conditions affect laminar flow extents," says Lewis Owens, CatNLF physics investigator at Langley. "How sensitive is this laminar flow shaping design to leading edge surface roughness changes? We created various 2D arrays of surface roughness elements to be temporarily applied to the wing leading edge to test the laminar flow sensitivity to increased surface roughness levels.

"Another important question to ask is, 'Can we restore the laminar flow lost at off-design conditions?'" Owens adds. "We developed discrete roughness elements—linear arrays with various heights and spacings predicted to stabilize boundary layer disturbances to maintain laminar flow for longer extents. Answering these questions will help us understand challenges of maintaining laminar flow for this type of wing design."

Initial high-speed taxi tests with the stub wing attached were completed in mid-January to check for potential sideload issues. None were found, so initial flight tests will focus on envelope expansion for structural dynamics purposes, Jack Ly, subproject manager for CatNLF at Armstrong, says.

"Because it's a wing, there are some concerns about flying at particular altitudes because of the maximum dynamic pressure," Ly says. "We'll aim for an altitude of approximately 30,000 ft., and then we'll drop down from there, increasing the dynamic pressure so that we can clear the test article before we gather any flight data or test condition data for the researchers."

Following two planned envelope expansion flights, the CatNLF campaign is expected to include about eight more flights. Test goals include acquiring data at Mach 0.85 at altitudes of 5,000-49,500 ft.

# Otto Aerospace Begins Slotted Natural Laminar Flow Wing Tests

- INITIAL ICING TESTS ARE UNDERWAY
- FULL AIRCRAFT WIND TUNNEL TESTS ARE PLANNED BY YEAR-END

**Guy Norris** Colorado Springs

As NASA evaluates natural laminar flow for potential application on future commercial airliners, business jet developer Otto Aerospace is relying on another form of this drag-saving phenomenon for its pioneering Phantom 3500.

Aiming to exploit the aerodynamic benefits of a slotted natural laminar flow (SNLF) wing, Otto plans to develop a midsize aircraft with the range and performance of a super-midsize jet but the operating costs of a light jet.

GUY NORRIS/AW&ST

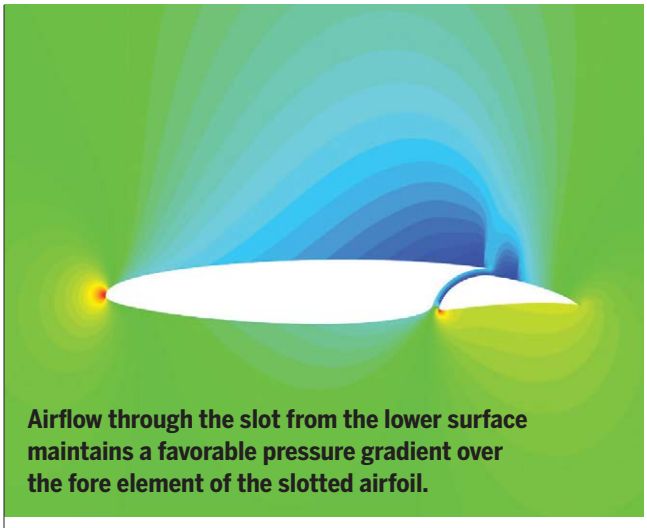

**Doubling as the hinge line for trailing edge flaps and ailerons, an open slot extends from the Phantom 3500's wing root, designed to enable natural laminar flow across most of the airfoil.**

While much of the reduced drag benefit will come from the Phantom's lozenge-shape fuselage with smooth skin contouring, the primary performance improvement is focused on the modestly swept 64-ft.-span wing.

Most conventional airfoils on subsonic business jets typically transition from laminar to turbulent flow over 5-20% of the wing chord, while NLF designs like HondaJet's can extend this to more than 40% on the upper surface and over 60% on the lower. The larger the percentage of laminar flow, the lower the overall drag and the better the performance.

Similar to earlier SNLF wings studied by NASA for potential applications, including the shelved transonic truss-braced wing full-scale demonstrator, the Otto airfoil is made up of two parts: forward and aft sections separated by a slot that runs for almost the full span from the wing root to near the tip. Air flows up through the slot from the higher-pressure lower surface of the airfoil, reenergizing the flow toward the trailing edge of the fore element and stabilizing the boundary layer.

NASA



**Airflow through the slot from the lower surface maintains a favorable pressure gradient over the fore element of the slotted airfoil.**

As a result, the boundary layer restarts on the aft element, which has a much shorter chord. The pressure gradients are adequate to maintain laminar flow to beyond mid-chord on the upper surface, similar to a conventional airfoil. But now the turbulent flow is confined to a much smaller percentage of the total airfoil system.

The SNLF design theoretically allows the fore element of the airfoil to be entirely laminar on both its upper and lower surfaces, while scaled tests of a similar design by NASA in 2022 showed the aft element achieved 60% laminar flow on the upper surface and 100% on the lower. As a result, the entire SNLF airfoil can potentially reach about 90% laminar flow.

"We have a transonic swept wing that has 85-90%-plus laminar flow coverage on the top and bottom surfaces," Otto President and Chief Operating Officer Scott Drennan says. "We're going to really be the first transonic aircraft to capture this much laminar flow. The real beauty of the slot, in addition to the laminar flow, is it creates a very simple hinge mechanism for the flaps and the ailerons. All the actuation is embedded in the aft cove and in the wingbox."

Following earlier low-speed wind tunnel tests at Wichita State University and high-speed tests of a 10th-scale model in the European Transonic Wind Tunnel, Otto began follow-up campaigns for icing in January at Cox & Co.'s LeClerc Icing Research Laboratory in Plainview, New York.

Otto plans to conduct a low-speed wind tunnel test at the National Institute for Aviation Research in Wichita in mid-2026 and a series of high-speed handling-qualities wind tunnel tests by year-end.

To ensure production quality and the smooth surface finish that is critical to achieving laminar flow, Otto plans to use an out-of-autoclave, net-shape resin transfer molding process for manufacturing composites. Leonardo will make the fuselage, while Belgian company Sonaca will make the wing.

Aircraft level preliminary design review is expected in February, and the assembly of the first of four prototypes—FTV-1—is due to begin this year at Otto's new Cecil Airport facility in Jacksonville, Florida. First flight is scheduled for 2027, followed by certification in 2030 and service entry shortly after.

# MOVING TARGETS

- PRODUCTION RATE INCREASES FOR SINGLE-AISLE AIRFRAMES KEEP PRESSURE ON ENGINE-MAKERS
- FACILITY AND AFTERMARKET INVESTMENT UNDERPINS CFM AND PRATT ENGINE CAPACITY BOOST
- SUPPORT FOR THE SUPPLY CHAIN IS ALSO VITAL, GE CEO ACKNOWLEDGES

**Guy Norris** Colorado Springs

Engine-makers have struggled for more than five years to keep pace with the delivery demands of the commercial aircraft-makers, particularly in the single-aisle sector, where production rates continue to accelerate.

Blamed by Boeing and particularly Airbus for slowing aircraft deliveries, CFM International and Pratt & Whitney have invested heavily in ramping up production capacity—a cost that has been compounded by dealing simultaneously with durability upgrades.

Much of this investment is paying off and supply chains are strengthening, so engine-makers are seeking a better relationship with airframers in 2026. CFM, the GE Aerospace and Safran joint venture, appears confident that it will reach its long-established target of producing 2,000 Leap-1 engines this year. Pratt, however, acknowledges challenges as it battles to catch up with Airbus and Embraer demand for its PW1000G geared turbofan (GTF) family.

Both engine-makers are working to future-proof production and overhaul capacity for delivery rates beyond 2026 that would have seemed mind-boggling just a decade ago. As Boeing shapes up for relatively short-term plans to boost 737 monthly production rates to 57, and Airbus aims for an even more ambitious 75 A320s per month, engine-makers are bracing for a potential combined tally of almost 3,200 units per year—not counting production for Embraer, Comac and spares.

And demand is expected to increase for the successors to today's narrowbody aircraft. As part of preparations for its Next-Generation Single Aisle, for instance, Airbus has outlined an industrial supply line that can support production rates of 1,000 aircraft per year.

For now, CFM and Pratt are set for a record year of production and deliveries in 2026. CFM, which is eyeing annual production of up to 2,500 Leap engines by 2028 based on current airframe delivery skyline trajectories, is on track to continue investing in baseline production, primary suppliers and supporting maintenance, repair and overhaul (MRO) facilities. GE is also invoking a set of key organizational changes which, along with further evolutions of its Flight Deck lean operating system, are designed to smooth the path forward.


GUY NORRIS/AW&ST

Boeing aims to ramp up production of CFM Leap-powered 737s in the near term to 57 a month from 42.

## CFM INTEGRATION PLANS

"We partnered more effectively with our suppliers," GE CEO Larry Culp said on the company's 2025 fourth-quarter earnings call on Jan. 22, "resulting in material input from our priority suppliers growing over 40% year over year in 2025 and up double digits sequentially in the fourth quarter, both translating to higher outputs.

"While we're making progress, we know our customers need more from us," Culp continued. "To further accelerate our progress in 2026, we're expanding Commercial Engine Services to include [Technology and Operations], now led by Senior Vice President and Chief Technology and Operations Officer Mohamed Ali.

"Integrating our product line, engineering and supply chain teams will improve our end-to-end engine lifecycle management," Culp added. Together with other changes, the more streamlined organization "will enable greater cross-functional problem-solving, agility and alignment to deliver for our customers," he said.

While precise production numbers are closely held, Aviation Week Fleet data projects that CFM will target deliveries of some 1,900 Leap-1s to Airbus

AIRBUS

**Airbus is targeting production of 75 A320neo-family aircraft a month, split between those powered by CFM Leap and Pratt & Whitney GTF engines.**

and Boeing as well as more than 100 other units for spares and the aftermarket. Of the new-build production engines, more than half are destined for Boeing's 737 lines in Renton, Washington—and a few are also likely to be mounted on initial aircraft running through the company's new "North Line" in Everett, Washington.

The bulk of the Boeing tally, around 790 Leap-1Bs, is expected to equip 737-8s; 106 engines are forecast for 737-9s. Boeing says about 30 737-10s are also due to be assembled, but not delivered, this year, requiring 60 engines—slightly higher than Aviation Week's forecast of 54. Another 154 engines are expected to be delivered for the 737-7, certification of which is likely by year-end, along with the stretched -10. Thirty-two engines are set for delivery to power 737 MAX 8-200s.

Deliveries to Airbus, where CFM competes with Pratt on the A320neo family, are forecast to reach up to 720 Leap-1As, with the bulk—some 378 units—destined to power A321neos. Airbus is expected to receive 326 engines for the A320neo line and 16 for the A319neo. In addition, the forecast calls for delivery of some 38 Leap-1Cs to Comac for the slowly accelerating C919 production line in China.

Although new engine production for the aircraft-makers remains a priority, GE recognizes that support of the supply chain is vital for all outlets—be it for baseline production, aftermarket support or the intimately linked MRO network. "From a new-make perspective, the supply chain that supports the new-make also supports the aftermarket," Culp said. "So no one can really isolate the new-make demand and invest for that without being mindful of the aftermarket demand as well."

The focus for the MRO network is on "removing waste to improve shop visit output and turnaround times," Culp said. "For example, we're converting from batch to flow production, which supported Leap, CFM56 and GE90 turnaround times, improving over 10% year over year in the fourth quarter."

GE's Celma facility in Petropolis, Brazil, turned engines around in less than 80 days in 2025. "This enabled us to deliver our highest Leap shop visit output of the year," Culp said. "With the Leap installed base expected to roughly triple between 2024 and 2030, we're expanding capacity across our global MRO network to support aftermarket demand." Additional sites added to the MRO network in 2025 included MTU Maintenance Dallas.

"We're dedicating approximately $500 million of our more than $1 billion of investment in MRO to Leap," Culp noted. "This includes expanding several MRO sites, including Malaysia, Celma and Dallas, and a new on-wing support facility in Dubai. We expect these investments will roughly double Leap internal capacity."

## PRATT'S BALANCING ACT

Pratt & Whitney, meanwhile, continues to face an uphill battle as it builds up PW1100G production capacity to meet Airbus' delivery demands. Although the number of "gliders"—as Airbus calls completed A320neo-family airframes without engines—is slowly diminishing, tensions clearly remain between the European airframer and Pratt.

Outgoing Airbus Commercial Aircraft CEO Christian Scherer noted in January that engines for the A320neo family continued to arrive "very, very late" in 2025. "We see that this trend continues in 2026 and, in particular, with Pratt & Whitney, with whom we are still in discussions," he said. "It is an issue that we need to resolve."

Scherer also said that, as of mid-January, Pratt parent company RTX and Airbus have yet to agree on the supply of GTFs for the foreseeable future. "All the other engine situations are, so far, under control and satisfactory," he said. At one point in mid-2025, Airbus had 60 gliders awaiting engines, but that is now at a low, manageable number, he said.

According to Aviation Week Fleet data, Pratt is forecast to deliver about 554 PW1100Gs to Airbus for the A320neo family in 2026, the bulk of which—some 462 units—will be destined for the A321neo and 92 for the A320neo. Pratt is also the exclusive engine provider to Airbus on the A220 and is expected to deliver around 182 PW1500G engines this year, 172 of which will power the A220-300 and 10 the A220-100.

Production of the PW1900 for Embraer's E-Jet E2s also continues to ramp up, with Pratt forecast to hand over some 76 units to the Brazilian company in 2026. Of these, about 10 are expected to power the E190-E2, and 66 are destined for the larger E195-E2 assembly line.

Challenged on multiple fronts as part of its recovery from production delays, the repercussions of parts made from flawed powdered metal and a series of considerable durability issues, Pratt is in for a busy year—particularly at Airbus, where it is due to support the service debut of its newly certified PW1100G GTF Advantage engine in the coming months.

"We have begun production cut-in of the Advantage engine and expect entry into service later this year, along with certification and first installations of the associated Hot Section Plus upgrade package for MRO customers," CEO Chris Calio said on the RTX fourth-quarter earnings call. "We're also progressing on our strategic partnerships."

Calio also reiterated the pivotal role being played by the company's expanding MRO network to reduce the number of A320neo aircraft on ground (AOG) awaiting refurbished engines. "PW1100 AOGs declined in the fourth quarter, and we expect this trend to continue as we move throughout the year," he said. "MRO output was up 39% in the fourth quarter and up 26% for the full year, even as heavier shop visits increased 40% in 2025."

To bolster its recovery plan for AOG, which have declined 20% from the peak in 2025, Pratt also announced that the Sanad Group in the United Arab Emirates and Spain's ITP Aero are joining the GTF MRO network. "We expect this momentum to continue in 2026, with year-over-year growth in PW1100 MRO output in line with what we saw in 2025," Calio said. "To support our operational growth, we continue to make significant investments in capacity and technology."

Pratt's new engine production, meanwhile, was up 26% in 2025. "That was with heavier shop visits increasing 40% year over year," Calio added. "So a really good improvement in the shops."

Like CFM, Pratt faces a production balancing act when it comes to delivering new engines to Airbus and Embraer versus supporting the in-service fleet and reducing AOG numbers. "We think we've put together a plan that does just that," RTX Chief Financial Officer Neil Mitchill said. "So we will see continued growth on the MRO side at Pratt that will support the GTF aircraft in particular. And the rest will go between Airbus and spares."

Gearing up for the longer term, Pratt also has "key investments coming online over the next 24 months," Mitchill said. These include new powdered metal facilities, a new forging press and additional turbine blade production capacity at the company's recently opened site in Asheville, North Carolina. In addition, Pratt is developing a casting foundry—the main material effects of which are likely to be felt in 2028-29. "We're 100% in support of continuing to drive deliveries on the program over the long term because the backlog is there and the customer demand is there," he added.

# FLYING UL

- AVIATION WEEK FLIES IN ELECTRA'S EL2 TECHNOLOGY DEMONSTRATOR
- ELECTRA WANTS TO REDEFINE REGIONAL AVIATION
- EARLY CUSTOMERS SEE POTENTIAL IN ULTRA-STOL

**Graham Warwick** Manassas, Virginia

Flying in Electra's bright yellow EL2 technology demonstrator proved to be both dramatic and not.

It was undramatic because taking off with a ground roll of less than 150 ft. on the power of eight electric propellers entails less noise and vibration than expected. It was dramatic because in a mere moment, the ground is 100 ft. below us. Within seconds we are airborne and in an elevator-like climb out of Virginia's Manassas Regional Airport.

Landing in less than 150 ft. is a bit more striking, largely because you have time to stare at the strip of mown grass in a farmer's field on which you are about to touch down. But even with a relatively steep glideslope of 6 deg., at an approach speed of 35 kt. the drama is muted.

After my flight in the EL2, I sat in the spacious nine-passenger cabin of the full-scale "glass airplane" mockup of Electra's planned production EL9 and reflected on the potential of combining that relative lack of drama with a sophisticated passenger experience to unlock "direct aviation."

This is Electra's term for reimagined regional aviation, where small aircraft connect airports small and large and provide a new level of accessibility to air transportation by operating not only from underused runways, but also taxiways, ramps and even heliports and parking lots.

Direct aviation is empowered by Electra's core technology—ultra-short-takeoff-and-landing using blown lift enabled by hybrid-electric distributed propulsion. Christened the Goldfinch, the pint-size EL2 was built to validate that technology and answer key questions posed by both Electra and its customers.

Electra has rebranded the capability, originally termed electric short-takeoff-and-landing (eSTOL). "We don't talk eSTOL because this is not STOL—this is Ultra Short," CEO Marc Allen says. "The difference in performance capabilities is so vast, it's the equivalent of calling a STOL airplane

# TRA SHORT


Electric propellers blow over the EL2's wing and flaps to increase lift coefficient and reduce takeoff and landing distances. Inset: Aviation Week Executive Editor for Technology Graham Warwick at the controls.

ELECTRA.AERO PHOTOS

a conventional airplane. We're talking 150-ft. takeoff and landing rolls for a nine-passenger airplane. STOL in that category normally means 800-1,000 ft.—eSTOL mischaracterizes what we're doing."

Ultra-short performance tackles what Electra views as the greatest constraints on the air transportation system—airspace, gate space and ramp space. "If you can deliver ultra-short capability, you can now enter into the airspace on helicopter routes," Allen says. "You can land not on runways, but rather ramps and taxiways, and you can address gates by using courtesy vehicles.

"What earns us the right to fly into a large commercial airport with a fixed-wing propeller aircraft and land not on a runway?" he asks. "The only thing that can earn us that right is demonstrated ultra-short performance with robust safety margins. We must demonstrate that we have roll and yaw control at super-low speeds, and we've flown [the EL2] slower than 20 kt."

First flown in November 2023, the demonstrator has a modified Cessna 172 wing, with eight electric-powered propellers mounted under a reprofiled leading edge so their slipstream flows back over the wing and blows large, double-slotted flaps and drooped ailerons to increase lift coefficient.

The two-seat demonstrator's purpose-designed composite fuselage has a turbogenerator in the nose, liquid-cooled battery packs under the floor with radiators on the sides, and a large T-tail to counteract the pitching moment generated by blowing the wing.

Blowing increases the airspeed experienced by the wing, but the biggest lift augmentation comes from the large flaps turning the flow. Blowing adds energy to the wake coming off the trailing edge and creates a jet flap that continues downward, like a flap extension. Essentially, the airflow sees a bigger wing. This effect strengthens as speed decreases and diminishes as speed increases and flaps are raised. This allows for a normal-size wing in cruise to

reduce drag and helps dampen the effects of turbulence.

The EL2's donor 172 wingbox has a break at about two-thirds span and is tapered outboard, so the outer pairs of propellers are smaller to avoid overblowing the outboard sections. All eight propellers are powered by the same MAGicALL motors. On the production EL9, all eight propellers will be identical.

The EL2's four inboard propellers blow the double-slot Fowler flaps that generate the majority of the lift augmentation. The four outboard propellers blow the drooped ailerons, which open a slot as they extend. Aileron and rudder deflection are coupled to propeller speed to augment roll and yaw control.

Inboard flaps have low-bandwidth actuators for drag control on takeoff versus landing. Ailerons are controlled by the pilot's yoke for high-bandwidth authority. Blowing the wing and producing a jet flap moves the center of pressure aft and causes a nose-down pitching moment. To maintain stability, the horizontal tail includes a high-lift slot.

The EL2's series hybrid-electric propulsion system is built around a 100-kW turbine engine based on a helicopter auxiliary power unit and driving a custom gearbox and generator. The turbine is sized for cruise. The two 10-kWh battery packs handle peak power and provide redundancy. The production EL9 will have a 600-kW hybrid powertrain with a 50-kWh battery system.

Aviation Week was invited to Electra's headquarters in Manassas in mid-December for a flight in the EL2, with Electra Chief Test Pilot Cody Allee at the controls. Allee is an experienced STOL flyer, as a former U.S. Marine Corps Boeing F/A-18 pilot and lead U.S. pilot on the Rockwell-MBB X-31 Vector project.

Most EL2 test flights have been from Manassas. But in cooperation with customers, the aircraft has operated off-runway from grass fields, a paved surface used for drone flights, a taxiway at Watertown International Airport and a ramp at Griffiss International Airport, both in New York. The aircraft also landed on a 400-ft. strip of graded land next to the Snowshoe Mountain ski resort in West Virginia in November—a 1-hr. flight from Manassas versus a 4.5-hr. drive on winding roads.

Sitting in the aircraft on Electra's ramp as Allee goes through the pre-takeoff checklist and starts up the EL2 provides a revealing glimpse into the complexities of hybrid-electric propulsion. High voltage is turned on, and red strobe lights warn the ground crew. Batteries are brought online, voltages matching and contactors closing. The turbogenerator is started, coolant flows, and temperatures rise and stabilize.

The details are fascinating. Impedance between the 700-volt high-voltage buses and the airframe is monitored continuously to detect a short circuit. To avoid arcing, a precharging circuit brings the bus voltages up before the contactors are automatically closed. A DC-to-DC converter takes the 700-volt battery output and converts it to 28 volts to power the avionics.

Throughout our flight—the 151st for the EL2—Allee is constantly switching the turbogenerator in and out of boost, the battery charging between high and low C-rate to manage the state of charge (SOC) and the large side-mounted radiators between inline and bypass to manage coolant temperatures. This is in part because the demonstrator's off-the-shelf turbine engine is not powerful enough both to cruise and charge the batteries at high rate at the same time, Allee says.

The fly-by-wire EL9 will have a more efficient purpose-designed turbogenerator provided by Safran that will power advanced axial-flux electric motors developed by Evolito. "All this will be automated," he says. "You'll bring up the high voltage, then you'll have a switch to turn the turbine on."

The EL2 is a flying testbed and provides the pilot with a lot of information on each system. "We can see each subcomponent temperature: generator, rectifiers, windings, bearings, coolant temperatures," Allee says. "And then you get the different cells in the batteries. The motor page gives me the exact rpm, what power it's pulling, the temperature—it's basically flight-test instrumentation.

The EL2 landed at the Snowshoe Mountain ski resort in November to demonstrate improved accessibility using ultra-short capability.

ELECTRA.AERO

"This will be vastly simplified in the production aircraft," he continues. "You'll have a high-level display that will give you overall system status, and you will be able to deep-dive on a synoptic display—essentially what we have outboard here." He indicates the information on the display: rpm of the motors, left and right battery SOC, turbogenerator power, flap and aileron positions.

Taxiing out to Runway 16 Right, we are instructed to hold for what seems like a continuous stream of private jets and training aircraft taking off and landing. Manassas is a busy airport. But this shows the flexibility of hybrid-electric propulsion, Allee says: "The beauty is we haven't bled any battery charge at all because we have the turbine on and we're making power."

Finally we are lined up on the runway, positioned on the letter R at the EL2's 3,300-lb. maximum takeoff weight after burning off a few pounds of fuel taxiing and holding. This is to be a maximum-performance takeoff, turbogenerator and batteries on, with an aggressive rotation at 27 kt. to 10-deg. nose-up and a climb at 35 kt. to 100 ft., where power is reduced.

MARK USCIAK/ELECTRA.AERO

**The hybrid-electric blown-lift EL2 lifts off from Electra's Manassas base after a takeoff ground roll of 150 ft. or less.**

Allee advances the throttles to full power, the EL2 responds with a noise like a manic lawn trimmer, and he releases the brakes. With the batteries boosting takeoff power close to 500 kW—almost four times that of a Cessna 172—we reach 27 kt. in seconds and leap skyward from the middle of the number 16 on the runway. My only response is: "That was ridiculous!"

Allee later calculates our ground roll was just 129 ft., considerably shorter than Electra's design goal of 150 ft. The takeoff demonstrates the rationale behind hybrid-electric distributed propulsion. Because the batteries provide a power boost, the turbine can be sized for cruise. "Our approach is that we have got this reserve of power for takeoff and landing, but we're not carrying all that displacement," Allee says.

The turbogenerator runs at a constant power point. "Turbine efficiency drops off precipitously when you reduce rpm, but we're running at peak efficiency all the time," he says. "And it's not being thermally cycled. When we need to meet a transient power demand, that comes from the battery."

Turbine maintenance cost is driven by cycle count, not running time. In operation, the EL9 could leave the turbine running while on the ground between flights, charging the battery, so that it is not thermally cycled. "You kill the cycle counts, and you kill the thermal stress of throttling the turbine," Allee says.

Heading south, we settle into a 70-kt. slow climb at 1,200 ft. on 95 kW of power, preserving the batteries for planned demonstration maneuvers. The EL2's maximum speed is around 100 kt., but integration of the motor pylons into the original Cessna 172 wing is draggy, Allee says. In hindsight, the company should have opted to design a clean-sheet wing for the demonstrator, says JP Stewart, senior vice president for product development.

When the EL2 first flew, its flaps did not fully retract, but after an upgrade they now do. The EL9 will have a more highly loaded, lower-drag wing and larger-diameter, variable-pitch propellers. The EL2 has fixed-pitch propellers that "are pitched so flat for takeoff that we run out of prop," Allee says. With fixed-pitch propellers governed on rpm, the throttles are decoupled from power and instead control motor rpm, he adds.

The outer motor pairs are coupled to the ailerons and rudder so that differential thrust augments the aerodynamic surfaces and improves control coordination. Handing me control of the aircraft for some gentle maneuvers, Allee points out how motor power settings change with aileron and rudder inputs.

A crucial task for the EL2 was to validate the buffet boundary where airflow begins to separate to ensure the blown-lift aircraft could be flown safely to the high angles of attack required for ultra-short takeoffs and landings with a safe margin to the stall.

Allee first demonstrates the buffet boundary with power off and no blowing over the wing. Setting flaps and droop to 30 deg. and 20 deg., he brings the power back to idle; a dip in motor rpm indicates there is no thrust. He pulls the nose up. Rumble starts at 19-deg. angle of attack (AOA); at 20 deg., the wing starts to drop. Recovering the aircraft, he gives me the chance to take the EL2 through the same maneuver.

Then Allee sets up to demonstrate the buffet boundary with power on, as it would be during takeoff and landing. Setting the rpm to 80%, he takes the aircraft up to 15-, 20-, 25- and finally 30-deg. alpha (AOA), making brisk left-right control inputs at each point to demonstrate the aircraft's controllability. "We can fly the airplane at 30 alpha with normal control inputs—and that's the big point," he says.

To demonstrate the redundancy provided by eight motors, Allee sets up to perform a simulated takeoff at altitude and directs me to switch off one of the outermost motors—the worst case—without warning. I cover both switches with my hands. At 25-deg. AOA and 25 kt., with the motors drawing 100 amps from the batteries for 100% power, I turn off the left outboard motor.

A wing dips slightly, but otherwise nothing untoward happens. "When you lose a motor, you lose a little lift," Allee says. "There was a yaw and a roll right, both simultaneous, but otherwise that was it."

Our next stop was Maples Field, a private airstrip on a farm where Allee planned a maximum-performance landing

on grass. He entered the pattern with flaps 30/20 and 85% power, leaving the turbogenerator in boost before lowering flaps to 60/25, derating turbogenerator and C-rate and coming in over the trees at 35 kt. on a 6-deg. glideslope. The 2,000-ft. airstrip looked short; we used only a fraction of it.

Almost immediately, Allee prepares for a maximum-performance takeoff. He sets the flaps to 40/25, turbogenerator to boost and C-rate to high and, when battery SOC reaches 85%, advances the throttles, releases the brakes and rotates at 27 kt. Later, he calculated our landing ground roll was 186 ft.—poor braking action on the grass extended it slightly—but our takeoff roll was just 110 ft.

Coming back around, Allee flies a second maximum-performance landing, then sets up to demonstrate a quiet takeoff. "This will be flaps 30/20 and a slightly lower boost and C-rate, 73% SOC for the simulated quiet departure," he says. "We'll take a bit longer on the takeoff roll, but it'll still be fairly fast." Acceleration is slower, and we rotate at 35 kt. but are still off the ground long before the end of the grass strip.

With the propellers always blowing over the wing, ailerons and flaps, the EL2 is highly maneuverable at low airspeed, which Allee demonstrates. With flaps 30/20 at 45 kt. and 60-deg. bank, he flies a figure eight at 2g and 50-60 deg./sec. Looking out, our wingtip appears anchored to a building on the ground below us. "That's the maneuverability this thing has, which is just nuts," he says.

Our activities at Maples have taken their toll on the batteries, and SOC has dropped to 60%. We need at least 75% to attempt the planned turbogenerator-off maximum-performance quiet landing back at Manassas. Allee puts the turbogenerator in boost and slows down to buy us more time to recharge, but the extra 15% SOC proves out of reach.

The demonstrator's turbine is a little too small and its batteries are not intended to enable the aircraft to fly for extended periods on electric power alone. But that is the point of a hybrid: the ability to size the turbine for cruise while minimizing the weight penalty from heavy batteries. The EL2's two battery packs can provide about 15 min. of all-electric flight when fully charged, Allee says.

The ability to fly turbogenerator-off reduces noise. Electra has not measured the EL2's noise during takeoff, when the turbogenerator is on and the electric engines are at full power, but in electric flight mode with the turbine off, the company has validated an overflight noise level of approximately 55 dBA at 500 ft., compared with 75 dBA for a conventional turbine aircraft flying the same altitude and flightpath.

Abandoning plans for a turbogenerator-off landing, Allee sets up for a steep approach back to Manassas' Runway 16, flaps 60/25 and an 8-deg. glideslope. The approach display comes on. Described as a "poor man's head-up display," this shows imagery from a camera on the EL2's nose overlaid with AOA, indicated airspeed, ground speed, radar altimeter, vertical speed, crosswind limit and velocity vector.

Electra is still deciding whether the EL9 will need a similar display for ultra-short landings. The production aircraft has been designed to provide a pilot with the same downward visibility as from a helicopter cockpit, with a lowered instrument panel glareshield and deep windshield.

Touching down, Allee says he landed a little long. I take his word for it, but video later verifies the ground roll was 155 ft. With the turbogenerator at idle and 67% SOC on the batteries, we begin taxiing back to Electra's hangar.


**A full-scale mockup of the EL9 has been built to showcase the cockpit and cabin design as well as passenger experience.**

Allee gives me the opportunity to taxi, steering in one of two ways. He can turn off the coupling between the rudder and the ailerons, and I can use the throttles for differential thrust—or he can leave the coupling on, and I can drive the aircraft like a car by using the yoke. The EL9 will have a single throttle, he notes.

I choose the throttles first, using my thumb and pinkie to move the levers controlling the outer pairs of propellers. I then try using the yoke. I find it easier to steer the aircraft using the throttles but still manage to overcontrol and cause pilot-induced oscillation. Allee comes to my rescue.

Shutting down the EL2 is as fascinating an insight into electric propulsion as was the start-up. After 3 min. at idle to cool down, the turbogenerator is turned off. We have 12 of our 33 gal. of fuel remaining, as planned, and battery SOC is 61%. The high-voltage system is turned off, followed by the batteries. High voltage is then turned back on and the motors are briefly spun to remove residual charge. "We kill the capacitance with the motors," Allee says. The remainder of the systems are turned off, and the EL2 is safely shut down.

"Two-plus years of flying the EL2 was all about getting real flight data to replace assumptions, allowing us to retire the hardest technical risks in the scaling around aerodynamics and blown lift," CEO Allen says. "We validated the ultra-short-takeoff-and-landing performance under real-world flight conditions, and we gave ourselves the confidence then to launch the product."

Electra submitted its application for Part 23 type certification of the EL9 to the FAA in November. Aiming for certification by late 2029 or early 2030, the company plans to build one Gen 0 prototype with known nonconformances followed by three Gen 1 conforming aircraft for certification testing.

"As we were flying the EL2, we were able to take down marks of consistency between this airplane and conventional airplanes, and we were able to build the certification strategy [for the EL9] around the fact that this is indeed just an airplane," Allen says. "We don't need powered-lift certification; we don't need rotorcraft certification. We filed under Part 23 because we are just an airplane."

Electra will need to raise additional funding to get to certification, but the startup has financial runway through the end of the year.

"We're still flying the EL2 because there are two things we still need," Allen continues. "One, we need to continue to do real-world demonstrations with customers, going to places airplanes haven't been before. Two, it's still a flying laboratory, providing pilot feedback on flight procedures, on precision landing."


DAVE KOCH/ELECTRA.AERO

But do Electra's prospective customers really need the EL9's unique capabilities, as demonstrated by the EL2, or will they just want a modern, more efficient replacement for the nine-passenger Cessna Caravan?

Bristow Group is the first to place a firm order with Electra, backed by multimillion-dollar deposits in January to secure five delivery slots, including the first EL9 off the line. The company is a major operator of medium and heavy helicopters for offshore support and search-and-rescue but wants to expand its offerings to existing customers as well as enter new markets with cargo and passenger networks.

Bristow was the first to sign a joint development agreement with newly founded Electra in 2021. "We then went through a very detailed analysis and modeling—Caravans, reengined Caravans with hybrid-electric powertrains, other reengined aircraft with hydrogen engines," Bristow Chief Transformation Officer Dave Stepanek says. "We analyzed the whole structure of it, both costs and reliability of future technologies, and it led us right back to the EL9.

"Specifically, we were looking at Scandinavia, where there are a lot of geographical barriers and older airports with shorter runways being serviced by turboprop aircraft," he continues. "And as they want to expand services, and the turboprop aircraft start to age out, they're going to have to make major investments in extending runways and improving facilities. The EL9 could eliminate that requirement for future investment. You can utilize the infrastructure that exists. That was very appealing to us."

Bristow projects the hybrid-electric EL9 will save on fuel and maintenance costs. "We think it's a 50% reduction in direct operating costs relative to turboprop aircraft, and it's greater versus a helicopter," Stepanek says. Bristow also plans to operate all-electric aircraft as part of a network and is testing Beta Technologies' Alia CX300. "But [the EL9 is] about half the price of 100% battery-electric because it has more payload and range," he notes.

Bristow plans to build out cargo networks as a step toward passenger transportation. "We're also going to be looking at direct aviation," Stepanek says. "In the '80s and '90s, when I was a helicopter salesman for Sikorsky, I used to fly a lot of Beech 1900s around the Midwest and Pacific Northwest, and I would be able to fly to town to town to town. That just evaporated. We think direct aviation is a great opportunity for low-cost transportation with airline-type reliability and safety."

JSX is a Dallas-based public charter operator that offers scheduled flights between smaller airports. The carrier now flies 30-seat Embraer ERJ 135/145s regional jets and ATR 42-600 turboprops, but it signed a letter of intent with Electra in 2023 for up to 82 EL9s.

"We don't fly any nine-seaters," JSX CEO Alex Wilcox says. "If we're going to enter that market, then why aren't we flying Caravans today? Every time we've looked at them, we've always decided 'no.' We came close on the Pilatus PC-12, then we decided to go with the ATR. They can both go in and out of the airports we want to go to, but we can take more than three times as many people in the ATR."

The EL9 begs the same question, he says. "Are nine seats enough to be meaningful? I think that the answer we're coming to is 'yes,' because it's got to be right for the market, and it's got to be a super-short market. So think not just Dallas to Austin, but Dallas to Fort Worth, McKinney to Fort Worth. There's a train that goes from Dallas to Fort Worth, and it takes twice as long to take a train as it does to drive."

Wilcox points out the investment that Dallas and other cities are putting into infrastructure for electric vertical-takeoff-and-landing (eVTOL) air taxis. "There is a ton of money right now chasing eVTOL infrastructure," he says. "I have my doubts about the certification timelines and the practical utility of those vehicles. Along comes Electra, probably years ahead of eVTOL in terms of certification timeline, more or less a standard Part 23 airplane, no new rules required. I think they have a multiyear head start."

Although JSX has another 20 Embraers in desert storage that it could bring into service, the carrier went with the ATR "because it goes places a jet cannot go," Wilcox says. "To me, it's the opportunity provided by the infrastructure that only this platform can accommodate. I can take that, map it onto the Electra, and I think there is going to be significant infrastructure that only this airplane is going to be able to access for a good period of time."

He gives the example of a passenger wanting to travel from downtown Dallas to Miami. "You can take the Electra from the [Kay Bailey Hutchinson] Convention Center straight to Love Field and just walk across the ramp and get on the JSX flight to Miami," he explains. "The way the airplane is going to be handled at Love Field is like a helicopter, not like an airplane.

"We're not going to have to get in the queue and wait for clearance," Wilcox continues. "It's usually [visual flight rules] here, so helicopters can come in right over the terminal between the two runways. It's more direct, more convenient, and it does not interfere with the airline operation."

While traveling on commercial airlines in the weeks following my EL2 flight, I paid particular attention to the takeoffs and landings. Going out of and back to Ronald Reagan Washington National Airport in an Airbus A319 and Boeing 737-800, the acceleration and deceleration, noise and vibration were substantial.

The EL2 does make some noise, but with a takeoff speed of only 35 kt., acceleration is car-like and climb elevator-like. Both are brief and far from uncomfortable, as is the landing.

The EL9, meanwhile, is a thoroughly modern design with a roomy cabin, big windows, wide aisle, ample legroom and no intruding wing spars to negotiate. Luggage or cargo is safely stored behind a solid divider. From the perspective of a passenger, I see nothing objectionable to the direct aviation experience.

**Video** *Graham Warwick flies in Electra.aero's eSTOL EL2 with the company's chief test pilot, Cody Allee:* **YouTube.com/watch?v=vUZWUQSD--U**

# TECH TAKE

By **Graham Warwick**

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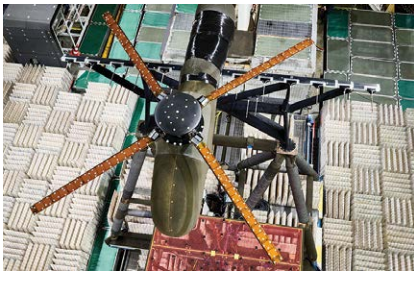
## Active Blade Twist Reduces Rotor Noise

An international team led by German aerospace center DLR has completed tests of a helicopter rotor with active blade twist in the DNW German-Dutch Wind Tunnels in the Netherlands.

DLR



**The active twist rotor model was mounted in the open test section of DNW's large, low-speed wind tunnel.**

Actively controlling the twist of rotor blades has been studied since the 1990s and has been shown to reduce both vibration and noise while improving the efficiency of the rotor system.

Under the Smart Twisting Active Rotor (STAR) project, a 4-m-dia. (13-ft.) four-blade active twist rotor was tested in the large, low-speed wind tunnel at DNW. Piezoceramic actuators integrated into the blade surface twist the blade when an electrical voltage is applied—statically with DC and dynamically with AC.

"The special thing about this approach is that the active twisting of a rotor blade requires no mechanical components and is only minimally affected by the centrifugal forces acting on the rotor blade," says Berend Gerdes van der Wall, STAR project manager at the DLR Institute of Flight Sciences.

Results of the three-week test campaign showed that rotor efficiency improved while noise and vibration decreased significantly. The sound-absorbing walls of the wind tunnel's open test section and cladding on the model fuselage enabled high-quality acoustic measurements, the DLR says.

A remote pilot controlled the rotor, and an experimenter was responsible for active rotor blade twisting. Noise sources were identified using microphones outside the rotor flow, while a "noise carpet" was measured using microphones mounted on a wing within the flow and on a traversing system.

The concept was first tested by NASA, the U.S. Army and the Massachusetts Institute of Technology (MIT) in the early 2000s under the Active Twist Rotor (ATR) program. Forward-flight testing of the rotor model was conducted in NASA Langley's Transonic Dynamics Tunnel in 2000 and 2002, achieving significant vibration and noise reductions.

The model rotor used MIT-developed active fiber composite actuators to twist the blades. Each of the 55-in.-long blades had 24 of the piezoelectric actuators embedded in the structure of its D-shape spar. The actuators were placed in four layers through the thickness of the spar, oriented so that the active strain was applied at ±45 deg. to the spanwise axis to permit maximum torsional control of the blade.

In addition to the DLR and DNW, the STAR program includes NASA, the U.S. Army, French aerospace research agency Onera, the Japan Aerospace Exploration Agency, Korea Aerospace Research Institute and South Korea's Konkuk University.

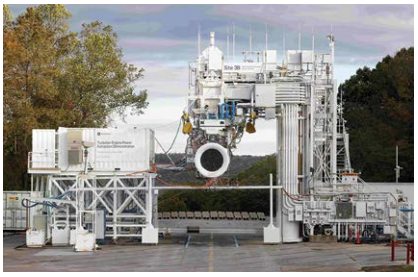
## GE's Hybrid Turbofan Exceeds Expectations

Ground tests of a modified GE Passport business jet engine in hybrid-electric mode have exceeded NASA's performance benchmarks for power transfer, extraction and injection, GE Aerospace says, marking a key step toward development of a future single-aisle propulsion system.

Conducted under CFM International's Revolutionary Innovation for Sustainable Engines (RISE) technology initiative, the Passport tests at GE's facility in Peebles, Ohio, marked the culmination of the Turbofan Engine Power Extraction (PEx) project under NASA's Hybrid Thermally Efficient Core (HyTEC) initiative.

While specific results have not been revealed, GE says performance exceeded NASA's targets, which the agency based on "industry input about engine capabilities that would provide meaningful fuel cost savings for U.S. aviation while also meeting the power requirements of future aircraft."

GE AEROSPACE



**Ground tests of GE's modified hybrid-electric Passport turbofan exceeded NASA's project goals.**

NASA's previously stated goals for hybrid core power extraction were a minimum of 5% and a target of 10%. Overall, as part of efforts to mature technology for a megawatt-class hybrid engine, HyTEC aims to demonstrate at sea level the equivalent of up to 20% power extraction from the turbofan at altitude—a fourfold increase over current commercial engines.

GE says tests also evaluated the impact of electric power on engine operating parameters, such as speed and temperature, as well as how hybridization affects steady-state and transient operating cycles. The project included runs with both spools powered purely electrically to test a zero- or low-emission mode in which future hybrid aircraft would use only electrical power for taxiing.

"Our latest milestone successfully demonstrated a narrowbody hybrid-electric engine architecture that doesn't require energy storage to operate," says Arjan Hegeman, vice president of future of flight for GE Aerospace. "It's a critical step to making hybrid-electric flight a reality for commercial aviation with technologies that meet customer needs for greater efficiency, durability and range."

The hybrid elements, which include motor-generators on the high-pressure (HP) and low-pressure (LP) spools along with offboard motor controllers, were first engaged with the Passport turbofan running at idle power in late October. Testing through year-end included runs of the Passport in full hybrid mode, which involved adding externally generated power into the engine.

The external power, representing

energy that might be supplied by battery or auxiliary power unit in a future hybrid-powered airliner, was supplied by a 2-megawatt, 480-volt diesel generator located at the test stand, along with a load bank to reject waste heat.

For the PEx demonstration, GE modified the Passport with an HP motor-generator that was located beneath the center of the engine, connected to the standard accessory drive system gearbox via a custom offset gearbox. The LP motor-generator was located aft of the exhaust mixer in an extended duct, driving the LP turbine via a series of shafts, bearings and a gearbox.

The aft gearbox, which was configured to match the rotation of the LP and HP spools closely, enabled the motor to operate at its design point. The thrust reverser was removed to provide space for the motor-generator, while the extended exhaust duct reduced mixing losses that could back-pressure the fan.

*—Guy Norris in Colorado Springs*

## Tailoring Microbes To Produce More SAF

One established method for producing sustainable aviation fuel is a fermentation process that uses microorganisms to digest biomass and convert it into alcohols that are upgraded into jet fuel.

LAWRENCE BERKELEY NATIONAL LABORATORY

**Berkeley Lab researchers are using AI and automation to boost the production of isoprenol from microbes.**

Researchers at Lawrence Berkeley National Laboratory have demonstrated complementary ways to speed up the process of teaching microbes to ferment biomass into a next-generation jet fuel.

These microbes produce isoprenol, an alcohol that can be converted into 1,4-dimethylcyclooctane—a blendstock for synthetic aviation fuel that offers higher energy density than conventional Jet A fuel.

Traditionally, the lab says, designing microbial mini-factories has been a slow and expensive "guess and check" process that relies on human intuition because of the unpredictability of biological systems.

A team of researchers at the Joint BioEnergy Institute (JBEI), managed by Berkeley Lab, combined artificial intelligence and automation to test rapidly and refine the genetic designs of biofuel-producing microbes, engineering strains that produce five times more isoprenol than before. The results have been published in Nature Communications.

A second JBEI team discovered the molecular system the microbe uses to sense isoprenol, rewiring it into a biosensor. They linked the sensor to genes that are essential to survival, so only the microbes that produce the most fuel can grow. This rapidly surfaced variants that produced up to 36 times more isoprenol. The results have been published in Science Advances.

The first team built an automated pipeline using robotics to create and test hundreds of strain genetic designs in parallel. After each round, according to Berkeley Lab, machine learning algorithms analyze the results to suggest the next set of genetic designs.

The automated system can insert genetic material into 384 microbe strains in less than a minute, a process that typically takes hours by hand, the lab says, adding that combining the automation with the machine learning model allows an optimized strain to be achieved in weeks versus years.

Both teams are now working to scale up their methods from laboratory experiments to industrially relevant fermentation systems, says Berkeley Lab, a crucial step toward the production of synthetic aviation fuel at commercial volumes.

## Edge Wins UAE Uncrewed VTOL Orders

Emirati defense conglomerate Edge Group has received additional orders for the HT-750 optionally crewed turbine-powered light helicopter from the United Arab Emirates.

The Tawazun Council for Defense Enablement defense materiel agency announced that the United Arab Emirates (UAE) armed forces are acquiring 92 HT-750 platforms for 1.4 billion dirham ($380 million). The order was announced at the Unmanned Systems Exhibition (UMEX) held in Abu Dhabi on Jan. 20-22.

Edge's Switzerland-based affiliate Anavia is developing the 1,150-kg (2,535-lb.) HT-750 primarily as a heavy-lift vertical-takeoff-and-landing uncrewed cargo aircraft system that could carry payloads up to 750 kg. The aircraft features a conventional four-blade single main rotor and two-blade tail rotor.


EDGE GROUP

**Edge affiliate Anavia is developing the HT-750 (foreground) and HT-100 (background) uncrewed helicopters.**

The company has previously displayed the HT-750 with different modules that can be fitted to the front of the aircraft. This allows it to carry cargo, perform intelligence, surveillance and reconnaissance (ISR) missions, or be used as a piloted training aircraft.

"Our contracts with the UAE's [defense ministry] highlight our ongoing dedication to enabling advanced unmanned intelligence and logistics operations through the latest technology in autonomous systems," Anavia CEO Jon Andri Jörg said. But the status of the HT-750's development is unclear.

Also at UMEX, Edge's Anavia received orders from Tawazun for 76 HT-100 uncrewed helicopters, worth $180 million. The 120-kg HT-100 uses a Flettner intermeshing rotor system to provide additional lift and can carry a 60-kg payload for logistics or ISR tasks.

The UAE military also placed a $6 million order with Edge to develop a gyrocopter into an uncrewed logistics aircraft. This is likely related to Edge's GY-300 platform, which was displayed at UMEX two years ago. Another $12 million contract covered development of QX quadcopter drones.

*—Tony Osborne in London*

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**March 4-5**—AeroEngines Asia-Pacific. Hong Kong.

**March 17-18**—Aviation Week Defense Conference. Washington.

**March 18**—Aviation Week Program Excellence Roundtable & Awards. Washington.

**March 19**—Aviation Week Laureate Awards. Washington.

**April 14-16**—Routes Asia. Xi'an, China.

**April 21-23**—Military Aviation Logistics & Maintenance Symposium. Orlando, Florida.

**April 21-23**—MRO Americas. Orlando, Florida.

**April 23-24**—CAPA Airline Leader Summit – Airlines in Transition. Berlin.

**May 13-14**—MRO Southeast Asia. Kuala Lumpur.

**May 18-20**—Routes Europe. Rimini, Italy.

**May 26-28**—MRO Greater China. Beijing.

**May 27-28**—GAD Americas. Charleston, South Carolina.

**May 27-28**—CAPA Airline Leader Summit – Americas. Charleston, South Carolina.

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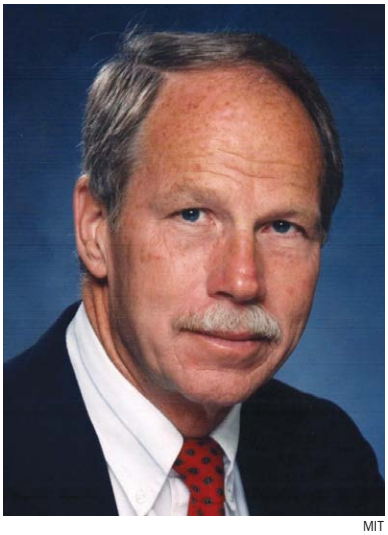
# ROBERT LIEBECK
## 1938-2026

As a McDonnell Douglas engineer, Bob Liebeck sketched out a concept for a revolutionary airliner. In response to NASA's 1988 call for ideas that could lead to a renaissance in long-haul air transport, Liebeck envisioned a swoopy design, dubbed the Batwing, that led to what is now known as the blended wing body, or BWB.



MIT

The renowned aerodynamicist died on Jan. 12 at age 87. While Liebeck is best known for coinventing the BWB, his achievements spanned far more. He pioneered high-lift airfoil designs that were used for high-altitude reconnaissance aircraft as well as racing cars, an America's Cup yacht and even a pterosaur flying replica.

In collaboration with race car driver Dan Gurney, Liebeck developed the Gurney flap, a small tab on the trailing edge of a wing that increases downforce. McDonnell Douglas further developed the device into the drag-reducing divergent trailing edge airfoil for the MD-11's high-speed ailerons.

Beyond aircraft, Liebeck's passions included teaching, running and motorcycles. He was a professor of the practice of aeronautics at the Massachusetts Institute of Technology (MIT) and an adjunct aerospace engineering professor at the University of California, Irvine (UCI), teaching classes on aerodynamics and aircraft design.

"Many of us knew Bob not only as a world-renowned engineer but as a generous colleague and mentor," said Julián Rimoli, professor and chair of UCI's Department of Mechanical and Aerospace Engineering. "Bob was universally respected in aviation, and he was a good friend to the department," MIT Professor Edward Greitzer said.

"It is the one job where I feel I have done some good—even after a bad lecture," Liebeck told MIT's *AeroAstro* magazine in 2007. "I have decided that I am finally beginning to understand aeronautical engineering, and I want to share that understanding with our youth."

Liebeck was born in Wheaton, Illinois, and studied at the University of Illinois Urbana-Champaign, where he earned his bachelor's, master's and Ph.D. degrees. While at university, he interned at Douglas Aircraft—he joined the company full-time in 1968 and remained there through mergers with McDonnell Aircraft and then Boeing. Liebeck retired as a senior technical fellow at Boeing in 2020.

He will forever be remembered for coinventing the blended wing body with Mark Page and Blaine Rawdon. NASA funded the first study of the BWB in the early 1990s, when it was an 800-seater with a 7,000-nm range. The span-loading flying-wing design promised to raise transport aircraft lift-to-drag ratios to 28 from 17. "You wind up with the same takeoff gross weight as a [Boeing] 747, carrying twice as many passengers and for half the fuel," Liebeck told Aviation Week in 1995.

At the time, Liebeck's wish was to see a BWB X-plane fly. "We're claiming incredible performance, and we need to back up those claims," he told Aviation Week. In 2007, NASA and Boeing flew the X-48B, a remotely piloted 8.5%-scale model of a conceptual 468-seat, 7,750-nm-range BWB that was built to demonstrate low-speed controllability.

NASA

**Liebeck's BWB vision took flight in 2007 as the 8.5%-scale NASA/Boeing X-48B demonstrator.**

Boeing continued to study the BWB, evolving conceptual designs for stealthy military variants. But the opportunity to fly the aircraft at full size arose when JetZero, a startup cofounded by Mark Page, won U.S. Air Force funding support in 2023 to build a full-scale demonstrator for a 250-passenger BWB airliner and a military tanker-transport derivative.

After retiring from Boeing, Liebeck served as technical advisor at JetZero. "For those of us at JetZero, Bob was our North Star and advisor," Julie Felgar, vice president of government affairs, posted on LinkedIn. "His pioneering work on blended wing body aircraft did not just advance aerodynamics, it gave us a cornerstone in our foundation of reimagining commercial and defense aviation. I wish he could have lived to see the first flight in 2027 of the full-scale demonstrator."

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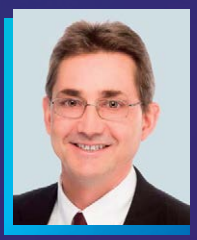

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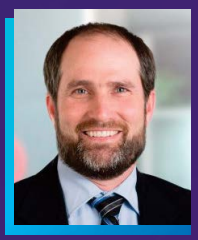

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