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AVIATIONWEEK & SPACE TECHNOLOGY

17 *Spain has ordered 45 Eurofighters over the past three years, which will expand its fleet to 115 aircraft once all the fighters are delivered.*

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## FEATURES



### DEFENSE



### DEPARTMENTS





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### VIEWPOINT



### ON THE COVER

*Like every industry, aerospace is chasing the promise of artificial intelligence and trying to determine how to incorporate the paradigm-shifting technology into its operations. Our special report on the state of the technology, including its applications to combat aircraft, begins on page 40. Main image by DKosig/Getty Images; runway image by Eric Meola/Getty Images.*

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# FEEDBACK

## CONTROLLED ECONOMY

Matthew Fulco's Going Concerns commentary "Rising Risk" *(Nov. 25-Dec. 8, 2024, p. 11)* leaves out a couple of key points about the position that China holds in many material supply chains.

They do not "have a competitive advantage due to economies of scale." Rather, it is near-zero environmental regulation combined with nearly endless money from the government.

When I was in the rare earth business in the early 1980s, almost all of our rare earth metals were mined at Mountain Pass, California, and processed in the U.S. We could also get material processed in Germany or Japan.

By the late 1980s, the Chinese had entered the market at low enough prices that they forced Mountain Pass to close. When rare earth prices went up in the 1990s, there was activity to restart the domestic mine. But before they could do it, the Chinese slashed prices, killing the project.

And so it has gone over the years with many markets. Run the competition out of business and then jack up prices. It is easy to do in a controlled economy.

*Ed Blessman, Waukesha, Wisconsin*

## TERRAIN TECHNOLOGY

"Terrain Fingerprints Could Enable GPS-Free Navigation" *(Dec. 9-22, 2024, p. 86)* indeed describes encouraging technology that could enable accurate navigation without GPS. However, while no doubt the new equipment is state-of-the-art, the approach is not new. In the early 1980s, the Pershing II missile used terrain-following radar with a digitized map to determine location. This was a highly accurate system not susceptible to GPS jamming that enabled very precise targeting of deeply buried Soviet military command and control centers situated well behind NATO front lines.

*Stewart Long, Seven Fields, Pennsylvania*

*Executive Editor for Technology Graham Warwick replies: Variously called scene matching, terrain contour matching and terrain profile matching, navigation by comparing sensor data with a stored image, map or database is nothing new and has been used in applications ranging from Tomahawk cruise missiles to Lockheed Martin F-16 fighters. What is new is the use of fingerprinting techniques to locate absolute position by identifying unique terrain features.*

## MELTING STRUCTURE?

Did the breakup of the Orion heat shield on Artemis I melt any aluminum-lithium structure? The Columbia Crew Survival Investigation Report mentions liquid aluminum flowing out of space shuttle Columbia's left wing. Some thought Orion needed stainless steel like Apollo and SpaceX.

*James J. Shortt, Garden City, New York*

*Senior Space Editor Irene Klotz replies: It did not. During Artemis I, Orion's heat shield experienced unexpected wear of its ablative outer coating due to a materials/structural/thermal issue that trapped hot gases, causing a pressure buildup that led to cracking and the liberation of charred particles.*

## CATCHING UP

Well, I must sound like I'm treading 80 kt. in a helicopter facing a 160-kt. headwind, but I'm finally reading William Garvey's Inside Business Aviation column referencing the Hughes helicopter, alias Schweizer *("Back in the Game," March 11-24, 2024, p. 12)*.

As a kid growing up along the Hudson River, I would see dozens of these Hughes pistons flying the river corridor, and I have always wondered what happened to them all. It is great to hear production is getting revamped.

I have a box full of *AW&ST*s, and I don't throw them out until I read them to catch up on "recent history."

*Edward A. Sarkisian, Wyckoff, New Jersey*

## DIGITAL CONVERT

The new year seems an appropriate time to congratulate you on the excellence of your reporting. Never missing an issue since 1971, I have always in your surveys voted for the printed issue—that is, until I purchased a large-screen high-quality tablet. What a joy it is to zoom in on text in the PDF version so as to ease reading, and what many hours one can spend immersed in browsing old issues.

I'll be with you for years to come but must admit these days the print version is often hardly used at all.

*Jens Hoeg, Herlev, Denmark*

## CORRECTIONS

"Airbus Future Fuselage Shows Weight Benefits" *(Dec. 23, 2024-Jan. 12, 2025, p. 22)* should have stated that conduction was one of the welding techniques used to join thermoplastic components for the Airbus Multifunctional Fuselage Demonstrator.

"China Races to AAM" *(Dec. 23, 2024-Jan. 12, 2025, p. 115)* should have stated that low-altitude Chinese advanced air mobility development costs could lead to vehicle costs that are 30-40% of those in the U.S. and Europe.

## BEHIND THE SCENES

SETH JAWORSKI

**Adrian Schofield**, Aviation Week's senior air transport editor for the Asia-Pacific region, was named Journalist of the Year in the 2024 Australasian Aviation Media Awards. Announced online on Dec. 20, the awards are organized annually by the Australasian Aviation Press Club. In February 2024, Schofield won the award for Best Asian Aviation Analysis at the Aerospace Media Awards Asia event held in Singapore *(Feb. 26-March 10, 2024, p. 9)*.

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

**Johannes Bussmann** has been named CEO of *MTU Aero Engines*, succeeding Lars Wagner. He was CEO at TUV Sud and before that at Lufthansa Technik, where he helped establish MTU-Lufthansa Technik joint venture EME Aero in Poland.

Satellite constellation company *Spire Global* has promoted **Theresa Condor** to CEO from chief operating officer. She succeeds founder Peter Platzer, who stays on as executive chairman. In addition, **Gabriel Oehme** has been named chief transformation officer and **Celia Pelaz** chief operating officer. Before joining Spire in 2013, Condor worked at Citigroup. Oehme was chief commercial officer at Aerotech Peissenberg, before which he worked at Airbus. Pelaz was chief operating officer at Hensoldt and previously chief strategy officer, with past positions at Airbus.

**Tony Gingiss** has been named CEO of Boeing-owned *Millennium Space Systems*. He was chief operating officer at Terran Orbital and prior to that at Virgin Orbit. Gingiss also previously headed Airbus OneWeb Satellites.

Air traffic control communications network developer *AURA Network Systems* has appointed **Kevin Steen** CEO and **Walter Berger** executive chairman. Steen was CEO of the combined Eutelsat America and OneWeb Technologies. Berger was president and co-CEO of Kymeta and before that worked at AppDynamics, Leap Wireless and SoftLayer.

**Dana Deasy** has joined *Boeing* as chief information digital officer and senior vice president for information technology and data analytics. He was chief information officer at the U.S. Defense Department and held similar roles at JPMorgan Chase, BP and General Motors.

*Voyager Space* has named **Wallis Laughrey** chief strategy officer. He was vice president of Anduril Labs and before that held senior positions at Raytheon Technologies and Northrop Grumman.

*Israel Aerospace Industries* has appointed **Yaakov Berkovich** vice president and general manager of its aviation group and **Oded Jacobowitz** general manager of the defense plant in its missile and space systems group. Berkovich was general manager of the conversion and upgrade plant within the aviation group, while Jacobowitz has been head of the land systems directorate and plant deputy general manager.

**Jennifer Lowe** has joined *AE Industrial Partners* as head of government affairs. She was a managing partner at Link Consulting Group and before that was senior vice president of national strategy and engagement at Boeing. Prior to joining the airframer, she worked in the U.S. Senate.

*Southwest Airlines* has hired **Aileen Furlong** as vice president of sales. She was managing director of global sales at United Airlines, where she worked for over 23 years.

**Ron Brower** has been appointed legal counsel of the *Air Charter Safety Foundation*. He is a longtime member of the organization's board of governors and the founder of aviation law firm RBAvLaw. He also has worked at FlyExclusive, NetJets and Wheels Up.

*Thales Defense & Security* has promoted **Steve Kutchi** to vice president of engineering and chief technology officer from director of hardware and support engineering. He has worked at Thales for over 20 years and before that at Hughes Network Systems.

**Lahiru Ranasinghe** has been named sustainability director at *EasyJet*, succeeding Jane Ashton. He was head of net-zero emissions at the carrier, where he has worked for more than five years. Ranasinghe also has worked at Virgin Atlantic and British Airways.

Aerospace engineering company *Stellar Solutions* has hired **Don Rynkowski** as vice president of intelligence. He was program director at SAIC, where he oversaw operations in defense, intelligence and space. Before that, he worked for Kinsey Technical Services and TASC.

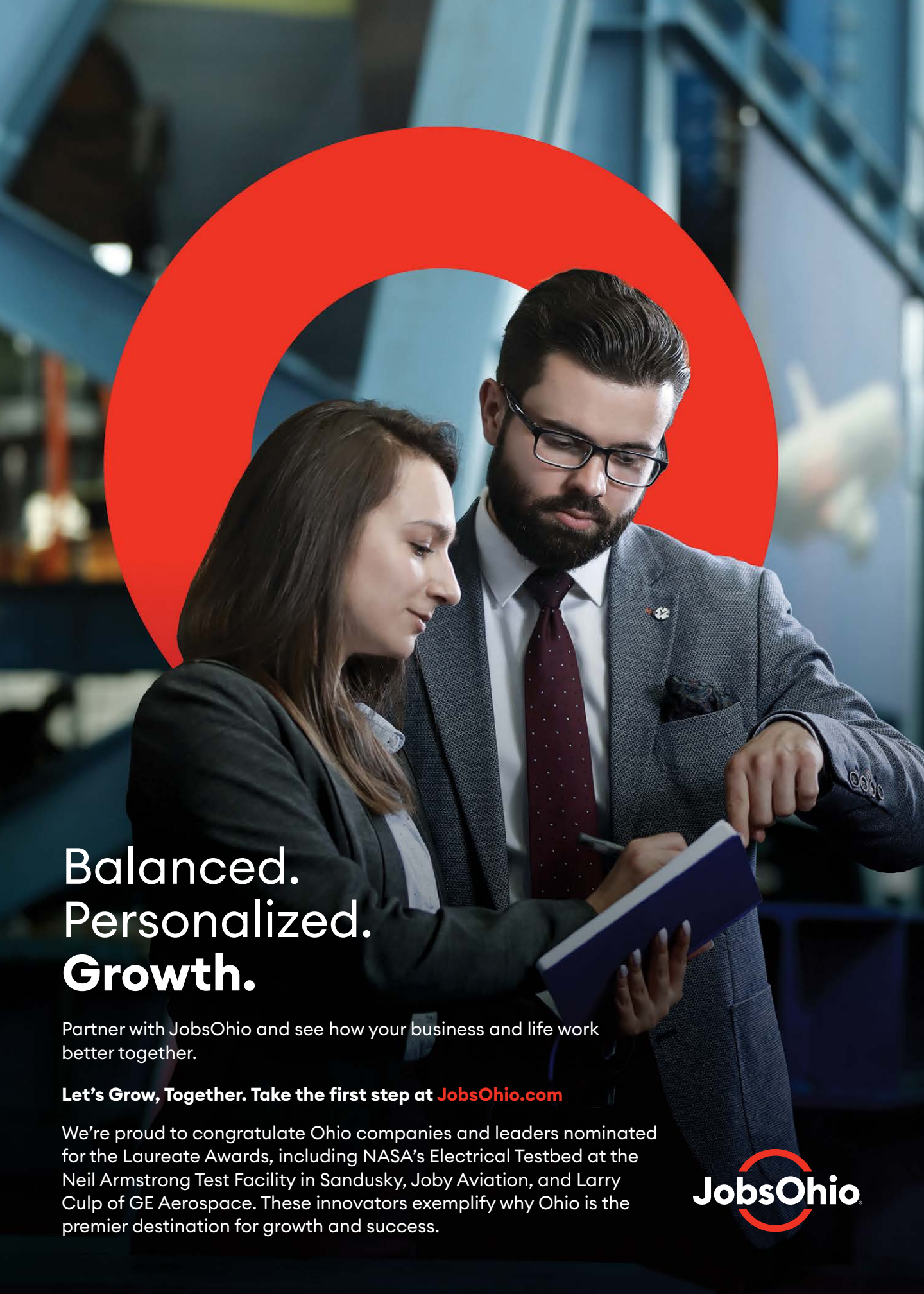
**James Hauslein** has been named chairman of the board of trustees of the *Aircraft Owners & Pilots Association*, succeeding William C. "Bill" Trimble III, who is staying on as a trustee. A member of the association since 1987, Hauslein is also president and CEO of private investment company Hauslein & Co., and he was chairman and CEO of Big Time Products and Sunglass Hut International.

Drone developer *AgEagle Aerial Systems* has appointed **Kevin Lowdermilk** and **Brent Klavon** to its board of directors. Lowdermilk is CEO and chief financial officer of hybrid rocket propulsion company Vaya Space; he previously held executive roles at CFO Strategic Partners, ISO Group and Exostar. Klavon is chief strategy officer at ANRA Technologies and a former board member for the Association for Uncrewed Vehicle Systems International.

U.S. Air Force Maj. Gen. (ret.) **Linda Urrutia-Varhall** has joined the board of trustees at *The Aerospace Corp*. Before retiring from the public sector, she held senior positions across the defense and intelligence agencies, including director of operations at the National Geospatial-Intelligence Agency and assistant deputy chief of staff for intelligence, surveillance and reconnaissance at the U.S. Air Force.

*Delta Air Lines* has appointed **Christophe Beck** to its board of directors. He is CEO and chairman of Ecolab, where he has worked for 17 years, before which he held senior positions at Nestle.

*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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# FIRST TAKE

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TURKISH AEROSPACE INDUSTRIES

## DEFENSE

**Spain has provisionally selected Turkish** Aerospace Industries' Hurjet to replace its aging fleet of Northrop SF-5 lead-in fighter trainers.

**China's Xian Aircraft flew a rotodome-**equipped airborne early warning and control aircraft based on the Y-20B strategic airlifter and unofficially dubbed the KJ-3000, photos that appeared Dec. 27 indicate.

**Italy has signed a long-awaited contract** for 24 more Eurofighter Typhoon combat aircraft days after fellow core partner nation Spain added 25 of the type to its procurement program (page 17).

**Austria has formally agreed to buy 12** Leonardo M-346 advanced jet trainers to replace Saab 105s phased out in 2020.

**Defense services company Babcock has** acquired 11 Aero Vodochody L-39 jet trainers in an effort to grow European training capacity as it sets up an academy in Dijon, France.

**An undisclosed African country ordered** four Embraer A-29 Super Tucano light attack/trainer aircraft on Dec. 31, a day after the company announced another undisclosed customer for six A-29s.

**Iraq is to become the first export customer** for the Korea Aerospace Industries KUH-1 Surion utility helicopter. It signed a contract to receive two multipurpose firefighting variants by March 2029.

**Stratolaunch is believed to have landed** its Talon TA-2 reusable high-speed test vehicle autonomously at Vandenberg SFB, California, on Dec. 20, on the third launch attempt.

**Kratos has been selected for the next** phase of the U.S. Defense Department's Multi-Service Advanced Capability Hypersonic Test Bed effort to increase the pace of hypersonic testing.

**Russian Aerospace Forces received the** initial modernized United Aircraft Corp. Tupolev Tu-160M strategic bomber in December, the first major upgrade of the variable-sweep, long-range aircraft.

**Turkish drone-maker Baykar has acquired** Piaggio Aerospace six years after the Italian manufacturer was forced into administration when its owner, Abu Dhabi sovereign fund Mubadala Development, suddenly withdrew its investment.

**Sierra Nevada Co.'s contract to build a** fleet of signals-intelligence aircraft for the U.S. Army stands after the U.S. Government Accountability Office denied a protest filed by losing bidder L3Harris Technologies.

**The latest electronic attack tool for the** U.S. Navy's Boeing EA-18G Growler, the Raytheon Next-Generation Jammer midband system, achieved initial operational capability in December.

## COMMERCIAL AVIATION

**South Korean investigators expect by** Jan. 14 to have preliminary analysis of flight data recorder data from the Jeju Air Boeing 737-800 destroyed during an emergency landing Dec. 29 that killed 179 passengers and crew (page 22).

**The Malaysian government plans to re-**start the search for Malaysia Airlines Flight 370 in 2025, more than 10 years after the Boeing 777-200ER disappeared over the Indian Ocean.

**Indonesia is planning to merge three** government-linked airlines—Garuda Indonesia, Citilink and Pelita Air Services—to streamline aviation within the country.

**An engine problem caused smoke to** enter the cockpit and cabin of a Swiss

## VIEW FROM KAZAKHSTAN

# Air Defenses Downed Airliner

An Azerbaijan Airlines Embraer 190 crashed in Kazakhstan on Dec. 25 after being struck by Russian anti-aircraft fire, killing 38 of the 67 people on board. Azerbaijan Airlines Flight 8243 was on approach to Grozny, Russia, when the crew diverted and sought an alternate airport. Preliminary findings deemed an anti-aircraft missile struck the E190 during its approach to Grozny. The airline said the occurrence was the result of "physical and technical external interference," likely including GPS signal interference as well as the anti-aircraft fire.

Russian President Vladimir Putin apologized "for the fact that the tragic incident occurred in Russian airspace" in a Dec. 28 Kremlin statement that did not accept responsibility. The incident came a little more than a decade after pro-Russian rebels in eastern Ukraine shot down Malaysia Airlines Flight 17.

Grozny, the capital of Chechnya, had seen a number of Ukrainian drone strikes and Russian anti-aircraft responses as part of the ongoing Russia-Ukraine war. Azerbaijan Airlines and other carriers suspended flights to Grozny and some other Russian destinations following the incident. Authorities in Brazil assisting in the probe say they have extracted information from the flight data and cockpit voice recorders and delivered it to the investigating authorities in Kazakhstan.

International Air Lines Airbus A220 on Dec. 23, resulting in the death of a flight attendant.

**Boeing will modify 737 MAX emergency** instructions to help pilots quickly recognize and respond to an engine failure that could lead to smoke entering the flight deck through the bleed air system.

**Comac wrapped up 2024 with 10 C919** deliveries to Chinese airlines. The narrowbody crossed the million-passenger mark since it entered service on May 28, 2023.

**The U.S. Transportation Department** has penalized a U.S. airline for the first time for "chronic flight delays," assessing a $2 million penalty against JetBlue Airways for infractions in 2022 and 2023.

SILVER AIRWAYS

**Florida-based regional airline Silver** Airways filed for Chapter 11 bankruptcy protection on Dec. 31 and expects to emerge from the process in the first quarter of 2025.

## TECHNOLOGY

**Electric air taxi pioneer Volocopter filed** for insolvency on Dec. 20 after failing to secure a long-planned capital increase from its existing shareholders (page 24).

**The group of investors seeking to take** over German electric aircraft manufacturer Lilium plans to invest more than €200 million ($205 million) into the insolvent company (page 24).

**China has type-certified the Rhyxeon** RX4E, the first electric aircraft to be approved to the equivalent of FAA Part 23 airworthiness regulations and first four-seat electric aircraft.

## SPACE

**Telemetry received from NASA's Parker** Solar Probe following its record close flyby of the Sun on Dec. 24 affirmed that the spacecraft had executed all commands and its four science instruments are operational.

**Chinese launch startup CAS Space has** begun an accident investigation after the first failure of its Kinetica-1 launcher on Dec. 27 after five successful launches.

**Eutelsat's OneWeb constellation went** down for 48 hr. after its ground segment, maintained by Hughes Network Systems, was not programmed for 2024, which was a 366-day leap year.

**Turion Space has won a U.S. Space Force** contract to build three multipayload satellites to demonstrate rendezvous proximity operations and high-resolution satellite-to-satellite imagery collection.

**AST SpaceMobile has obtained lower** midband spectrum for direct-to-device satellite communications in the U.S. from Ligado Networks, which has declared bankruptcy.

**NASA is to decide in 2026 whether to** use a beefed-up sky crane landing system or a commercially provided spacecraft for a revised Mars Sample Return campaign (page 34).

**Commercial lunar landers from Firefly** Aerospace and Japan's iSpace are scheduled for launch Jan. 15 by a SpaceX Falcon 9.

### Airbus Meets Lowered Delivery Target

| | Deliveries | Orders (Net) | Orders (Gross) |
|---|---|---|---|
| 2004 | 320 | 366 | 370 |
| 2005 | 378 | 1,055 | 1,111 |
| 2006 | 434 | 694 | 824 |
| 2007 | 453 | 1,019 | 1,458 |
| 2008 | 483 | 651 | 900 |
| 2009 | 498 | 269 | 310 |
| 2010 | 510 | 544 | 644 |
| 2011 | 534 | 1,387 | 1,608 |
| 2012 | 588 | 688 | 914 |
| 2013 | 626 | 1,415 | 1,619 |
| 2014 | 629 | 1,590 | 1,796 |
| 2015 | 635 | 1,126 | 1,190 |
| 2016 | 688 | 746 | 949 |
| 2017 | 718 | 1,139 | 1,229 |
| 2018 | 800 | 789 | 831 |
| 2019 | 863 | 1,035 | 1,131 |
| 2020 | 566 | 373 | 383 |
| 2021 | 611 | 763 | 771 |
| 2022 | 661 | 1,041 | 1,078 |
| 2023 | 735 | 2,094 | 2,319 |
| 2024 | 766 | 826 | 878 |

*Source: Airbus*

Airbus delivered 766 commercial aircraft in 2024, up 4% from the prior year and meeting a lowered forecast of around 770. The company initially planned to ship 800 units in 2024 before it cut its outlook because of supply chain issues. Airbus delivered 123 aircraft in December and said on Jan. 9 that it had booked 826 net orders throughout 2024, factoring in 52 cancellations.

## 50 YEARS AGO IN AVIATION WEEK

**The angle says it all.** Two 30mm GAU-8A Gatling gun-toting Fairchild Republic A-10 test aircraft dive in close formation over the Tehachapi Mountains in California on our Jan. 13, 1975, cover.

The context for the photo is not provided, but the A-10s are likely testing or simulating a classic Thunderbolt II—ahem, Warthog—strafing run, the signature maneuver of a close-air support fighter.

Conceived in the late 1960s as a killer of Soviet tanks, the A-10 stood out in service for its close-air support exploits over battlefields from Bosnia to Afghanistan. The U.S. Air Force designed the A-10 to take a beating in the air, but it proved even more survivable against the Pentagon's bureaucratic infighting. Despite a series of attempts over several decades to retire all of the Warthogs, the fleet continues to survive, with 229 aircraft still in service.


Alas, its days appear to be numbered. The Air Force plans to withdraw South Korea-based A-10s from service in 2025 and the rest of the fleet by the end of the decade.

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UP FRONT

# KEVIN MICHAELS

**HONEYWELL INTERNATIONAL IS** in the news after an activist investor called for its breakup. Should this happen, bright lights will shine on a standalone aerospace business that is a shell of its former self after being "cash cowed" by its parent company for several decades. How did this happen? And what is next for this major aerospace supplier?

Much like the tale of Boeing's decline, Honeywell's story begins with the merger of two major companies—AlliedSignal and Honeywell—in 1999, which created the first "supersupplier," with aerospace revenue of $10.5 billion. A failed merger with GE and the onset of a deep industry recession in the early 2000s left the company in a funk, and two factions emerged. One was "Honeywell red" (mostly electronics); the other was "AlliedSignal blue" (mostly mechanical components and engines).

In 2002, new CEO David Cote took the helm. Like former GE CEO Jack Welch, Cote had a laser focus on shareholder value and believed that growth could be balanced with significantly higher profits. He established the "Honeywell Operating System," which heavily emphasized productivity, facility rationalization and movement of value chain activities to low-cost countries. The system centered on a fixed overhead, which meant that as the company grew, its support function expenses remained frozen. This led to the creation of a very complex matrix organization, which made it challenging to fund R&D and enormously frustrating for customers to locate decision-making authority. By 2007, Honeywell Aerospace revenue hit $12.2 billion with an 18% profit margin—up from 14.8% in 2002.

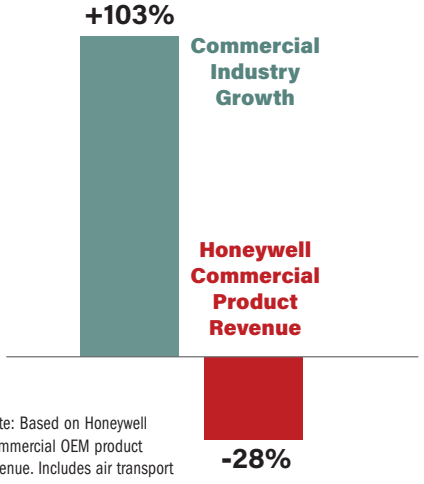
In the booming 2010s, Honeywell extracted cash from aerospace to boost shareholder returns and invest in its non-aerospace businesses. The dearth of aerospace investment, risk-taking and mergers and acquisitions (M&A) manifested itself in falling original equipment market share in key businesses. Once a leader in wheels and brakes, Honeywell fell to fourth place by not investing in carbon-carbon technology. Its engine business lost market share to more nimble competitors, such as Williams International and Pratt & Whitney Canada. In avionics, it ceded territory to Rockwell Collins, Thales and Garmin. It undertook no major acquisitions as its competitors bulked up and consolidated the supply chain.

Fast forward to today: Honeywell's commercial product revenue is 28% lower than in 2007 despite the industry's doubling in size since then. Its $13.6 billion in aerospace revenue has remained flat through aggressive aftermarket price increases—extracting value from airlines and maintenance, repair and overhaul providers—while its forward-fit positions diminished. It finishes at or near the bottom of customer satisfaction surveys. At any industry event, the anger about Honeywell's lack of performance is palpable. Employee morale has also suffered as the workforce has endured multiple unpaid leaves of absence to fatten the bottom line. The company's growth story is focused on advanced air mobility, which is likely to disappoint investors.

## Diminished Giant

Why Honeywell **must change**

**Increase and Decline, 2007-23**




Note: Based on Honeywell Commercial OEM product revenue. Includes air transport and business jet production.

*Sources: AeroDynamic Advisory and Honeywell*

Honeywell retains islands of strength in auxiliary power units, business jet avionics and compact navigation systems. Its product management philosophy is disciplined. And it is among the most profitable aerospace suppliers, with a pretax margin of 27%—nearly double what it was when Cote took over. In exchange for this level of profitability, however, the company gave up investment, growth, employee morale and customer satisfaction. It turns out that the Honeywell Operating System and growth were not compatible.

Where does Honeywell go from here? Should it become a standalone aerospace company? The first option is to maintain the status quo, emphasizing shareholder returns and aftermarket price increases. That would lead to the same results, customer vitriol and, eventually, a contracting business.

The second option is to reverse course and become a growth-oriented aerospace company again by investing in innovation, taking better care of employees, closing performance gaps and pursuing M&A. That would require courageous leadership, since it would disappoint Wall Street when investment grew and profitability came down.

The third option is to sell and/or break up the company—perhaps returning to the original "red" and "blue" factions. The "blue" engine and auxiliary power unit businesses likely would be more valuable in the hands of a major aeroengine OEM like GE Aerospace than part of the current structure.

Let's hope Honeywell chooses change. After an unfortunate two-decade journey into the "shareholders first" cul-de-sac, our industry deserves better.

*Contributing columnist Kevin Michaels is managing director of AeroDynamic Advisory in Ann Arbor, Michigan.*

## GOING CONCERNS
# MICHAEL BRUNO

**THIS YEAR COULD BE A TURNING** point for the industry. Honeywell International, one of the last major aerospace and defense suppliers that is also a multi-industrial conglomerate, is possibly headed for a breakup, while Boeing CEO and President Kelly Ortberg might divest parts of that storied airframer.

Honeywell issued a statement Dec. 16 saying that an ongoing strategic review of alternatives has made "significant progress to date," and the corporation is "well-positioned for significant transformational alternatives." That explicitly entailed the potential separation of its aerospace and defense business, for which activist investor Elliott Investment Management called in November (*AW&ST* Nov. 25-Dec. 8, 2024, p. 16).

Honeywell said more will be revealed during discussion of its fourth-quarter financial results and year-ahead outlook, which in recent years occurred at the start of February. In the new year, Honeywell is likely to be one of many players looking to divest and focus its aerospace business.

Indeed, industry insiders have been scrutinizing Boeing's empire and imagining what could be carved out since October, when Ortberg said he would have a better sense of what to do with Boeing's portfolio by the end of 2024.

For years, Boeing has been expected to divest some of its space business, with at least a potential sale of half of United Launch Alliance. Lately, financial analysts have suggested Jeppesen and parts of Boeing's KLX-Aviall buildup from years ago also could be spun off. Other brands that could be sold include ForeFlight, Insitu and Liquid Robotics as well as additional technology specialists.

It is a far cry from just six years ago, when Boeing was in a roll-up phase that had industry cognoscenti wondering how vertically integrated the then-leading OEM and large defense prime would become and whose business was at risk of being dwarfed. From AvionX and HorizonX to Boeing Global Services' $50 billion revenue bogey, simulation and training and underwater vehicles, the aerospace and defense world seemed there for Boeing's taking.

After its 1997 merger with McDonnell Douglas, Boeing acquired $15 billion more in assets (measured in then-year dollars), according to a report by Jefferies analysts. Now up to $12 billion could be divested as the company recovers and reorganizes from multiple crises in recent years.

While Boeing's and Honeywell's divestitures have their own explanations, together they point to a definite swing away from the conglomeration trend of the 2010s. Still, a major question in 2024 was whether the recent urge to tighten large companies would lead to industry consolidation. Instead, the end result could be fragmentation of the sector and emergence of more up-and-coming middle-market players.

Take drone manufacturer AeroVironment's announced purchase of defense tech company BlueHalo in an all-stock deal valued at $4.1 billion. The acquisition is seen by many as a harbinger of the rise of middle-market players that can move into a space large companies help create.

"Midtier suppliers largely disappeared in the 1990s during sector consolidation," notes Byron Callan of Capital Alpha Partners. "There was another wave of [mergers and acquisitions] in the mid-to-late 2010s as force-protection companies that thrived during the Iraq and Afghanistan wars were bought up. The 2010s and 2020s have seen a rise in new defense tech entrants, with capital provided by venture and private equity. BlueHalo is an example of that change."

Callan expects the emerging middle market to take share from larger contractors. AeroVironment leaders echoed as much during the Nov. 19 announcement.

On the commercial side of the industry, consultants tell Aviation Week the combination of large-company divestitures, distressed assets such as aerostructures and the continued high-level interest of private equity investors in the expected commercial ramp-up could lead to more middle-market players rising there.

Whether that leads to a healthier, more robust supplier base remains to be seen. With increased defense spending and commercial manufacturing, maybe the market will grow, making more middle-market players.

But as Callan noted, consolidation comes in waves. There are plenty of examples of midsize and large companies that quickly ran into trouble and eventually sought buyouts, such as Spirit AeroSystems, which was less than 20 years old after being spun out of Boeing. Regardless of when the next consolidation wave comes, it looks like industry is going to get more crowded first.

## New Middle Market

The yield of **industry fragmentation**

AEROVIRONMENT

**AeroVironment, a UAV specialist that provides the Switchblade loitering munitions system (pictured) among others, is buying defense tech company BlueHalo to form a growing middle-market provider.**

## INSIDE BUSINESS AVIATION
## WILLIAM GARVEY

# Providing Birds' Eyewitness

### Volunteer pilots take flight **to protect the natural world**

**FACT: PIG EXCRETA GENERATED AT** giant factory farms is flushed into large earthen pits, and the malodorous waste, which bacterial digestion turns to a darkish pink, is later spread as fertilizer—a controversial practice that can also threaten nearby waterways.

Fact: The cargo door on a Pilatus PC-12 facilitates the loading of crates containing endangered animals. With the passenger seats removed, the turboprop's pressurized cabin can accommodate five of the sturdy units.

Those details came to the fore on opposite sides of the U.S. as volunteer pilots and many others go aloft to help preserve and protect the natural world. Such aviators are typically affiliated with LightHawk or SouthWings, 501(c)(3)nonprofits that work with conservation organizations ranging from The Nature Conservancy and National Audubon Society down to local groups to provide media, government officials, scientists, riverkeepers and others with views of the conditions 1,500 ft. below. The pilots volunteer their services and aircraft, while the organizations depend on grants and donations to support their small staffs.

Launched in 1979 and based in Colorado, LightHawk counts on its 150-200 active aviators for "accelerating conservation success through the powerful perspective of flight." The majority of LightHawk pilots are based outside of the Southeast, which is SouthWings' focus area. Founded in 1996 with headquarters in Asheville, North Carolina, SouthWings has 74 pilots actively covering 15 states.

Jim Becker, a former U.S. Air Force C-130 pilot and LightHawk CEO, says his organization has a "gentlemen's agreement" with SouthWings to abstain from poaching pilots or territory. He describes the counterpart operation as a "wonderful organization" and says the two of them regularly "compare notes to see what's working."

The organizations mirror each other in most of their missions, such as the passengers they carry and the procedures they follow. They are well known among conservation groups, government offices, journalists, researchers and environmental advocates. When a flight request is made, staff environmentalists evaluate the proposed mission for its likely conservational effectiveness in safeguarding ecosystems, protecting habitats and imperiled species and advancing effective policies and practices, or for its educational value or impact on public consciousness. If the project is accepted, then staff contacts local pilots to determine their availability and interest and assigns the mission.

LIGHTHAWK

SouthWings pilots logged more than 100 flights in 2024 and provided some 200 passengers with eyeball confirmation of on-the-ground conditions that otherwise might have gone unseen. After all, airplanes soar over obstacles and can travel easily to remote and isolated locations far from the view of ground-bound inquisitors.

The flights serve to monitor cleanup of spills and toxic sites, document human- or storm-caused threats to waterways and communities, document the impact of mountaintop mining in Appalachia, survey conservation site acquisitions and ensure compliance with proper livestock waste disposal. "We find ourselves very busy after hurricanes," one pilot said. It is that last role to which the opening fact about earthen pits filled with gross pink liquid refers. Details follow.

A SouthWings mission involved flying a photographer over eastern North Carolina, where numerous large pork and poultry farms—aka "concentrated animal feeding operations"—are located. Its resulting aerial image of two slop "lagoons" helped to make the concerns about such operations graphic and compelling for readers of *Sierra* magazine last year. SouthWings notes its flights have resulted in the filing of more than 180 pollution reports with state and federal agencies, a record that received national media coverage.

Meanwhile, Becker says LightHawk pilots last year flew 230 missions, one-fifth of them transporting endangered animals. So, to explain the other introductory fact, while LightHawk's fleet comprises mostly small piston aircraft, it includes four PC-12s, a Beechcraft King Air and several light jets. Because those fly faster, farther and carry more, they are better suited for hauling animals—cheetahs, black-footed ferrets and whooping cranes among them—to breeding centers or for release in appropriate habitats, points often thousands of miles apart.

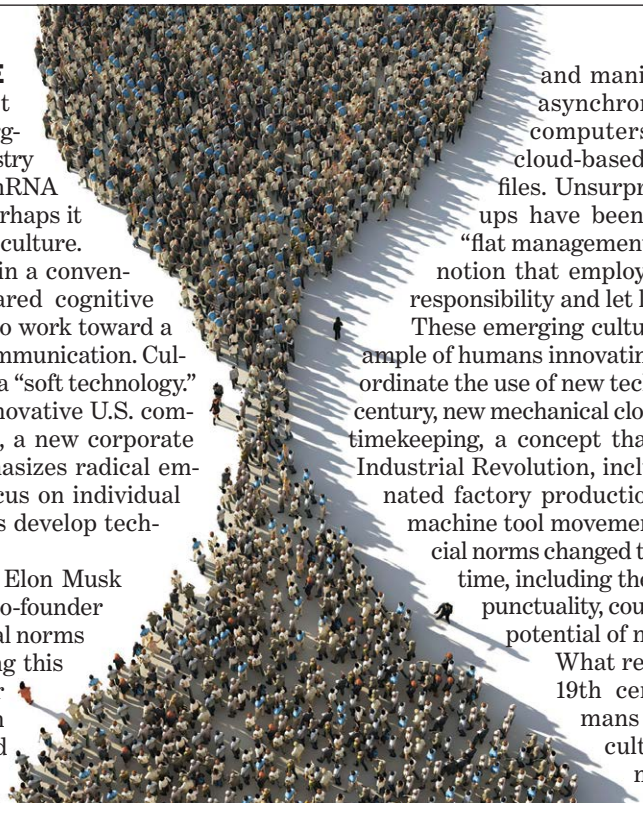
Becker himself planned to begin 2025 co-piloting a LightHawk PC-12 on several roundtrips between British Columbia and Colorado, where 15 freshly captured gray wolves (see photo) were to be released. He says wolves are "intelligent and adaptable," and the mission goal is for the animals to form packs and multiply.

If successful, that would help the once nearly extinct wilderness icon achieve sustainability and balance a natural ecosystem—a fundamental goal of both aviation organizations.

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

QUANTUM LEAP

# GARRETT REIM



## Emerging Cultures

Why social norms are changing **to match new technologies**

**WHAT IS THE** most important technology emerging from U.S. industry today? Artificial intelligence? mRNA vaccines? Reusable rockets? Perhaps it is something less tangible: new culture.

Culture is not a technology in a conventional sense but rather a shared cognitive framework that allows groups to work toward a common goal with minimum communication. Culture is what scholars might call a "soft technology."

Behind many of the most innovative U.S. companies, including in aerospace, a new corporate culture is emerging that emphasizes radical employee autonomy. This new focus on individual judgment is helping companies develop technologies faster.

It is hard to ignore the role Elon Musk has played in this. The SpaceX co-founder and CEO is upending managerial norms for corporate America by taking this idea to new extremes. Consider his advice to Tesla employees on meetings in a now-famous leaked email. "Walk out of a meeting or drop off a call as soon as it is obvious you aren't adding value," Musk wrote. "It is not rude to leave; it is rude to make someone stay and waste their time."

Meetings have long been corporate junctions for information-sharing, decision-making and coordination. Too often meetings become an end, not the means to an end, so employees hate them. People have an intuitive sense that there is something very wrong with the practice.

The problem with too many meetings is that the format is inefficient. Humans process information via reading, speaking or memorizing at a relatively slow pace—about 10 bps, according to an academic article published in December by California Institute of Technology researchers Markus Meister and Jieyu Zheng. What is worse, the 10-bps rate likely reflects short-term, peak performance, with 20 min. generally understood to be the typical human attention span, explains Zheng, a Ph.D. candidate in neurobiology. In other words, the human brain's processing capacity is severely limited.

Perhaps just as bad as a meeting-based culture is one in which information-sharing and decision-making are the privilege of a few managers in the corporate chain of command. Every manager becomes a 10-bps bottleneck, slowing down the engineering process. "The way to solve this is to allow free flow of information between all levels," Musk writes in his companywide email.

Meetings and chains of command are less valuable than ever. Information can now be acquired, shared and manipulated rapidly and asynchronously via personal computers, email, chat and cloud-based digital engineering files. Unsurprisingly, digital startups have been at the forefront of "flat management structures" and the notion that employees should be given responsibility and let loose.

These emerging cultures are the latest example of humans innovating social norms to coordinate the use of new technologies. In the 19th century, new mechanical clocks enabled precision timekeeping, a concept that made possible the Industrial Revolution, including tightly coordinated factory production and synchronized machine tool movement. But only when social norms changed to value the concept of time, including the unheard-of virtue of punctuality, could humans realize the potential of mass manufacturing.

What really happened in the 19th century was that humans used clocks and new cultural values to maximize productivity for the bottleneck of the era: lack of skilled labor. In the 21st century, information technologies and a new autonomy culture are being used to optimize for the bottleneck of this era: lack of thinking capacity.

Zheng says there is little evidence humans can expand their 10-bps processing bandwidth. Human brainpower is likely to remain the chief bottleneck of technological development. Experts in manufacturing or logistics will tell you that if you cannot eliminate or expand a bottleneck, you must optimize for it. In this case, everything must accommodate limited human thinking capacity.

Here is where culture behaves like a super-scalable technology. Humans are adept at recognizing patterns and inferring generalizations, concepts and principles. When Musk emails a list of best practices, emphasizes "common sense" over formal company rules and sets colonizing Mars as SpaceX's goal, employees can fill in the blanks—no need to waste brainpower in a meeting or consulting a manager. Precious thoughts can be spent on engineering instead.

The role of a culture-guided, autonomous modus operandi is likely to grow within the most innovative companies as software expands access to information and artificial intelligence increases productivity of individual employees—allowing one staffer to do what was previously multiple jobs. Expect more workplace norms to be broken.

PHOTO: MIKE KIEV/ALAMY STOCK PHOTO

# MISSION POSSIB

> DESIGNERS ARE PUZZLED AFTER CHINA'S DOUBLE-AIRCRAFT REVEAL

> TRIJET LAYOUT FEATURES POINT TO REGIONAL BOMBER ROLE

> TWINJET CONFIGURATION MAY FACE SPEED AND PAYLOAD CONSTRAINTS

**Graham Warwick** and **Steve Trimble** Washington

China's debut of two new combat aircraft sparked immediate speculation that Beijing had revealed sixth-generation fighters ahead of anything similar emerging in the U.S. But close analysis indicates one is optimized for medium-range strike missions while the other features puzzling design choices that appear to compromise its performance as an air dominance fighter.

Both aircraft have unconventional tailless configurations with no analogs among crewed aircraft known to have flown in the West. While presumably capable of supercruising, the aircraft appear to be shaped more by a desire for all-aspect stealth than by a need for speed.

The two configurations—a delta-diamond wing and a modified lambda wing—have been widely studied as concepts in the West, but the Chinese aircraft are the largest known instantiations to have flown. The designs emerged on Chinese social media Dec. 26, the 131st birthday of Mao Zedong.

The chase aircraft pictured in videos and images posted on social media hint at the manufacturers of the new designs. A Chengdu J-20S shadowed the new trijet, suggesting it is a product of the Avic Chengdu Aircraft Research and Design Institute. A Shenyang Flanker-series fighter chased the new twinjet, linking it to the Shenyang Aircraft Design Institute.

The Chinese government has remained largely silent about the aircraft, which military analysts have speculatively dubbed the Chengdu J-36 and Shenyang J-50. But in a celebratory New Year's Eve video, the People's Liberation Army's Nanjing-based Eastern Theater Command, whose area of responsibility includes Taiwan, hinted at their existence with images of a ginkgo leaf, which resembles the planform of the trijet, and a photo illustration of a bird, which matches that of the twinjet.

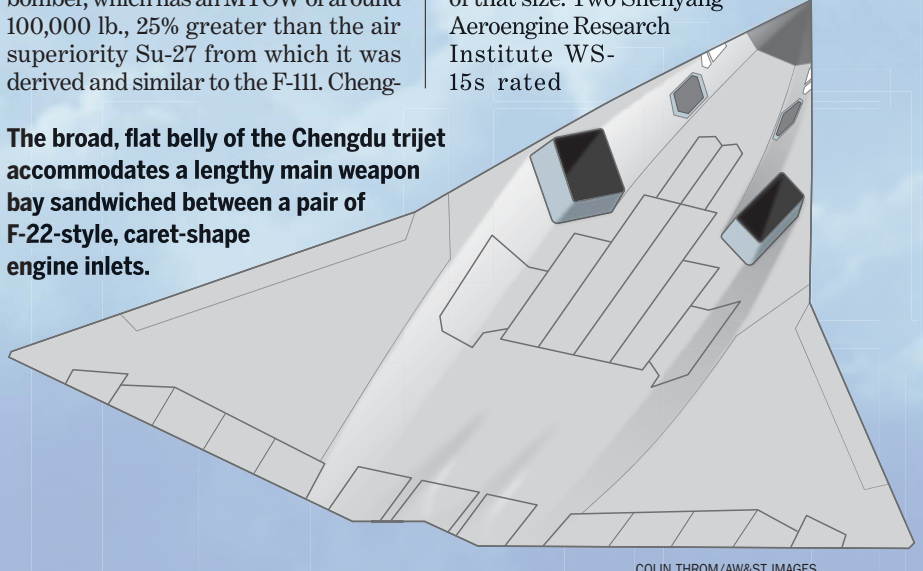
Chengdu's delta-diamond design is a sizable aircraft, likely conferring long range with a heavy internal weapon load. Compared with the 13-m (43-ft.) wingspan of the J-20S chase plane, the trijet is clearly far larger. The new aircraft's tandem-wheel main landing gear and twin-wheel nose gear point to a heavy maximum takeoff weight (MTOW).

The aircraft appears to be at least as big as if not likely larger than the 100,000-lb. General Dynamics F-111, reinforcing the impression that it is intended to serve as a regional bomber. Russia has employed a tandem gear on the Sukhoi Su-34 heavy fighter-bomber, which has an MTOW of around 100,000 lb., 25% greater than the air superiority Su-27 from which it was derived and similar to the F-111. Chengdu's design is probably larger and heavier and may have a greater combat radius than the F-111's 800 nm. The Chinese aircraft appears to have side-by-side cockpit seating, a feature shared with the Su-34 and F-111.

The Chengdu aircraft's most unusual feature is its three engines. The center engine is fed by a dorsal inlet behind the cockpit. The outboard pair are fed by Lockheed Martin F-22-style caret side inlets. All three exhaust into a row of Northrop YF-23-style nozzle trenches on top of the aircraft forward of the wing trailing edge.

"Looking at the Chengdu aircraft, I have a hard time with the three-engine design with the centerline upper inlet," says Darold Cummings, president of ForzAero and chief configuration designer of the YF-23 fighter. "This upper inlet really only works up to about 10 deg. angle of attack, which tells me it is more of an F-111-type bomber-attack aircraft."

There are multiple reasons for using three rather than two engines. One is that China lacks an engine powerful enough to support a twinjet of that size. Two Shenyang Aeroengine Research Institute WS-15s rated



**The broad, flat belly of the Chengdu trijet accommodates a lengthy main weapon bay sandwiched between a pair of F-22-style, caret-shape engine inlets.**

COLIN THROM/AW&ST IMAGES

impact on Russian attack helo **p. 20**

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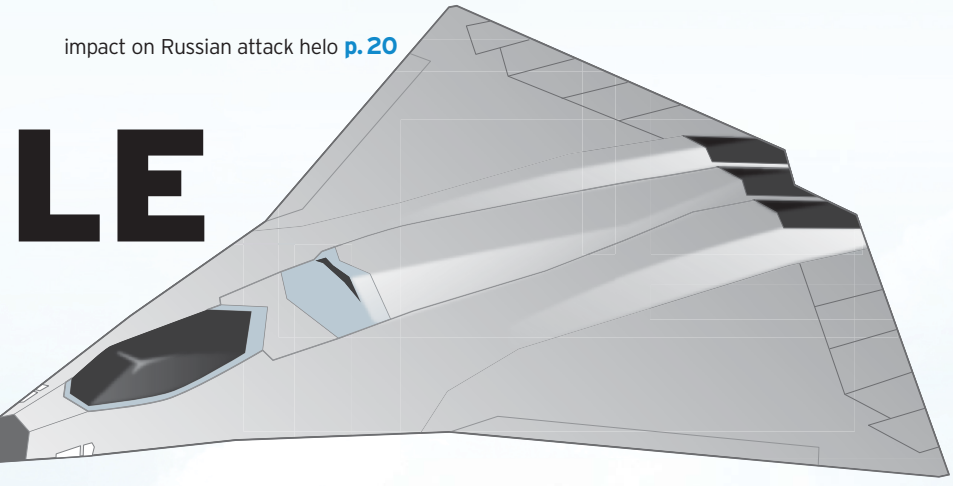


at 40,000-lb. thrust with afterburner power the roughly 80,000-lb. J-20, and the new Chengdu design could be 50% heavier.

There are other possible reasons for the design, too. The center engine could be used for takeoff and sprints but shut down during cruise to extend range. The third engine may support advanced payloads by supplementing the aircraft's electrical power and cooling capacity. Combat aircraft have become ever more hungry for electric power and cooling to satisfy onboard processor and sensor demands.

While the dorsal intake appears to be a diverterless supersonic inlet (DSI), in keeping with the relatively featureless upper surface of the aircraft, the side intakes are not. This is notable because the in-service Chengdu J-20—presumably an older design—has distinctive DSI bumps to improve stealth.

For flight control, the new Chengdu design has five movable surfaces per side on the wing trailing edge: three elevons and an outer pair of split rudders for redundant yaw control in the absence of tails. Air gaps along the edges of the lower outboard nozzle panels suggest the ability to vector thrust for pitch control.

The wide, flat fuselage bottom provides room for a large central bay for air-to-surface weapons, flanked by a pair of smaller bays for air-to-air missiles. Large bays for the forward-retracting main gear are outboard of the weapon bays.

Overall, Chengdu's aircraft seems relatively mature. It is perhaps a later-stage prototype, as suggested by the sensor windows on the forward fuselage chines on both sides, large dielectric panels on either side of the nose and sensor mounts elsewhere on the airframe.

Shenyang's aircraft is more puzzling. It is clearly smaller, similar in size to the Flanker-series fighter chase plane,

**The Chengdu trijet features a dorsal inlet, a delta-diamond planform and possibly a side-by-side cockpit.**

and appears to be twin-engine, with Lockheed Martin F-22-style thrust vectoring nozzles. Its single-wheel main gear provides further indication that it is a smaller, lighter aircraft. Size may indicate that this is a demonstrator or intended for a different requirement than the much larger Chengdu design.

The Shenyang design has a lambda wing, a swept wing with inboard trailing edges that extend back. This increases aspect ratio for higher aerodynamic efficiency while providing more volume for structure and fuel. But for aerodynamic balance, the aft-set wing demands that the forward fuselage generate substantial lift. That was the case with the YF-23 prototype, Northrop's losing bid in the Advanced Tactical Fighter contract that went to Lockheed in 1991.

Boeing used a lambda wing with lifting forebody on its X-45A uncrewed combat aircraft demonstrator aircraft, but Shenyang has taken a different approach. "The forward fuselage of the X-45A is broad and flat and tends to act as a large fixed canard," Cummings says. "The Shenyang [design] has a more conventional forward fuselage, which will not produce as much lift. To achieve increased maneuverability and low speed control, it would probably require thrust vectoring."

Digitally enhanced images show the Shenyang aircraft has control surfaces on the inboard and outboard wing trailing edges. It also has undefined features at the wingtips, which could be embedded drag rudders for tailless yaw control.

"The wingtips appear to fold for added yaw stability and control," Cummings says. "While previous Chinese documents indicate the tail would likely fold up on some concepts, I believe the wingtips on the Shenyang fold down and resemble the Boeing Bird of Prey [stealth testbed]."

The underside of Shenyang's design is the most perplexing. A deep channel down the center of the fuselage divides the area that could otherwise be occupied by a central weapon bay. Flat areas behind the inlets could be weapon bays, but the volume occupied by the intake trunks and main gear bays would seem to restrict their size severely.

Large inlets—flat-sided, roughly triangular and slightly swept—nestle up against the underside of the forebody and may have DSI bumps, although the observations are hampered by the low quality of the available images. The design also appears to concentrate significant cross-sectional area in the middle of the aircraft, where intake trunks and internal bays all occupy considerable space. "I can't imagine the aircraft going supersonic with the area plot that would be generated by stacking up the cross-sections," Cummings says.

"The bottom view of the aircraft is confusing, as there does not seem to be a clear weapon bay, and it would seem the landing gear would be in the way of a side-launch bay," he adds. "That big 'trough' down the center makes no sense. There is no real room for a weapon bay, just the main gear and inlet ducting. Makes me wonder what is the actual purpose of the aircraft."

The appearance of the new combat aircraft did not come completely out of the blue. Since 2019, Pentagon and Defense Intelligence Agency reports about China's military have noted that a medium-range, fighter-bomber aircraft was in development. Wang Haifeng, Chengdu's chief designer, said in 2019 that China would field a sixth-generation fighter by 2035. Yang Wei, chief designer of the J-20, published a 2020 essay previewing requirements for a next-generation Chinese fighter.

These projects should not be confused with the development of China's first long-range stealth bomber. The Xian H-20, which the Chinese Air Force commander acknowledged in 2016, remains hidden from public view. Pentagon reports predict the heavy bomber will enter service by the end of the decade.

*—With Tony Osborne in London*

**Check 6** *Aviation Week editors unpack design details of the two new Chinese combat aircraft:* **AviationWeek.com/Check6**


The 461st Flight Test Sqdn. is tasked with performing 40 F-35 test flights per month.

KYLE LARSON/U.S. AIR FORCE

# U.S. Air Force Faces Key Milestones in Clearing Awaited F-35 Upgrade

> COMBAT-CAPABLE DELIVERY IS EXPECTED THIS YEAR

> MORE COST REDUCTIONS ARE NEEDED, AIR FORCE SECRETARY SAYS

**Brian Everstine** Edwards AFB, California

Long-awaited and much-needed upgrades to the Lockheed Martin F-35 should finally come this year, with deliveries of Block 4-capable aircraft expected. A small unit at the U.S. Air Force's main test base has its work cut out for it to achieve that.

At any time, the 461st Flight Test Sqdn. at Edwards AFB, California, has 10-15 F-35s of all variants and is tasked with flying 40 sorties per month to meet a large backlog of test points. Although the Pentagon has cleared the jet for full-rate production, top officials have long said the delayed Technology Refresh 3 (TR-3) software and hardware modifications in the Block 4 upgrade are necessary to unlock the combat capability needed for the Joint Strike Fighter.

The squadron is flying 20-30 sorties with the new upgrades, albeit limited by a "truncation" plan outlined in the summer to free up a seven-month delivery backlog. The F-35 Joint Program Office began accepting aircraft from Lockheed Martin with a limited TR-3 so more fighters could start flying; additional software upgrades are to come.

Lt. Col. Philip Jackson, commander of the 461st Flight Test Sqdn., said recently that the initial deliveries have functional TR-3 hardware and software, but layered capabilities are still coming online. The Joint Program Office first wanted a reliable trainer, "a jet that can get up, get down, fly around, be dependable," he said.

Within the year, the 461st Flight Test Sqdn. expects to fly all 40 monthly sorties on TR-3 aircraft, coinciding with the expected first delivery of combat-ready aircraft.

In a recent rare visit by media to the Edwards flight line, Jackson showed a small group of reporters the squadron's test plan. While the bulk of flights are on TR-3 aircraft, about 10 sorties per month still focus on testing TR-2 capabilities. "TR-2 is a fantastic [software version], but it's got to end at some point," he said.

The first TR-3 aircraft arrived at Edwards in early 2023, after which about 15 software upgrades were needed for particular fixes. Each upgrade takes about a day to install before it can be tested.

"Everybody wanted TR-3 to show up and be just fantastic, right?" he said. "It turns out it's actually pretty darn difficult to replace not only all the hardware but also all the software."

Each of the aircraft's subsystems is tested individually, and they all must come together for the biggest test point: weapon releases. "To get a weapon to shoot, you're getting a lot of the systems to start fusing together and working together," Jackson said. "We still baby-step it. It's a test."

For example, the F-35's unique Distributed Aperture System (DAS) is "always a tricky one," he noted. The system of cameras around the aircraft fuse in the pilot's helmet-mounted display to provide the ability to look through the airframe, but software complexity has led to issues.

"There are a lot of things not always working perfectly; the DAS is always going to be a bit troublesome," Jackson said. "It's pretty fantastic what it

can do, but again, with that level of capability comes a lot of difficulty, too."

While the new software upgrades are ongoing, the squadron is working to wring out the aircraft's flight sciences. During Aviation Week's visit, the fleet's most recognizable F-35—an A variant with a blue tail, red lightning bolt and flags of all participant nations—landed at the base and taxied by the visitors. Designated AF-01, the flight sciences aircraft was the first F-35 ever built and still flies regular tests at Edwards.

The F-35 Joint Program Office has made it a priority to obtain new-build flight sciences jets for testing, but Jackson expects that will take years. In the meantime, the squadron can outfit other F-35s with sensors and equipment in weapon bays for such tests. However, they lack the wires and other equipment inside the wings that the factory is to install.

**F-35 Production Deliveries**

| | |
|---|---|
| 2011 | 9 |
| 2012 | 29 |
| 2013 | 35 |
| 2014 | 36 |
| 2015 | 45 |
| 2016 | 46 |
| 2017 | 66 |
| 2018 | 91 |
| 2019 | 134 |
| 2020 | 120 |
| 2021 | 142 |
| 2022 | 141 |
| 2023 | 98 |
| 2024 | 110 |
| TOTAL | 1,102 |

*Source: Lockheed Martin*

The squadron at Edwards regularly rotates its aircraft through other test locations, such as NAS Patuxent River, Maryland. Unlike F-35 units elsewhere, such as at training bases, the squadron does not need to fly multiple sorties back-to-back—it can be more deliberate about its flights, which means concerns about mission capability are not as high.

"We're test; we don't double-turn," Jackson said. "We could, but generally we don't. Generally, it's not a good idea because of the level of complexity we have. We have time to sit in the jet for 6 hr., unfortunately, and through the levels of stability and issues we're fighting."

The unit must compete with combat and training units for spare parts, which can be difficult. However, the squadron presses for priority for components needed for TR-3 because the upgrades must go through developmental testing in order to be cleared, Jackson said.

In December, the Joint Program Office and Lockheed Martin agreed on a new contract worth up to $11.8 billion to build 145 more F-35s for production Lot 18. Deliveries are expected to begin in 2027. Air Force Secretary Frank Kendall said at a Mitchell Institute event on Dec. 19 that the deal did not bring costs down enough.

"We need better performance out of Lockheed, quite honestly," Kendall said. "[They're] not delivering what they've been promising, and they're not going as fast as they could by a wide margin."

# Italian and Spanish Eurofighter Orders Propel Production Into 2030s

> ITALY AND SPAIN ORDERED 49 EUROFIGHTERS IN DECEMBER

> UK PURSUES EXPORT CONTRACTS FROM TURKEY AND SAUDI ARABIA

**Tony Osborne** London

Production of the Eurofighter appears assured well into the 2030s following a spate of top-up orders at the end of 2024.

Italy and Spain together ordered 49 aircraft in mid-December—24 for Rome and 25 for Madrid, which is in addition to 20 ordered in 2022—providing an early Christmas present for Airbus, BAE Systems and Leonardo, the manufacturers at the heart of the four-nation fighter program.

The latest orders were "another proud chapter in the program's 'renaissance' period, which is set to continue into the mid-2030s," then-Eurofighter CEO Giancarlo Mezzanatto said in December. He was replaced in early January by Jorge Tamarit Degenhardt, who previously ran the Airbus Defense and Space Eurofighter program.

Airbus Defense and Space CEO Michael Schoellhorn said the Eurofighter orders were not only an "important demand and defense signal" but also would "secure the Eurofighter supply chain . . . across Europe."

Less than a decade ago, Airbus, BAE Systems and Leonardo were debating if they could sustain production of the Eurofighter after completing deliveries to Kuwait and Qatar.

Russia's invasion of Ukraine in 2022 and the resulting uptick in European defense spending have reignited interest in the Eurocanard, however, as the partner nations have acknowledged the need to press forward with its development road map.

Even Germany, which had placed a top-up order for 38 Eurofighters in November 2020, is mulling another 20 aircraft. The timing of the order is uncertain, though, as the country prepares to go to the polls in February.

The new orders guarantee that three of the four Eurofighter assembly lines—in Getafe, Spain; Manching, Germany; and Turin, Italy—will churn out Eurofighters for their respective nations into the 2030s.

The exception is BAE's assembly line in Warton, England, which faces the prospect of a gap in final assembly once it completes the aircraft destined for Qatar.

Labor union calls for a UK Royal Air Force (RAF) top-up order for 24 Eurofighters are unlikely to be heard, given the UK's fragile finances. Instead, London is hoping for new export orders to fill the final assembly gap. It sees prospects from Qatar, Saudi Arabia and Turkey.

Following the state visit of Qatari Emir Tamim bin Hamad Al Thani, a communique from Doha appeared to declare orders for 12 more Eurofighters, but mention of that order was removed in a later version of the document.

Ratcheting up efforts to sell to Turkey, the UK government sent two RAF Eurofighters to Ankara in December to give government officials a closer look at the aircraft. This coincided with a visit by UK Defense Procurement and Industry Minister Maria Eagle. Turkish interest in ordering some 40 aircraft is at an early stage but has advanced since Berlin allowed UK officials to provide Tur-

key with classified briefings on the fighter's capabilities.

In Italy, as in Germany, the new Eurofighters will replace the earlier Tranche 1 aircraft, which are costly to upgrade with active, electronically scanned array radars. Meanwhile, the new batch of aircraft that Spain is acquiring through the Halcon II program will replace part of its mainland-based McDonnell Douglas EF-18 Hornet fleet.

All 49 aircraft will come from the Tranche 4+ production batch, and deliveries are planned for 2030-35.

Questions remain about how Spain will replace the remainder of the mainland-based EF-18 Hornet fleet. Madrid is expected to opt for the Lockheed Martin F-35 Joint Strike Fighter, given its previous stance on operating both European- and U.S.-made types. Yet F-35 procurement in Spain is controversial. The type is jokingly referred to as the "Voldemort"—a Harry Potter reference to a name that should never be uttered—because of political and workers union concerns (*AW&ST* June 5-18, 2023, p. 35).

Beyond new orders, the Eurofighter partner nations have agreed on the first contracts that will pave the way for the Long-Term Evolution midlife update. The program funds initial work to upgrade the cockpit, mission and flight control computing and the

# Boeing 757 Testbed Modified To Validate GCAP Sensors

> EX-TITAN AIRWAYS AIRCRAFT TO TEST COMBAT FIGHTER SENSORS

> MORE MODIFICATIONS TO BE ADDED BEFORE TEST FLIGHTS IN 2026

**Tony Osborne** MOD Boscombe Down, England

One of the most complex UK civil aviation certification programs in a generation aims to shorten and derisk development of the complex mission systems for the trinational fighter that is to emerge from the Global Combat Air Program.

The adaptation of a former Titan Airways Boeing 757-200 airliner into a flying testbed has presented its share of engineering challenges for 2Excel Aviation, the company contracted by the UK arm of Italy's Leonardo to build and operate the flight-test aircraft.

The primary role of the 757—named Excalibur—is inflight testing of the technologies associated with the Integrated Sensing and Non-Kinetic Effects (Isanke) and Integrated Communications Systems (ICS) planned for the Global Combat Air Program (GCAP) fighter (*AW&ST* Dec. 9-22, 2024, p. 34).

Testing these systems demands as

**The 757 was modified to include a large cheek blister and under-fuselage fairings. More external fairings will be added over the next year.**

DAVE TURNBULL/QINETIQ

AIRBUS DEFENSE AND SPACE

**Spain has ordered 45 Eurofighters over the past three years, which will expand its fleet to 115 aircraft, once all the fighters are delivered.**

aircraft's communications equipment. The upgrade, due to reach the front line in the 2030s, aims to keep the aircraft relevant into the 2060s.

In a further sign of increasing harmony, the partner nations also agreed on funding for a single type of helmet-mounted display, the BAE Systems Striker II. That lays the groundwork for integrating the helmet on Eurofighters in the Phase 4 Enhancements upgrade package that is to enter service before the end of the decade.

wide a field of regard as possible, so 2Excel has designed and built several fairings to prove Isanke-ICS systems such as the Multifunction Radio Frequency System (MFRS), infrared search and track and defensive aids technologies.

The first phase of this modification work, including two cheek blisters mounted on the fuselage near the cockpit and a single underbelly fairing, was completed in November. The modified aircraft made its first flight from the Qinetiq-operated airfield here Nov. 26.

The blister design had to take into consideration the impact of drag, noise, icing, vibration and aircraft performance, says Chris Norton, one of 2Excel's founders.

Ahead of their installation, 2Excel dismantled another 757 to generate data for the modifications. Engineers confirmed the need for radical strengthening of the fuselage around where the fairings would be installed, as well as the addition of a new air data system mounted atop the vertical stabilizer to address concerns that the aircraft's air data system would be "corrupted" by the addition of the fairings and the associated impact of shock and pressure waves on the system.

Through early flights, engineers have been able to understand the impact of the modifications on the system, and they introduced a "correction curve" to the air data system.

Despite increased noise, test pilots reported that the aircraft "still flies like a 757," Norton says. He describes the project as "the biggest thing to have happened in [UK] civilian flight test for decades."

Internally, the aircraft is being adapted to fit workstations for 10 engineers, mission equipment racks, seating and space for future requirements. Wiring and networking cables have been installed, along with a liquid cooling system that will feed into a pair of external heat exchangers mounted on small ventral fins, which will improve the stability of the aircraft as it receives additional modifications.

**"Next steps for the 757 testbed include**

the fitment of a new nose into which the MFRS radar will be installed, along with an infrared search and track system, while a chin fairing will likely feature an electro-optical targeting system."

Next steps for the 757 testbed include the fitment of a new nose into which the MFRS radar will be installed, along with an infrared search and track system, while a chin fairing will likely feature an electro-optical targeting system.

Because the Isanke sensors weigh about half a metric ton—considerably heavier than the 757's standard weather radar—2Excel had to prove that the aircraft can handle three-point and nose-wheel-first landings in the event of a high-sink-rate touchdown.

Also planned is the addition of another, even larger under-fuselage fairing with a flat panel behind the wing, as well as sensor housings on the wings outboard of the engines. 2Excel has made accommodations for further changes to the airframe should they be needed.

Once those are completed, 2Excel hopes Civil Aviation Authority certification will allow the aircraft to begin flying technology demonstration program (TDP) elements of the Isanke and ICS systems in 2026. Those elements would be added progressively to the aircraft, although some TDP trials already have taken place, officials say. Initial trials are expected to focus on UK-developed technologies, but GCAP partner nations Italy and Japan also will likely want to use the platform, says Andrew Howard, director of Future Combat Air Systems at Leonardo UK. Such flights could start in the late 2020s.

"This is the most efficient route to derisking that capability before we put it on the very expensive and high-demand development aircraft," says Jonathan Smith, Leonardo vice president of capability for Future Combat Air Systems.

Such airliner testbed conversions are not new. Lockheed Martin used the Catfish 757 for its F-22 program and a Boeing 737 for the F-35, while China adapted a Tupolev Tu-204 for the Chengdu J-20 program.

The UK has not been able to lean on the U.S. experience over concerns about the impact of International Traffic in Arms Regulations.

RUSSIAN DEFENSE MINISTRY

# Western Sanctions Cause Havoc for Russian Helicopter Radars

> RADAR-MAKER ZASLON SEEKS ALTERNATE COMPONENT SUPPLIERS

> MIL MI-28NM RADARS REPORTEDLY REMOVED AFTER CRASH

**Piotr Butowski** Gdansk, Poland

Russian military aerospace industry has been able to sustain production of combat aircraft and helicopters, but Western sanctions mean some of the systems' operations have become degraded.

One indicator that Russia may be struggling under the sanctions is production problems with the RZ-001 Rezets radar for a new version of the Kamov Ka-52M Hokum attack helicopter. While the country has tried to gloss over the impact of trade restrictions, legal documents from litigation between Ka-52 manufacturer Progress Arsenyev and St. Petersburg-based radar-maker Zaslon in the Moscow Arbitration Court in 2024 have revealed industrial disruptions.

According to the legal documents, Zaslon was supposed to deliver 15 RZ-001 Rezets radars for the first production batch of the updated Ka-52M helicopters in 2022. Some two years later, no radars had been delivered.

Th RZ-001 is a key feature of the Ka-52M, which has new sensors and weapons. Among them are the modernized GOES-451M electro-optical targeting turret that offers increased target detection and recognition range and the L418 Monobloc self-defense suite. The most important novelty in the helicopter's armament is the Kh-39 guided missile, which has a range of up to 14.5 km (9 mi.).

The radar operates in the X-band and features a fixed 900 X 300-mm (35 X 12-in.) active, electronically scanned array, with 640 transmit-receive modules. Zaslon says the system can detect a group of tanks at a range of 45 km and a railway bridge at 100 km. In air-to-air missions, the company says it can detect a fighter aircraft up to 50 km away and a hovering helicopter 20 km away. The radar weighs 130 kg (287 lb.), 10 kg less than the current FH-01 Arbalet-52.

**Russian Mil Mi-28NM attack helicopters have allegedly been operating in Ukraine without their mast-mounted radar.**

According to the legal documents, Zaslon said some foreign electronic components it required were missing because suppliers and logistics companies balked at delivering the needed items to Russia. The company said it could not source some of those components locally because the production capability does not exist in Russia. While Zaslon said it was looking for alternative suppliers, the lack of radar deliveries suggests it has not been successful.

The radar-maker tried to deflect blame, noting that it signed the original supply agreements before expanded Western sanctions on Russia came into force in the wake of the February 2022 attack on Ukraine; Moscow's 2014

invasion and annexation of Crimea had triggered the first round of trade limits. The court nevertheless found Zaslon in breach of contract because it had failed to prepare an import substitution program for the RZ-001 radar as required by government regulations issued several years earlier.

The documents also revealed the radar's unit cost: 150.6 million rubles, including 20% value added tax, adding up to about $2.2 million at 2022 exchange rates before the ruble plunged in the face of sanctions. The radar costs about twice that when adjusting for purchasing power parity.

The situation raises questions about the Ka-52M helicopters Russian forces have used in Ukraine. In 2022, the Progress plant made about 12 Ka-52Ms; it produced 25-30 in 2023 and 2024 each. Russia may be operating the helicopters without a radar or relying on the Arbalet-52 system used on earlier Ka-52s. The radar is a secondary sensor on that type, with weapons guided via electro-optical sensor.

The Mil Mi-28NM Havoc attack helicopter also appears to be struggling with its radar supply. The type originally sported mast-mounted N025M radars made by GRPZ. The first test helicopters, produced in 2016-19, featured the system, as did the initial production batches produced starting in 2020.

However, all Mi-28NMs being used against Ukraine allegedly appear to be operating without radar. According to assertions on Russian social media channels, the systems were removed after an Mi-28NM crashed on May 12, 2023, when the radar ball broke off.

The N025M is a multichannel $K_a$- and X-band radar used for surface mapping, surface-target detection and target indication to cue the electro-optical sight. It also has weather detection and air-to-air functions, plus a third channel in L-band for identification friend-or-foe functionality.

Russia's equipment woes likely go beyond helicopters and might be affecting and may be, potentially affecting its most advanced tactical combat aircraft, the Sukhoi Su-57 Felon. The Komsomolsk-on-Amur Aircraft Plant producing the rotorcraft has repeatedly missed delivery targets, including a plan to hand over 12 in 2024. Available satellite imagery indicates that few Su-57s are in service, underscoring that deliveries have fallen short.

# Investigators Seek Clues in Jeju Air Accident Sequence

> A BIRD STRIKE PRECEDED THE EMERGENCY LANDING

> THE PILOTS EITHER COULD NOT OR DID NOT EXTEND LANDING GEAR

**Sean Broderick** Washington

A poorly conceived navigational antenna explains why a runway overrun escalated to a catastrophic accident that killed 179 people on a Jeju Air Boeing 737-800 on Dec. 29. But investigators are still piecing together the disaster's bigger mystery: What prompted the rapid emergency landing with no landing gear that put the out-of-control aircraft on a collision course with the antenna?

JUNG YEON-JE/AFP/GETTY IMAGES

**The remains of Jeju Air Flight 2216's empennage lay next to part of the concrete foundation (far left) used to reinforce the antenna it struck. The airport's perimeter fence is in the foreground.**

Jeju Air Flight 2216 was concluding an otherwise routine early-morning flight from Bangkok to South Korea's Muan International Airport when its problems began. On final approach to Muan's Runway 01, the pilots declared an emergency, citing a bird strike, per a timeline released by South Korea's Ministry of Land, Infrastructure and Transport (MOLIT).

The pilots broke off the initial approach and requested permission to land immediately on Runway 19—the opposite end of the originally assigned runway. Muan air traffic controllers approved the request. The 737-800 landed within 2 min., but its landing gear remained stowed.

The aircraft touched down on its belly, skidded beyond the 2,800-m (9,200-ft.) runway's end, through the runway end safety area (RESA) and into an instrument landing system localizer antenna mounted on a dirt-covered concrete foundation. The impact and resulting fire killed all but two people onboard and destroyed most of the aircraft.

A joint investigation team led by South Korea's Aviation and Railway Accident Investigation Board (ARIB) gathered at Muan International to conduct the on-site portion of the probe. Representatives from the U.S. NTSB and FAA as well as Boeing and GE Aerospace are assisting. GE and Safran are joint-venture partners in CFM International, which makes the 737-800's CFM56-7B engines.

Officials have released few technical details about the accident sequence. Lead investigator Lee Seung-yeol confirmed during a Jan. 7 press briefing that bird residue was found in one engine, although he stopped short of linking the bird strike to any technical faults that may have contributed to the overrun. The second engine is still being analyzed, as are other key parts that may have played a role in the accident.

Investigators expect to have preliminary analysis of the aircraft's flight data recorder (FDR) data by mid-January, Lee said. Jeju Air Flight 2216 's FDR was flown to Washington on Jan. 6 for data extraction at the NTSB's labs. Damage to the recorder had prompted ARIB to seek the NTSB's assistance. The FDR was recovered without a connector linking the data storage and power supply units, complicating the data extraction process, MOLIT said.

Investigators have compiled a transcript from the aircraft's cockpit voice recorder, but no details have been made public.

Clues from both recorders are expected to help investigators understand why the pilots landed so quickly after declaring an emergency and why the landing gear was not deployed.

Pilots faced with inflight alerts often take time to troubleshoot, running checklists to isolate potential failures and eliminate risks if an emergency landing is necessary. But some problems, such as indications of onboard fire or loss of all engine power, require an immediate landing.

Investigators will look closely at the bird encounter and any failures that may have compromised key systems on the 737-800 or prompted the crew to land quickly. They also will examine why relevant backup systems, such as the 737-800's ability to lower landing gear manually, were not used.

The localizer antenna struck by the out-of-control aircraft is being scrutinized as well. The structure was located about 260 m beyond the runway end and 45 m from an airport perimeter road, Google Earth imagery shows (see diagram).

International Civil Aviation Organization design standards for air carrier airports call for RESAs, or obstacle-free space beyond runway ends, to be at least 240 m long, meaning Muan's configuration technically complied. But the structure itself, a mound of earth covering a solid concrete foundation that protruded significantly above grade, did not appear

to comply with the latest standards.

International standards for any object in a RESA call for specific design features that minimize risk to aircraft in an overrun. FAA guidance requires any navigational aids within a runway safety area to be frangible to within 3 in. of grade, for instance. Examples include antennas with concrete foundations buried in the ground. Elements that extend above the 3-in. maximum height must be constructed to break away using frangible bolts, couplings or similar design elements.

The Jeju Air accident has prompted South Korean officials to order reviews of landing systems at 13 airports and evaluate regulations governing their installations.

"Localizer structures will be rapidly improved to better address safety concerns, regardless of compliance," MOLIT Minister Park Sang-woo said during a Jan. 7 briefing.

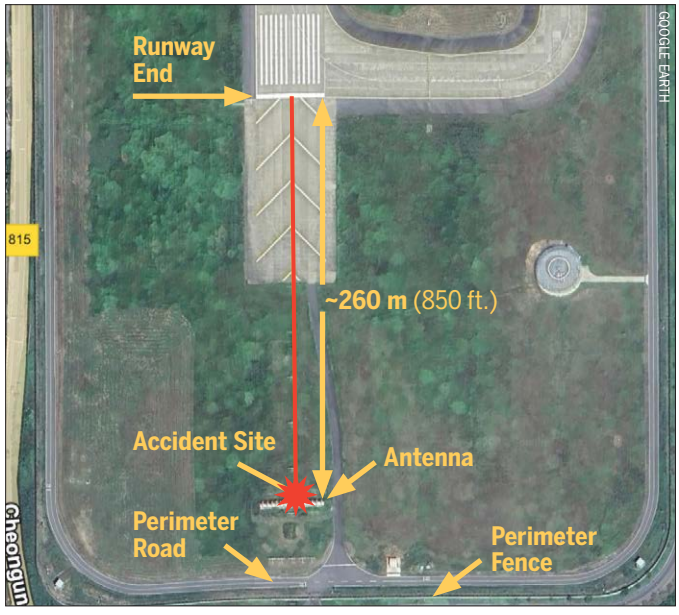
MOLIT also ordered safety inspections at six airlines that operate 737-800s.

Separately, South Korea will assemble an expert team to review national aviation safety, Park said.

Police investigations into Jeju Air and Muan International have also been launched.

Park said he intends to resign as part of the accident's fallout. "I feel a heavy responsibility for this disaster," he told reporters. "I intend to act appropriately and am currently discussing appropriate methods and timing."

## Jeju Air Accident at Muan International Airport




**The 737-800 slid past the runway end and into the concrete-reinforced antenna located 260 m away.**

# Europe's eVTOL Sector on the Brink

> LILIUM FACES UPHILL CLIMB AFTER SECURING INVESTORS

> VOLOCOPTER DECLARES BANKRUPTCY AS SHAREHOLDER TALKS LANGUISH

**Jens Flottau** Frankfurt and **Ben Goldstein** Boston

The divergence between the prospects for advanced air mobility startups in Europe and the U.S. is growing more stark by the week.

While U.S. companies Archer Aviation, Beta Technologies and Joby Aviation are flush with cash and accelerating their development and certification programs, European startups Lilium, Volocopter and Vertical Aerospace are each confronting financial crises that could threaten the future of Europe's nascent advanced air mobility (AAM) industry.

VOLOCOPTER

Volocopter is aiming to certify the two-seat VoloCity this year.

Two of the three European companies—German startups Lilium and Volocopter—were forced to declare bankruptcy after German lawmakers rejected their last-ditch attempts to secure loan guarantees, drawing their futures into question.

For Lilium, at least, things may be looking up. In what some industry-watchers described as a Christmas miracle, a consortium of European and North American investors under the moniker Mobile Uplift Corp. (MUC) agreed on Dec. 24 to buy the company's assets and finance operations until maturity, likely meaning type certification. The group has pledged to inject €200-300 million ($209-309 million) into the startup, which it estimates should be enough to see the Lilium Jet through to certification. The transaction is expected to close in the first quarter.

MUC is led by Munich-based private equity firm General Capital and its Founding Partner Philipp Schoeller. Primary investors include a fund managed by U.S. venture capital group Fifth Wall and a yet-unnamed European party. General Capital and Early-bird, the initial MUC backers, also are participating with small stakes, as are battery producer CustomCells and some of Lilium's creditors and pre-insolvency shareholders. While Schoeller will lead the group initially, industry sources say Lilium CEO Klaus Roewe may eventually fill that role.

Tencent, currently Lilium's largest investor, has notably stayed away from the group and would no longer own a stake in the company upon emergence from the insolvency proceedings.

While resuscitating the company is certainly good news for Lilium, it will be anything but easy. Creditor committees of its two subsidiaries still must form and subsequently approve the asset sale to MUC. That process could last until the end of the first quarter, which leaves considerable uncertainty for Lilium's former employees, nearly all of whom were laid off on Dec. 20.

It is also unclear whether MUC will have the wherewithal and patience to commit the funds needed to finance Lilium's long road to certification. The company had been planning to certify in 2026, but that target likely will slip to 2027 or 2028, estimates Sergio Cecutta, a founder and partner at SMG Consulting. Before entering insolvency, Lilium had been spending around €100 million per quarter, raising questions about how far the €200-300 million committed will go.

"The extra €200-300 million is not nearly enough to certify unless some big changes are made," Cecutta says. "Also, a lot of talent in the rank and file will likely be lost by the restart date, making the work ahead even more challenging."

Like Lilium, Volocopter is in dire straits. The startup announced on Dec. 29 that it had filed for bankruptcy after failing to secure a long-planned capital increase from existing shareholders. Normal business operations will continue during the insolvency process, but the company is under pressure to find new investors before an end-of-February deadline.

Before declaring insolvency, Volocopter had been in negotiations with shareholders for months, but it ran out of time and money as talks dragged on. Chinese technology group Geely—which owns the Volvo and Geely car brands—has reportedly been in talks about acquiring a majority stake in the company. While it may never materialize, such a move would likely see Volocopter shift its operations to China, where the AAM and commercial drone industries are booming under Beijing's low-altitude economy initiative.

Volocopter is currently in the middle of the certification campaign for

the two-seat version of its VoloCity, initially planned for mid-2024. The two-seater is not seen as commercially viable for operators, given that it can accommodate only one passenger. The company therefore plans to make a larger four-seat version.

Despite its financial woes, Volocopter probably still can certify the VoloCity in 2025, according to SMG Consulting forecasts. But certifying the larger, next-generation aircraft will require sizable further investment—although not as much as the first-generation VoloCity, considering the two aircraft are likely to share the same basic design.

"The difference between Lilium and Volocopter is that €200 million will be enough for Volocopter to certify, enter service and start low-rate initial production," Cecutta says. "For Lilium, the €200 million will last them 6-9 months."

Over in the UK, meanwhile, Vertical Aerospace finally has resolved a dispute with an activist investor and creditor in a deal that raises $50 million, deleverages its balance sheet by converting $130 million in debt notes and grants majority ownership to the investor, U.S.-based Mudrick Capital.

With its balance sheet shored up, Vertical says it is now in better shape to raise additional funds this year. But as capital markets remain tight, doubts persist about whether the startup can finance its path to certification in 2028.

The turmoil facing Europe's three leading AAM startups stands in contrast to the scene in the U.S., where Archer, Beta and Joby have raised billions of dollars and appear on track to certify by late this year. Similarly, China already has certified the first electric vertical-takeoff-and-landing (eVTOL) aircraft from EHang and AutoFlight, and plenty of other Chinese startups are waiting in the wings.

To be sure, none of Europe's three major eVTOL companies can be written off yet. Volocopter is well into its certification flight-test campaign; Vertical is approaching its first crewed flight; and Lilium's first piloted aircraft is in final assembly.

But certifying an eVTOL is expensive: SMG Consulting estimates the price at $1.5-2 billion. Unless the financial prospects of Lilium, Vertical and Volocopter radically improve in 2025, it appears increasingly likely that U.S. manufacturers will come to dominate the European market.

# Europe's SAF Mandate Comes Into Force, But It Is Just the Beginning

> ReFuelEU sustainable aviation fuel mandate is now in effect

> Legislation includes a submandate for e-fuel

**Helen Massy-Beresford** Paris

**THE NEW YEAR BRINGS** new rules, in Europe at least. The EU's sustainable aviation fuel mandate took effect on Jan. 1, requiring the use of a progressively growing proportion of the alternative fuel, starting at 2%.


NESTE

The mandate, part of ReFuelEU legislation, is aimed at kick-starting the mass production of sustainable fuels and encouraging development of the e-fuel that should take on an increasingly important role in decarbonizing aviation.

But airlines say the mandates are not enough and more needs to be done to help them incorporate sustainable aviation fuel (SAF) into their operations.

The International Air Transport Association (IATA) said in December that growth in SAF volumes was still disappointingly slow. At its annual global media day on Dec. 10, IATA put the focus on traditional oil companies, saying the onus is on them to boost SAF volumes and on governments to make that a reality.

IATA Director General Willie Walsh said the role of traditional fuel producers is "a big problem" in the global drive to ramp up SAF volumes so that the aviation industry could make progress toward meeting its net-zero-emission goal.

"The big fuel producers have made great announcements and look for lots of plaudits, Shell and BP included," Walsh said. "[But they] have . . . pulled back from the commitments that they made in terms of producing sustainable fuels. They need to play their part. We can't just rely on new entrants into the market."

Part of the problem is mixed signals from governments that continue to offer subsidies for exploration and production of fossil fuels, IATA said.

"Governments can accelerate progress by winding down fossil fuel production subsidies and replacing them with strategic production incentives and clear policies supporting a future built on renewable energies, including SAF," Walsh said.

IATA's chief economist and senior vice president for sustainability, Marie Owens Thomsen, also said that the "elephant in the room" of government fossil fuel subsidies needs to be addressed. "Governments are driving the car with a foot on the brake and a foot on the gas pedal, both at the same time, and then they're pretending to look surprised when we're going nowhere," she said.

Owens Thomsen noted that all industries rely on fossil fuels, but not all are coming under the same pressure over decarbonization as the airline sector. "The enemy is not the activity—the enemy is the energy source," she added.

IATA released new SAF production estimates indicating that 1 million metric tons of SAF was produced in 2024, double the volume in 2023. But SAF accounted for just 0.3% of global jet fuel production, although previous estimates had projected SAF production would reach 1.5 million metric tons in 2024. The shortfall is because key SAF facilities in the U.S. have pushed back their production ramp-up to the first half of 2025.

**SAF volumes in Europe are growing, but airlines say they are not increasing quickly enough.**

The association said SAF production was expected to reach 2.1 million metric tons, or 0.7% of the total for jet fuel in 2025.

In Europe, the new mandate requires 2% SAF at EU airports this year, rising to 70% by 2050. Synthetic fuel should account for 1.2% by 2030 and 35% by 2050 under the new rules.

A recent report by the European Union Aviation Safety Agency (EASA) highlighted the big stumbling block for airlines when it comes to SAF uptake: the price. The Dec. 5 EASA report noted that the price for conventional jet fuel was €816 ($847) per metric ton in 2023; SAF, excluding e-fuel or synthetic fuel, was €2,768; and synthetic SAF was €7,500, an estimate given that synthetic fuel was not available on the market.

EASA said its production capacity assessment for the EU showed that the announced SAF capacity is expected to meet the minimum SAF share requirement by 2030. Walsh said he is less optimistic.

"SAF volumes are increasing but disappointingly slowly," he said. "We're not making as much progress as we hoped for, and we're certainly not making as much progress as we need."

An IATA analysis shows that to reach net-zero $CO_2$ emissions by 2050,

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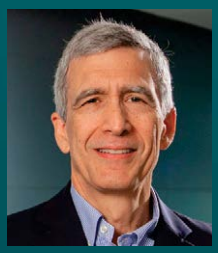

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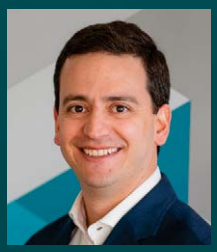

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TT REPAIRS

between 3,096 and 6,658 new renewable fuel plants will be needed. These will also produce renewable diesel and other fuels for various industries.

The capital expenditure needed for those new facilities could total $3.9-8.1 trillion, IATA said, with an average annual capital expenditure over the 30-year period of about $128 billion, in the best-case scenario.

IATA called for three key steps to boost SAF progress. First, increase co-processing. By using existing refineries, the lead time for producing SAF could be reduced to 18-24 months from 4-5 years for an all-new plant.

The association called for allowing more renewable feedstock to be co-processed alongside fossil streams. The current limit is up to 5%, but discussions are underway to increase that to 30%, which would help, said Preeti Jain, IATA's head of net-zero transition programs. For now, though, achieving even the 5% level could make a difference.

The second key step is diversifying SAF production from the current 11 certified pathways.

The third major step is establishing a global SAF accounting framework to increase transparency as well as a book-and-claim approach to allow airlines in parts of the world without SAF production to use the fuel without physically having to transport it around the world, IATA said. The association's SAF Registry is in the pilot stage; 30 airlines are taking part. The system is expected to be launched in April.

"Such a registry is necessary for achieving a global SAF market where all airlines can buy SAF, and all SAF producers can sell their fuel to airlines," IATA said.

Walsh also said mandates in some European countries were not having the desired effect, because producers that are fined for not meeting the required levels simply pass the penalties on to airlines, which then pass them on to consumers.

"There's zero environmental benefit," Walsh said. "Politicians are patting themselves on the back for the wonderful measures they have taken to try and promote the production of sustainable aviation fuel without actually asking themselves: 'Are these measures leading to the result that we want?' And that's what we find disappointing."

# French Aerospace Engineering Schools Expedite Green Curricula

> TEACHING PROGRAMS AND CAMPUSES ARE TRANSFORMING

> WITH TRAINING CENTERED ON SUSTAINABILITY, GRADUATES SHOULD INFLUENCE THE INDUSTRY IN THE COMING YEARS

**Thierry Dubois** Toulouse and Lyon

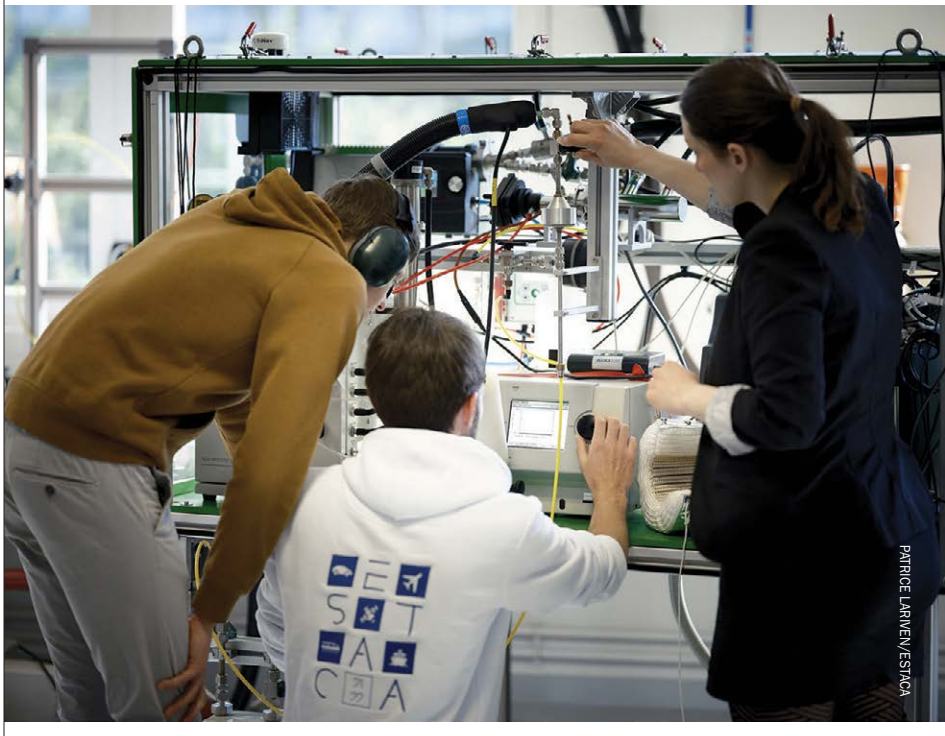
**FIRST IN A SERIES** France has half a dozen engineering schools feeding the entire European aerospace sector. Airbus CEO Guillaume Faury graduated from Toulouse-based ISAE-Supaero in 1992; European Union Aviation Safety Agency Executive Director Florian Guillermet graduated from ENAC, also in Toulouse, in 1997; and numerous senior executives at various companies graduated from Supaero, ENAC, Estaca, ISAE-ENSMA and others.

Those schools have been adjusting to meet a legal requirement that their teaching programs include environmental issues. Among the main factors in the accelerating transformation is the scientific culture of teachers, many of them researchers, which adds to widespread public awareness of climate change.

The teaching programs' greening is in full swing, although some schools are moving faster than others. This means young graduates are well aware of aviation's climate impact, which is taking center stage, and they have an expanding knowledge of breakthrough technologies that may cut air transport's carbon footprint. The new syllabi are expected to influence the entire industry.

Thanks to their new skills and more comprehensive vision, future engineers' professional profiles should be more attractive, and it should be easier for them to make themselves heard.

Student expectations have helped boost this transformation, although several have remarked that the industry is doing too little, too late. At some schools, such as Supaero, students have voted with their feet, choosing




PATRICE LARVEN/ESTACA

**Estaca is one of France's engineering schools where students are learning breakthrough technologies that might slash aviation's carbon footprint.**

to work in other sectors in an increasing proportion.

A speech at Supaero's graduation ceremony in December 2023 sent shock waves through the aerospace industry and academia. "Becoming an engineer, is that the solution or the problem itself?" Anais Bouchet, the student delegate, asked in her address.

Bouchet had been at the forefront of an awareness-raising campaign at Supaero in the preceding years. "I participated in Supaero's sustainability working group, which was active in 2020-22," she says. "The group spent one year defining a road map and one year starting to implement it. The implementation phase was planned over five years."

She saw fast beginnings in Supaero's three-year program, but after a self-congratulatory period, progress waned, she says. "Supaero did not follow the road map it assigned itself," she recalls. "Environmental issues have yet to be included across the board in teaching programs.

"The industry is not evolving fast enough," she adds. "I believe few promises will be kept. The sector's thinking is based on techno-solutionism. In fact, aerospace players do not see a path for the technologies they are researching."

Bouchet understands those who leave aerospace. "To have the greatest impact, you have to feel you belong to where you are," she notes. "Staying in the industry in the hope of contributing to change is perfectly respectable. If students leave the sector because they find it is doing too little, too late, then they make their point. That's a respectable attitude, too."

Becoming aware of environmental issues while studying is quite normal, she adds: "That's when you think about your future job. It is commendable. It means the student develops a critical eye and finds motivation for change."

Bouchet created Erable, a finance company outside the aerospace sector, to spur sustainable investments. "Under our revenue-sharing model, investors can fund impactful projects," she explains.

Bouchet's speech echoed widely shared views. Students have expressed their expectations for more environmentally oriented courses in different ways, with varying levels of success. Edouard Butaye, who graduated from Poitiers-based ENSMA in 2021, participated in an attempt at the ENSMA level, a partnership of six aerospace schools in France, including Supaero, ENSMA, ENAC and Estaca.

Butaye served as president of the ENSMA social and environmental students' association, which aimed "to discuss social and environmental issues with ISAE's management team," he says. "The idea was approved, but red tape impeded the effort." ENSMA, which also is reviewing its programs, did not return Aviation Week's requests for an interview.

At Paris Saclay-based Estaca, Baptiste Loose leads the environmental branch of the RHEA student association for personal development. RHEA introduced the Ogre, a workshop focusing on what producing energy entails and the energy impact of our ways of life. "Estaca has now integrated it in its teaching programs at the start of the second year [in its five-year program]," Loose says.

While students have pushed engineering schools on including environmental issues in syllabi, most of the power to change lies in the hands of management teams and boards of directors.

ENAC says it is revamping course content. "In every subject, we integrate environmental issues," ENAC Director Olivier Chansou says. "That can take various forms, depending on whether we are talking about a theoretical matter, such as mathematics, or something more applied. We created a large matrix to determine where environmental and societal topics should be added."

Every year, Chansou and his team update more courses. "In two years, we have completed what we see as most important," he says. "Over 3-4 years, we will have ticked all the boxes."

Estaca has been thorough when including sustainability issues in teaching programs. Among five new courses, four are environment-related: carbon footprint, energy technologies and low-carbon energy, design life-cycle assessment and smart city, which has to do with the integration of transport modes in society. "Over their five years at Estaca, students have time to assimilate those topics," Training Director Philippe Guibert says.

With the help of RHEA, Estaca has created Transition Wednesdays: lectures and panel discussions on the environmental transition. "We organize 10-14 of them per year, and they are part of mandatory courses," Guibert says. Mining resources and the relationship between capitalism and sustainable development are among the topics covered. "Engineers must have a critical perspective on their work to assess the impact of their decisions," he stresses.

At Estaca's Bordeaux campus, students can spend their fifth and final year focusing on sustainable transport. "Sustainable aviation fuel (including biomass-based fuel, e-fuel and hydrogen) and eco-design courses are new and specific to our Bordeaux campus," Guibert says. "In our new courses, we have included hybridization and electrification. Those topics are studied more in-depth in Bordeaux."

Supaero President Marie-Helene Baroux is betting on research. "Most of our teachers are also researchers," she says. "Some 35% of their projects relate to sustainability. By the end of 2026, we are aiming to increase that proportion to 40%. That research work on sustainability feeds into our teaching programs."

Some teachers come from industry, and sustainability has a growing importance in their lectures, she adds.

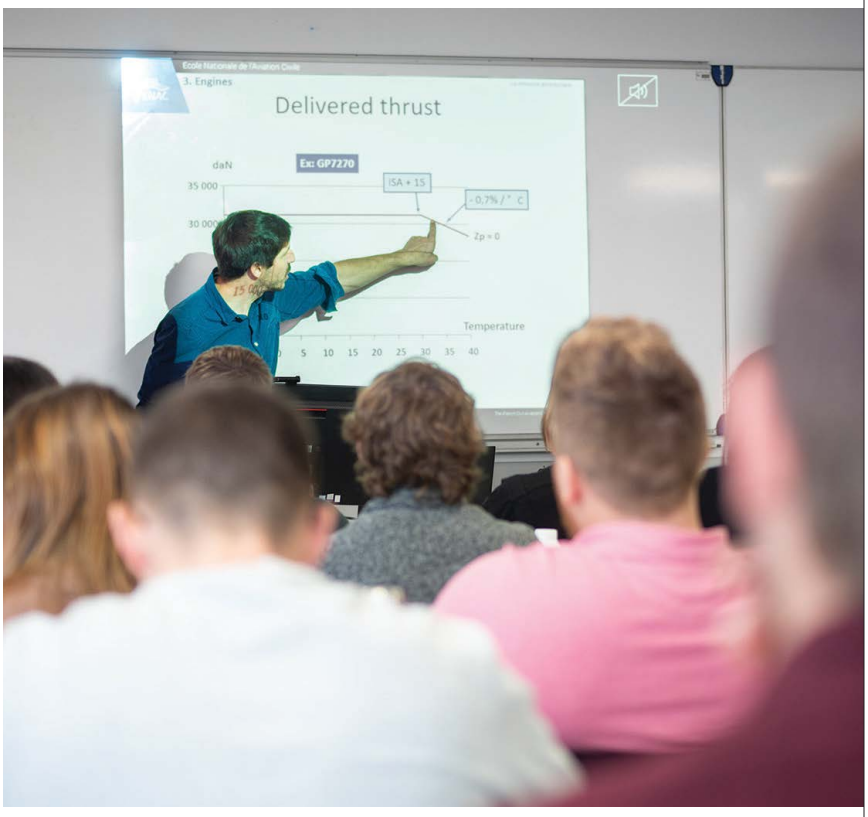
Supaero has a contract with the French National Center for Scientific Research to create theoretical and practical courses on hydrogen for sustainable aviation. "In technologies, our role is to show students the scope of the possibilities," Baroux says. "They will make their own judgment. Then, when working at a company, they will see concretely what a technology choice involves."

Baroux has more ideas about how to continue the transformation. "With Toulouse University, we would like our teaching programs to reflect the ecological transition even more, with new formats that would better suit the new generation of impatient, connected students," she says. "We are seeking funding to help us evolve in that direction."

Implementation challenges to greening syllabi abound. Under Supaero's Horizons road map, the start of the first year is dedicated to climate issues. "For that period, we created a 'low-tech workshop,'" Bouchet says. "Students would build a small water turbine to generate electricity. Before they delved into theoretical studies, that made them realize what it takes to produce energy, even at a low power level."

Baroux says she found the workshop valuable because students were making something by hand. However, it was terminated for budget reasons. "We are creating a new format on the same theme," she promises.

ENAC




**ENAC professors have been reviewing teaching programs, using a large matrix to determine where environmental topics should be added.**

Funding is a challenge for Estaca, too. "We need hardware for practical work," Guibert says.

Training teachers, meanwhile, is a relatively long-term effort. "We have rewritten the definition of our engineering degree, integrating sustainability issues," Guibert says. "Teachers have to meet those new requirements, and they must train accordingly. Some of them are leaders." As a result, transforming Estaca's offering could take 4-5 years, he estimates.

When devising the new programs, teachers find it difficult to add to the syllabus without overloading students. The uncertain future of some technologies, such as hydrogen propulsion, is also a challenge for teachers, Chansou points out.

In addition to incorporating more environmental issues into their programs, engineering schools are making their physical plants more sustainable. On ENAC's campus, photovoltaic panels produce most of the school's electricity. "Our heating system relies on biomass, and the temperature in our buildings is adjusted to their actual use," Chansou says. "Thermal insulation improvement works are ongoing. We have set a goal in carbon footprint reduction with a defined trajectory."

Similarly, Supaero has been renewing its buildings' thermal insulation and installing photovoltaic panels.

Estaca has calculated its carbon footprint. "Travel comes first, from both employees and students," Guibert notes. "International travel accounts for half of that." Before students travel, they are required to calculate the carbon impact of their trip. "Some might decide, after a long-haul trip, to pause air travel for 2-3 years," he says.

Supaero's Baroux has a more cautious approach to air travel demand management. "We do not want to preach to students," she says. "Our duty is to teach them how to forge a personal opinion on scientific grounds."

When they see changes at their universities, students offer positive feedback overall. "Every student feels environmental issues are crucial," says Sacha Sayah, president of ENAC's student association. "No one wants to ignore them." Some students express reservations because the ongoing changes may mean more work, Guibert notes.

The level of motivation to respond to environmental issues varies from student to student, Loose notes. Some feel they are prevented from studying what they like, such as aeronautics. "Others are aware of the issues but find responding challenging because it requires concessions on their dreams," he explains. "Some are convinced that change is needed, and they are already committed, both on a personal level and for the industry. Some become aware of the problem and change their minds."

"Our students see themselves as being about to participate in a transformation," Chansou says. "In 10 years, the ideal impact of our evolution would be that our students participate in that transformation. In future, there will be aviation, but we do not know its shape or size. And let's not forget safety!"

Debates are ongoing. Bouchet and Baroux diverge on when graduates have an impact. "At the start of my first year, then-President Olivier Lesbre told students their generation would solve this century's problems," Bouchet says. "In fact, if you do the math, this is incorrect. The current state of aviation is the outcome of actions by people in positions of responsibility. By the time today's young graduates reach such positions, it will be too late for them to have an impact."

"Our students will be essential actors in aviation's decarbonization," Baroux retorts. "As our alumni can already tell, there is no need to be in a high-ranking position to make things change. Let's not underestimate their power. The industry badly needs engineers, and when an engineer is not happy with their job, they quit."

A substantial proportion of Estaca's students will work in R&D departments and will have a direct impact on the future of aviation, Guibert says. They will work on hybridization, airframes, materials or optimization of airport operations. "In the coming years, if we see change, we can say we did our job," he says.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# How China's Minerals Hegemony Imperils the Defense Industrial Base

> MINERAL EXPORTS BAN TARGETS U.S. AEROSPACE AND DEFENSE

> SUPPLIER DIVERSIFICATION WILL REQUIRE BOTH DOMESTIC AND GLOBAL SOURCING

**Matthew Fulco** Washington

China banned the export of gallium, germanium and antimony to the U.S. on Dec. 3, directly targeting minerals integral to the aerospace and defense industry and raising the stakes in its intensifying rivalry with Washington.

In a statement, the Chinese Commerce Ministry said that the ban sought to safeguard Beijing's national security and interests. The statement further alleged that the U.S. "in recent years has overgeneralized the concept of national security, . . . abused export control measures and imposed unwarranted restrictions on the export of certain products to China."

As technology, trade and geopolitical frictions have increased between the world's two largest economies, each has tried to leverage strategic supply chains it controls. While the U.S. leads in advanced semiconductors—and has curbed Beijing's access to related technology—China dominates global production and processing of the 17 rare earth elements and other critical minerals crucial for defense systems.

Gallium-nitride technology—known to outperform silicon in speed, power handling and resistance to extreme temperatures—is used in a wide array of military radars and defense systems. These include Raytheon's Patriot, GhostEye and SPY-6 as well as TPY-2, the primary radar in Lockheed Martin's Terminal High-Altitude Area Defense system.


STOCKTREK IMAGES INC./ALAMY STOCK PHOTO

**Gallium-nitride technology is used in TPY-2, the primary radar in Lockheed Martin's Terminal High-Altitude Area Defense system.**

Germanium supports night-vision and thermal-sensing devices in platforms such as Abrams main battle tanks, BAE Systems Bradley Fighting Vehicles, Boeing AH-64 Apache helicopters and naval systems.

Antimony's usage ranges from creating tungsten steel and hardening lead bullets to night vision goggles and infrared sensors.

China is the top producer of all three critical minerals. It produced almost 99% of refined gallium and 59.2% of refined germanium in 2024, according to consultancy Project Blue. It further accounted for 48% of the antimony mined globally, by far the largest share of any country, as well as 63% of U.S. imports of the metal and 32% of reserves.

A shortage of any of these elements could disrupt the U.S. defense industrial base, which has limited domestic production ability and small or nonexistent strategic stockpiles. In a report published Oct. 15, U.S. Geological Survey researchers found the country's GDP could fall by $3.4 billion in the event of a total Chinese ban on gallium and germanium exports.

A report published in December by defense software firm Govini states that Beijing's export controls affect 1,000 weapons systems and more than 20,000 individual parts in every branch of the U.S. military except the Space Force. The company assessed that 87% of the supply chains for those systems have exposure to China.

While Beijing did not ban the export of antimony to the U.S. until Dec. 3, restrictions that it had imposed Sept. 15 effectively choked off the supply and caused prices to surge. The Center for Strategic and International Studies (CSIS) states in a Dec. 4 report that antimony shipments from China to the U.S. had fallen 97% while prices had jumped 200%.

"While the mechanism of a full-on ban is novel, they hit us in areas where we already have had an impact," says Gracelin Baskaran, director of Critical Minerals Security Program at CSIS. Beijing is telegraphing its willingness to escalate techno-industrial tensions between the two countries, she notes.

Given the minerals' importance to national security, efforts to find alternative suppliers to China are accelerating. Perpetua Resources and Sunshine Silver Mining & Refining, which are leading a Pentagon-backed antimony project in Idaho, signed a memorandum of understanding on Dec. 9. Under the agreement, the two companies will evaluate the technical potential for processing and refining antimony from the Stibnite Gold Project at the Sunshine Mine Complex in Idaho. The Pentagon awarded the project $59.4 million under the Defense Production Act, $34.6 million of which was distributed last February.

"With this export ban, it is clear that this is an issue that needs urgent attention," Perpetua Public Affairs

Manager Marty Boughton tells Aviation Week. "[With antimony,] we've got a mineral that is necessary for all sorts of defense applications."

Perpetua is confident in the project's economic viability—a frequent challenge with niche minerals—because the mine also will produce gold, prices of which hit an all-time high of $2,788.54 on Oct. 30 and outpaced the growth of the S&P 500 and Nasdaq for the year. "The antimony is the reason for the project, while the gold is the economic driver," Boughton says.

The U.S. Forest Service issued final approval on Jan. 6 for the Stibnite Gold Project, allowing mining to resume at the Sunshine Mine Complex after a 24-year hiatus. Perpetua lauded the decision as "a first major strategic counter" to China's antimony export curbs in a news release that day. The project can meet 35% of U.S. antimony demand in the first six years of operation while fulfilling the country's long-term defense needs, Perpetua added.

Other minerals could prove harder to source domestically, although Utah-based U.S. Critical Materials has identified what it describes as "a strategically significant deposit of high-grade gallium" on its 6,700 acres of claims in Sheep Creek, Montana.

Until the early 2020s, germanium was extracted as a byproduct of zinc mining in Alaska, Tennessee and Washington state. Netherlands-based Nyrstar, which operates a zinc processing facility in Clarksville, Tennessee, has proposed expanding the facility to enable both gallium and germanium reclamation.

However, some analysts say the U.S. would be best served by sourcing gallium and germanium from overseas. Cory Combs, associate director at consultancy Trivium China, says that high production costs and stringent environmental regulations are considerable challenges for such projects.

"The U.S. trying to onshore those capabilities just doesn't make sense," he says, adding that Washington should explore partnering with countries interested in obtaining the critical minerals from their own existing mining operations.

In the case of antimony, the No. 2 producer is Tajikistan, which accounted for 26% of global production in 2023 despite its small reserves. Because China dominates overall production, Tajikistan still exports most of its antimony to Beijing for refining.

Some countries are wary of sharing strategically valuable commodities. "We're seeing a lot of resource nationalism in the countries with which we want to partner," Aditya Ramji, an economist at the University of California-Davis Institute of Transportation Studies, said in October at the Zero Gravity Summit in Salt Lake City.

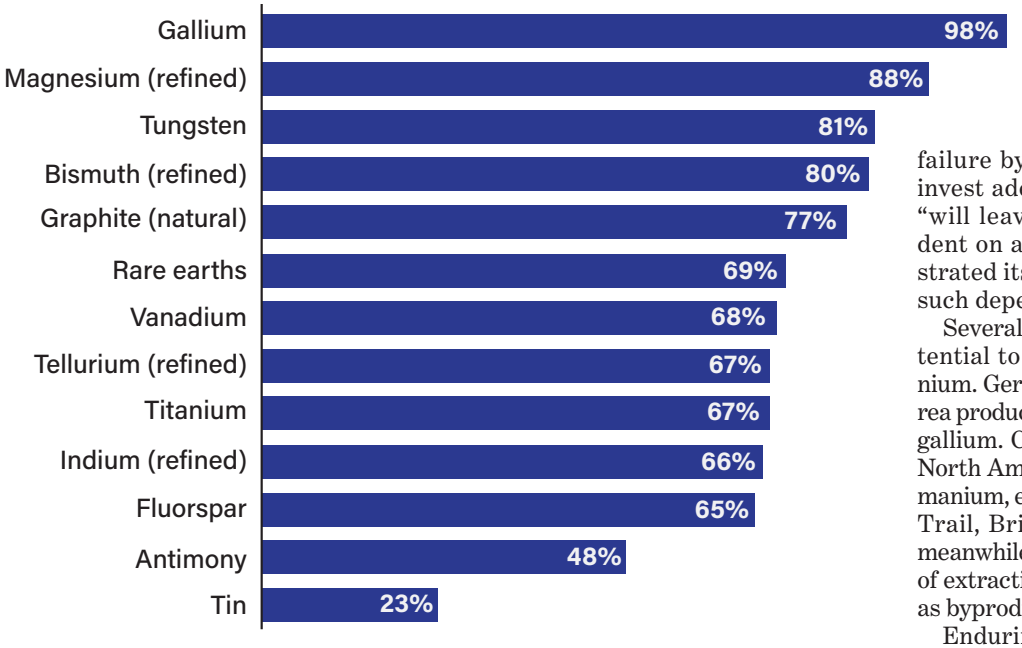
The White House has called for a stronger effort to diversify supply chains. At an October Brookings Institution event, National Security Advisor Jake Sullivan warned that failure by the U.S. and its allies to invest adequately in diversification "will leave us increasingly dependent on a country that has demonstrated its willingness to weaponize such dependencies."

Several key U.S. allies have the potential to supply gallium or germanium. Germany, Japan and South Korea produce small amounts of primary gallium. Canada's Teck Resources is North America's top producer of germanium, extracted from its smelter in Trail, British Columbia. Australia, meanwhile, is exploring the possibility of extracting gallium and germanium as byproducts of mining operations.

Enduring public-private partnerships will be integral to the success of efforts to develop resilient critical minerals supply chains. Japan's experience is instructive, as it was the first country to face a rare-earth metals ban by China in 2010, which Beijing imposed to gain leverage in a territorial dispute between the two countries. In response, the Japanese government invested $250 million in the Australian rare-earths mining company Lynas in 2011. Trial production did not start for two years, and the company was not profitable until 2018, according to Bloomberg News.

Yet Japan ultimately succeeded, reducing its reliance on China for rare earths to 60% of its supply from about 90%. "As we are facing a global challenge of heavy dependence on Chinese inputs, we must respond globally," Tatsuya Terazawa, CEO of Japan's Institute of Energy Economics, said in October 2023. "This will require the world to learn from the experience of 2010."

## Share of Critical Mineral Production Controlled by China, 2023




*Source: U.S. Geological Survey via The Heritage Foundation*

# NASA Recasts Plan To Return Samples From Mars

> SOLAR-POWERED PLATFORM SCRAPPED > SMALLER MARS LAUNCH VEHICLE PLANNED

NASA/ESA/JPL-CALTECH

**Irene Klotz** Cape Canaveral

**NASA is looking to simplify plans to return a cache of science samples collected by the ongoing Mars Perseverance rover mission. The original architecture, conceptualized here, could cost up to $11 billion and return the samples in 2040.**

The departing leadership of NASA outlined a simpler, less expensive plan to return science samples from Mars, hoping the incoming administration of President-elect Donald Trump and the new U.S. Congress will champion the plan to reality.

After decades of groundwork, a carefully curated collection of Martian rocks and regolith samples awaits return to Earth for analysis. Scientists expect to learn more about the origin and evolution of Mars—and potentially if the planet most like Earth in the Solar System supported life.

The Mars Sample Return (MSR) campaign began in 2021 with the arrival of NASA's Mars Perseverance rover to collect and cache samples from Jezero Crater, site of an ancient lake bed and river channels. The sediment may have preserved evidence of past microbial life.

Independent and NASA reviews, however, have determined that the cost to retrieve, launch and fly the bounty back to Earth would reach as much as $11 billion—more than twice original estimates—and would take years longer to complete.

Last year, NASA turned to private industry and its field centers for alternative ideas to simplify the mission, cut costs and return the samples sooner. The effort proved fruitful, and on Jan. 7—less than two weeks before NASA Administrator Bill Nelson and the rest of the Biden administration leave office—the agency outlined a path forward.

The revamped program includes:

- An Earth Return Orbiter (ERO) provided by the European Space Agency to capture the orbiting sample container after it has been launched into Mars orbit from the planet's surface. The ERO, which was part of the original architecture, would then fly the canister back to Earth. The orbiter would launch in 2030.
- A simplified collection system to transfer and pack 30 sample tubes from the Perseverance rover to the sample container. The system simplifies planetary protection procedures for spacecraft return to Earth.
- A scaled-down solid-propellant Mars Ascent Vehicle (MAV) to launch the sample container into Mars orbit.
- A nuclear-powered—rather than solar-powered—landing platform. Using a radioisotope thermoelectric generator (RTG) would enable sample loading and other surface operations to continue during the Martian dust storm season, which hampers solar battery charging. An RTG, which provides power from the natural decay of radioactive plutonium, also would alleviate concerns about keeping the MAV's solid propellant at the proper temperature for future operations.

To land the hardware on Mars, NASA wants to assess using an enhanced sky crane system, which delivered the Curiosity and the Perseverance rovers to the planet's surface successfully. The MSR sky crane would need to be about 20% larger than systems previously flown.

NASA also could decide to buy a commercial lander, such as a variant of SpaceX's Starship or Blue Origin's Blue Moon crewed lunar landers, both of which are in development to support its Artemis program. The agency would like to issue a request for proposals for commercial Mars lander preliminary design work in the next few months, MSR Program Director Jeff Gramling says.

Nelson said NASA should be in a position to decide in 2026 between the sky crane or a commercial lander. Either option would cut the $11 billion MSR mission cost 30-47% and return

the samples in the mid-to-late 2030s—1-5 years sooner than the original plan.

The program needs at least $300 million this year to remain on track, Nelson said Jan. 7 during a conference call with reporters. The Senate is allocating $200 million in fiscal 2025 for MSR program development, while the House has budgeted $600 million, he added.

Nelson said he had not discussed the revised MSR architecture with Trump's nominee to head NASA, Jared Isaacman, or members of the incoming administration. "What we wanted to do was to give them the best possible options," Nelson said. "If they want to have a Mars sample return—which I can't imagine that they don't—I don't think we want the only sample return coming back on a Chinese spacecraft."

China has announced plans for a Mars mission launching in 2028 that includes sending a sample back to Earth.

"Our [sample return] . . . is an extremely well-thought-out mission created by the scientific community of the world [to assess] various sites in and around Jezero Crater that will give us a picture of the historical record when there was water there," Nelson said. "You compare that to—at least what has been said publicly by the Chinese government—that they're just going to . . . go to a landing site of their choosing, grab a sample and go. That does not give you the comprehensive look for the science community.

"You cannot compare the two missions," he added. "Of course, people will say there is a race, but it's two totally different missions."

Perseverance so far has filled 22 cigar-size tubes with rock cores, two tubes with regolith and one with an atmospheric sample. It also carries three so-called witness tubes for calibrations. Thirteen tubes remain to be filled.

"It is of utmost importance to us that we bring back these samples to Earth as quickly as possible," NASA Science Associate Administrator Nicola Fox said. "To do that, we needed to get very creative."

NASA/JPL-CALTECH/MSSS

**NASA's Perseverance rover has collected rock, soil and atmospheric samples, most of which are stored aboard the vehicle for future transfer to a return spacecraft. Ten sample tubes were deposited on the ground as a backup cache.**

# TRANSFORMING LONG-HAUL

> THE AIRBUS A350 MARKS 10 YEARS OF SCHEDULED FLIGHTS

> THE TYPE SET A NEW REFERENCE FOR LONG-HAUL OPS ALONGSIDE BOEING'S 787

> ITS COMPOSITE FUSELAGE WAS A FIRST FOR AIRBUS


Emirates took delivery of its first A350 in November.

AIRBUS

**Jens Flottau** Toulouse

On a December day at Toulouse-Blagnac Airport toward the end of 2024, the apron is full of new aircraft, some ready to be picked up by their customers but many waiting for components. Airbus A350s are parked everywhere, even in front of the old Jean-Luc Lagardere site on the other side of the runway, once built for the A380 and now hosting an A321neo final assembly line. "We are disappointed," says Julien Puyou, head of Airbus widebody programs.

Of course, there is no reason to be disappointed in the A350 per se. Ten years after the latest Airbus widebody entered service with Qatar Airways on Jan. 15, 2015, it is fair to say that the project has become a big operational and commercial success, despite its tumultuousness. Along with the Boeing 787, the A350 reshaped long-haul travel once again—and killed the A380 as an unintended side effect.

Moreover, given Boeing 787 quality issues and 777X delays, as well as the strongest widebody demand in a long time, Airbus is convinced that the harvest season for its big twin has arrived. The airframer just needs to figure out how to assemble and deliver more of the aircraft to customers faster.

For Puyou and his veteran colleagues, 2024 must have felt like a throwback to 2016, early in the A350 production ramp-up. Airbus delivered 49 of the aircraft that year on the way to its planned target rate of 10 per month. In 2019, the airframer finally reached that goal, and the program broke even on an operational basis for the first time as well.

It took Airbus five years to achieve that level—but the OEM was not able to maintain it. The COVID-19 pandemic changed everything and slashed demand for widebodies in particular. In 2024, the second or third year of post-pandemic recovery, depending on how you count, Airbus delivered just 33 A350s through November, far fewer than even at the crisis' peak in 2020, when it delivered 59, and fewer than in any year since initial production began.

The slow pace of production recovery is what frustrates Puyou.

## CONCEPT AND DEVELOPMENT

Well before the first delivery, the A350 program experienced several unforeseen twists. Its development was triggered by competition with Boeing, which had launched studies into a new widebody that eventually morphed from the early-2000s "Sonic Cruiser" concept into today's 787.

Whatever Boeing did, Airbus had to react. Its widebody lineup in the early 2000s consisted of the A330, an effi-

cient and versatile twin that had big sales success in Asia and good incumbency in Europe but was less popular in the U.S. Airbus' weak point was the increasingly uneconomical four-engine A340. The A380 had been launched in 2000 but not yet delivered. Production flaws and billions in cost overruns had brought Airbus to the brink, forcing it to institute a major cost-cutting program dubbed Power8. In the mid-2000s, the company was vulnerable, despite the growing success of the narrowbody A320 program.

Airbus leaders initially thought there was a quick and relatively cheap fix. All Airbus needed to do was modernize the A330 into the A350 by adding new engines and some other tweaks to make it more efficient, the argument went. It would appeal to the large A330 customer base, plus those operating A340s, by ensuring a great deal of commonality. A revamped A330-to-A350 also would be available sooner than a new Airbus or Boeing aircraft. It all seemed to make sense.

The market, however, did not buy it. Steven Udvar-Hazy, then-chairman of International Lease Finance Corp., made no secret of his view that Airbus' plan would not give customers what they actually wanted.

Lessors were never going to be the main target audience for widebodies, given the relatively small numbers produced. Still, Udvar-Hazy's opinion was valued then, as it is today. "I did not design the A350; I just redesigned it," he once joked. Other players agreed with Udvar-Hazy's view that the initial concept was just a "Band-Aid reaction" to the 787. Singapore Airlines was unusually clear that if Airbus wanted it to buy the A350, the airframer would have to offer something better.

In the early part of 2006, it became increasingly clear that the original idea was a nonstarter. Airbus officially announced the clean-sheet concept of what would become today's A350 at the 2006 Farnborough International Airshow. The Airbus board finally approved the decision almost six months later, illustrating how difficult it was for the distressed company to move ahead with another multibillion-dollar development program when the troubled A380 had yet to enter service (and would not do so until October 2007).

In hindsight, the debates of 2006—and ultimately the decision to move ahead with the much more expensive

JENS FLOTTAU/AW&ST

**Airbus plans to raise A350 production to 12 aircraft per month by 2028.**

A350 version—proved pivotal for the future of Airbus, considering how the long-haul aircraft market has developed in the 18 years since.

The A350 also marked Airbus' full shift into composite manufacturing. While the company had used the material for some components, the A350 was the first with an entirely composite fuselage. Unlike Boeing, which used all-composite sections produced in one piece, Airbus chose composite panels. With the A350 already behind the 787 in timing, that move proved quicker, less expensive and less risky, avoiding the massive investment in tooling and large autoclaves that full barrels would have necessitated. Airbus also asserted that panels would be easier to repair.

The airframer initially conceived of the A350 as a three-member family with a baseline A350-900, a smaller -800 and a larger -1000. However, it soon dropped the -800 to cut back on development efforts and costs. The market also clearly favored the larger versions. Much later, a third family member was added: the A350F.

## IN-SERVICE PERFORMANCE

The -900 made its first flight on June 14, 2013, in front of a large crowd of Airbus employees, among them program chief Didier Evrard. It was certified on Sept. 30, 2014. Although its initial schedule had projected first delivery for mid-2013, the A350 stayed remarkably on track compared with the extent of recent delays across many Airbus programs.

In the years since, customers have ordered 1,345 A350s, 628 of which were delivered by the end of November. There have been 2,388 orders for the Boeing 787, which was launched

in 2004 and entered service in 2011, four years before the A350.

Since its service entry, the A350 fleet has accumulated 10.6 million flight hours and 1.6 million flight cycles. The -900 variant leads the fleet with 37,000 hr. and more than 7,800 takeoffs. According to Airbus data, the fleet achieved 99.3% dispatch reliability in Year 2, 99.5% in Year 5 and is currently at 99.2%.

The A350 has experienced one hull loss: On Jan. 2, 2024, a Japan Airlines A350-900 attempted to land on Tokyo-Haneda Airport's Runway 34R but struck a Japan Coast Guard De Havilland Canada Dash 8-300 maritime patrol aircraft that had entered the runway without clearance. While five onboard the Dash 8 lost their lives, everyone on the A350 survived, although some were injured. The accident validated the structural strength of the A350's composite fuselage as well as its ability to withstand a forceful impact and heat long enough for passengers and crew to evacuate.

## STRONG CUSTOMER BASE IN EUROPE AND ASIA

The evolution of the A350 customer base since 2015 reflects that of air transport as a whole. The type's predominant success has been in Asia, where most of the big players have placed substantial orders. China's Big Three carriers—Air China, China Eastern Airlines and China Southern Airlines—operate substantial fleets. Singapore Airlines bought 65 of the type, and the A350 has become the dominant long-haul aircraft for airlines in Taiwan and South Korea. In Europe, Lufthansa, International Airlines Group and Air France-KLM have purchased large numbers of A350s.

The U.S. is the program's weakest major market. Delta Air Lines so far has committed to 69 -900s and -1000s. A United Airlines order for 45 -900s remains in Airbus' backlog, but it has been pushed back repeatedly over several years. The airline is not showing much interest in receiving the type anytime soon, if ever, considering it also has ordered 237 of the competing 787s since 2005.

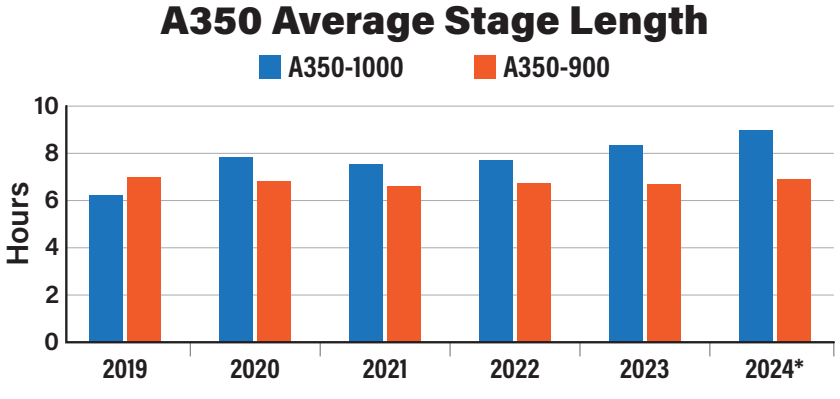
After settling a bitter fight out of court over surface degradation on many of its Airbus aircraft, Qatar Airways has remained the largest A350 customer in the Middle East, with orders for 76 aircraft. Emirates finally joined the program in 2019, after many years of hesitation, with an initial order for 50 -900s; it expanded that to 65 in 2023. Its first aircraft was delivered in November. Emirates has highlighted severe durability issues on the -1000's Rolls-Royce Trent XWB-97 engines and made clear that it will not order the larger variant until the engine-maker can guarantee much longer time on wing.

Emirates' future operating profile for the A350 reflects the aircraft's in-service profile. The average stage length of the -900 in-service fleet is a relatively short 6.35 flight hours; for the -1000, it is 8.24 flight hours. Many Asian carriers use the aircraft for true long-haul services to Europe and the U.S. as well as on dense regional and sometimes even domestic routes.

Emirates' incoming fleet is split into two parts. One is a 312-seat version, with 32 seats in business class, 21 in premium economy, 259 in economy and no crew rest area. That variant is operated on routes to Europe, Africa and India, as well as within the Middle East. It is being deployed to Edinburgh, Scotland, in early January and later to other European destinations including Bologna, Italy, and Lyon.

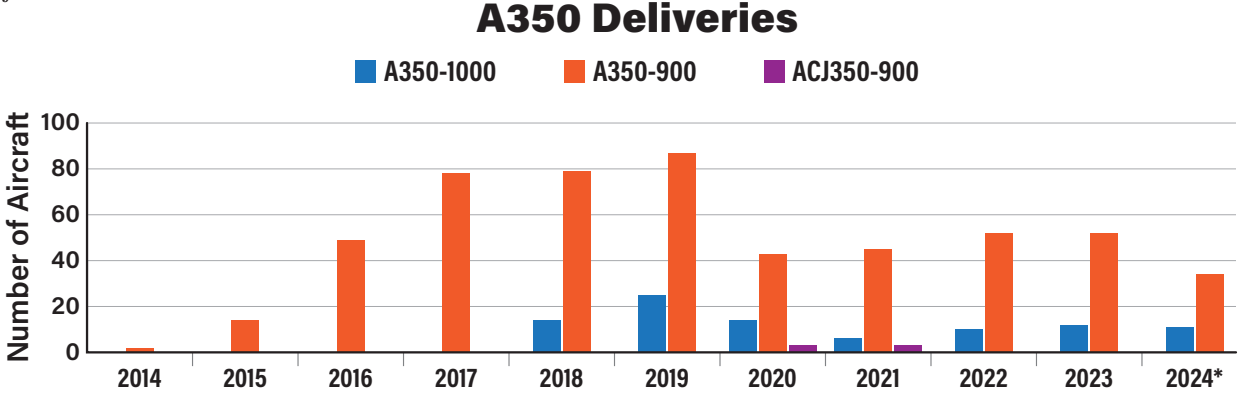
The second batch of A350s will lose 22 economy cabin seats to make space for a crew rest area. The long-range version is planned to fly to destinations in the U.S., Australia and possibly Latin America. According to Emirates Airline Chief Commercial Officer Adnan Kazim, the exact split between the two variants is not yet decided but could be roughly 50-50. "We will decide as we progress," he says.

Airbus' ultra-long-range A350-900ULR entered service with Singa-




*Through November.

*Source: AWIN Tracked Aircraft Utilization*




*Through November.

*Source: AWIN Fleet Discovery*

## A350 In-Service Fleet by Region

| | Africa | Asia-Pacific | China | Europe | India | Latin America | Middle East | North America |
|---|---|---|---|---|---|---|---|---|
| **2014** | - | - | - | - | - | - | 1 | - |
| **2015** | - | 4 | - | 3 | - | 1 | 7 | - |
| **2016** | 2 | 32 | - | 8 | - | 7 | 13 | - |
| **2017** | 8 | 78 | - | 18 | - | 7 | 23 | 6 |
| **2018** | 12 | 120 | 13 | 28 | - | 9 | 37 | 11 |
| **2019** | 20 | 153 | 29 | 51 | - | 12 | 53 | 13 |
| **2020** | 20 | 134 | 31 | 75 | - | 6 | 53 | 15 |
| **2021** | 21 | 171 | 43 | 101 | - | 6 | 32 | 15 |
| **2022** | 23 | 185 | 59 | 136 | - | 8 | 28 | 24 |
| **2023** | 24 | 203 | 75 | 160 | 3 | 8 | 63 | 28 |
| **2024** | 25 | 219 | 78 | 188 | 6 | 6 | 64 | 33 |

*Source: AWIN Fleet Discovery*

pore Airlines in 2018 on the carrier's Singapore-New York route, currently the longest commercial service at 8,300 nm. Qantas has ordered 12 A350-1000s with additional fuel tanks for its Project Sunrise, a nonstop Sydney-London trip of up to 22 hr. and 9,800 nm. Following several delays, the service is to be launched in 2026. Turkish Airlines also plans to fly Istanbul-Sydney nonstop using the A350.

The A350 currently is operated on four of the 10 longest scheduled routes, including the top three. The 787 is used for five of the top 10 and the A380 for one, according to OAG data.

### PRODUCTION CHALLENGES

Airbus had 717 A350s to deliver as of November. To Puyou's frustration, the airframer delivered fewer aircraft in 2024 than planned. The ambition is clear: Airbus wants to ramp up to a rate of 12 aircraft per month, exceeding its 2019 peak of 10 per month.

The program has been hit hard by the supply chain constraints visible elsewhere. Structural components supplier Spirit AeroSystems in Kinston, North Carolina, required financial infusions in 2024 from its financially strained future and past parent company Boeing. Moreover, the carve-out of the Airbus work and transfer into its ownership is a long and complicated process.

Cabin parts are another constraint. "We have no seats for some aircraft," Puyou says, looking out across the final assembly line in Toulouse. The line itself has never stopped, but many aircraft are leaving the hangar with parts missing. They remain parked on the apron at Toulouse-Blagnac, waiting for seats, engines or galley parts.

The good news is that once other obstacles are cleared, the airframer's current tooling suffices even for rate 13. "Nothing will change between now and rate 12," Puyou says.

The final assembly system for the A350 is made up of four main stations: 59, 50, 40 and 30. At Station 59, some cabin elements like the galley are usually loaded before the fuselage sections are moved to Station 50, where the fuselage itself is assembled. There, the wings, tailplane and landing gear are attached, and other parts of the cabin installed. Station 30, located in another hangar, is used for testing and further cabin work.

There are three Station 50s and four Station 40s and 30s each. During the height of the pandemic, Airbus idled two Station 50s in order to maintain relatively high-speed production even at low rates. At the moment, it is using two Station 50s for passenger aircraft while dedicating another to the first A350F prototypes. In future normal production, freighters, -900s and -1000s are to be built on mixed lines.

The freighter introduction is not the only change in Airbus' future backlog. After a slow start, the larger -1000 has attracted a higher share of orders, so its allotment of production capacity will increase. Still, Puyou says that will have "no big impact on the final assembly line." The target is to keep the same sequence as for the -900.

Airbus' recent success in selling the A350 to new customers also brings further complexity. In spite of industry efforts to offer more standardized cabin configurations, a high level of customization is still popular with airlines. Emirates alone made the request for two versions, one with and one without a crew rest area. First class also has made a comeback with many customers; 70% of the in-service fleet has a premium economy cabin. Offering four different cabins is no longer unusual, and Airbus has launched a special project to deal with these adjustments more efficiently.

The A350 is now the main platform with which Airbus aims to capture a bigger share of the large freighter market, which Boeing has dominated. Production of the Boeing 747 has ended, the 767F and 777F are in their last phase, and the 777-8F is delayed until 2028. Airbus has announced firm orders for 55 A350Fs, the variant largely based on the -1000 passenger version. The company is producing sections of the first test aircraft, and the final assembly line is slated to be started in mid-2025. First flight is to follow toward year-end and certification in 2026, some two years before the 777-8F.

Given that the A350F is a version of the -1000, Airbus has no major flight-test campaign planned and anticipates around 450 hr. of flight testing.

The aircraft has a 111-metric-ton overall payload capacity, with room for 30 containers on the main deck and 40 LD3 containers on the lower deck. The A350F has the largest main deck cargo door, at 175 in. wide, allowing for the transport of large commercial aircraft engines, among other voluminous cargo.

**ARTIFICIAL INTELLIGENCE >** Military autonomy software **p. 44** "Super analyst" for airline prices **p. 46**
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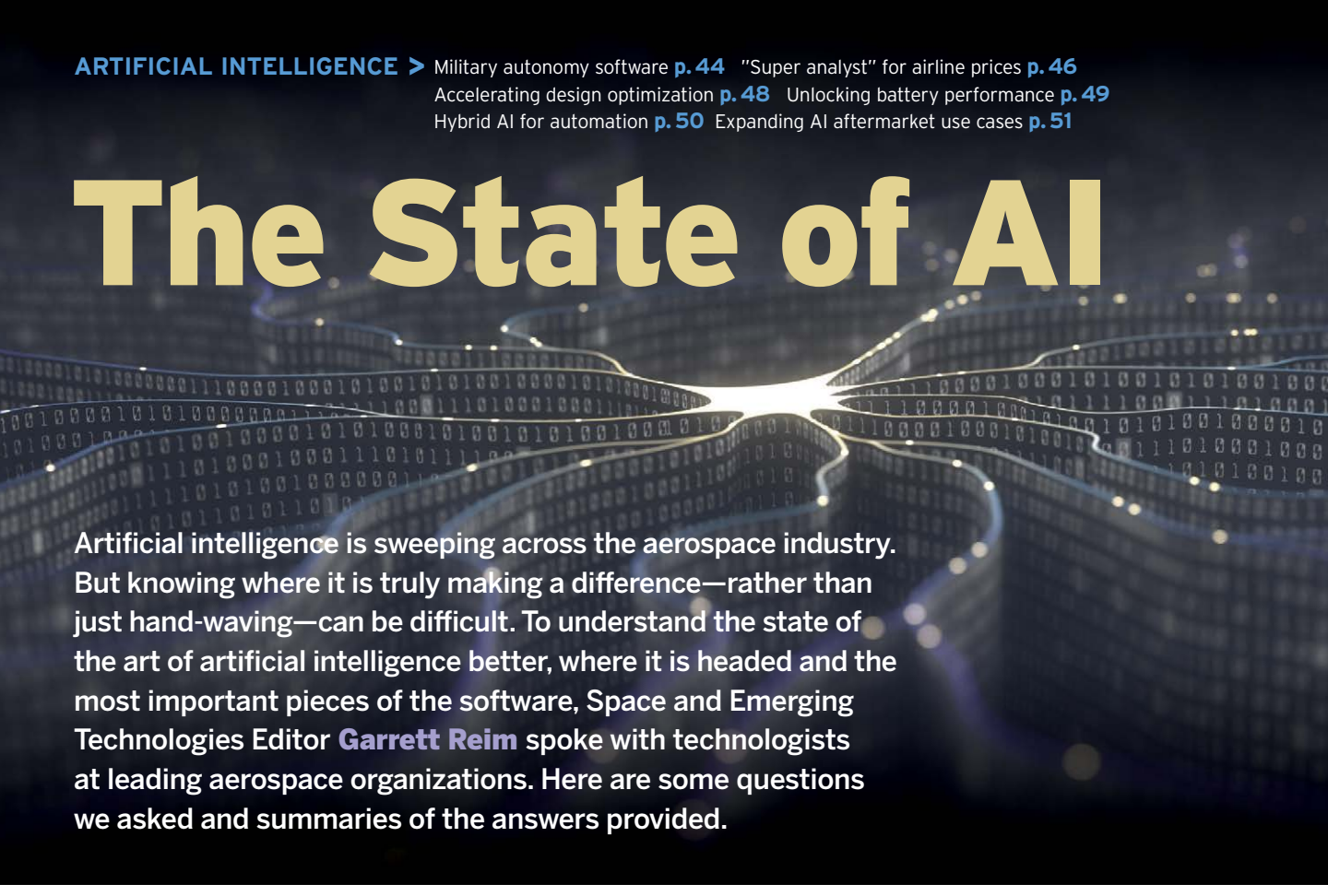
# The State of AI



Artificial intelligence is sweeping across the aerospace industry. But knowing where it is truly making a difference—rather than just hand-waving—can be difficult. To understand the state of the art of artificial intelligence better, where it is headed and the most important pieces of the software, Space and Emerging Technologies Editor **Garrett Reim** spoke with technologists at leading aerospace organizations. Here are some questions we asked and summaries of the answers provided.

**What forms of artificial intelligence are being tested or used in operational systems today?** Despite the nonstop talk about artificial intelligence (AI) these days, testing and operational adoption within the aerospace industry is nascent, mostly focused on non-safety-critical applications, such as data analysis, or computer vision tasks, such as object detection.

For example, the National Oceanic and Atmospheric Administration is using an AI system to classify sea ice from synthetic aperture radar imagery, and others are using deep-learning techniques to detect satellite maneuvers for space situational awareness, says **Elizabeth Davison**, associate principal director of integrated data and applications at The Aerospace Corp.

Elsewhere, autonomous aircraft startup Merlin Labs is testing computer vision to help pilots by recognizing runway markings or obstacles, Chief Technology Officer **Tim Burns** says. Merlin Labs is also using natural language processing to allow its autonomous flight system to communicate with humans in air traffic control.

NASA is using AI to detect and filter "the signal from the noise in large data sets," says **David Salvagnini**, chief data officer and chief artificial intelligence officer. For example, the agency is using AI to "explore the cosmos through applications like ExoMiner, a neural network leveraging supercomputers to identify exoplanets from data gathered by NASA's Kepler spacecraft and K2," he adds.

Of course, the maintenance, repair and overhaul industry has used machine learning for predictive maintenance for years. But adoption is also growing within manufacturing as aerospace companies use computer vision and machine-learning programs to detect component flaws and production problems.

"One current process under investigation involves collecting and interpreting real-time images and video to enable teams to provide insight into potential plan optimizations and sources of production slowdowns," says **Trevor Johnson**, project executive for Acubed, Airbus' Silicon Valley innovation center.

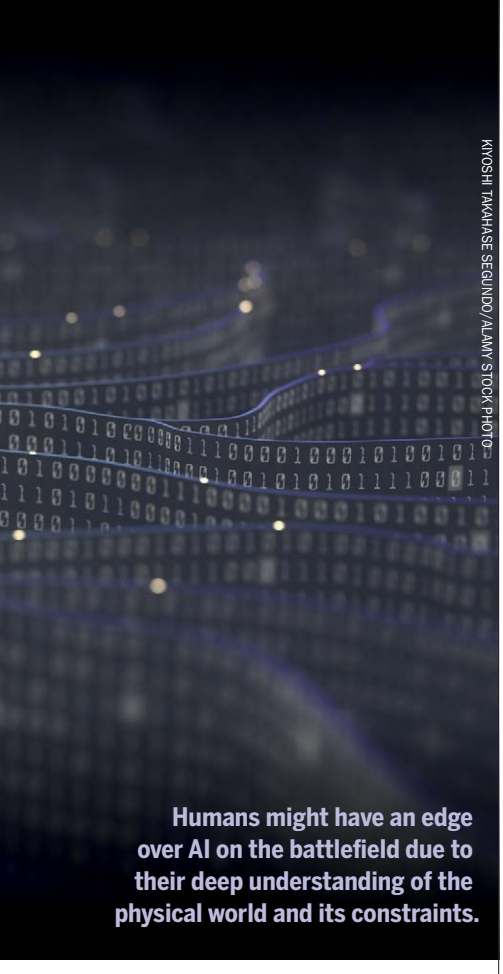
Companies including Reliable Robotics, a startup developing an autonomous Cessna Caravan, note that AI systems, despite their seemingly superhuman abilities, are unable to demonstrate compliance with existing FAA regulations and technical standards due to their proneness to error.

"We believe that deterministic software and systems are crucial," Reliable Robotics CEO **Robert Rose** says, adding that the National Airspace System is not equipped to handle nondeterministic systems.

**What forms of AI will be used in operational systems in 3-5 years?** In 3-5 years, humans will still make decisions, but AI tools will speed the process, Lockheed Martin Chief AI and Digital Officer **Mike Baylor** says. In other instances, operators may debut agentic AI systems—programs that can make decisions, plan and execute toward a specific goal with less human supervision, he adds.

AI also could help manage and fuse intelligence, surveillance and reconnaissance from swarms of uncrewed air vehicles, says **Christian Gutierrez**, Shield AI's vice president of Hivemind engineering, the company's autonomy software. "With human oversight, these systems will enable autonomous platforms to share information and coordinate actions as a unit, even in communications- and GPS-denied environments," he says.

"Prototypes of advanced AI-driven tools are anticipated to emerge, enabling commanders to shape electro-



KIYOSHI TAKAHASE SEGUNDO/ALAMY STOCK PHOTO

**Humans might have an edge over AI on the battlefield due to their deep understanding of the physical world and its constraints.**

magnetic spectrum operations," L3Harris Technologies Chief Technology Officer **Andrew Puryear** says, pointing to optimizing communications, jamming or data collection in contested radio frequency areas.

**What forms show great promise but are still at least 10 years away?** A decade from now, AI could take on an even greater role, including decision-making responsibilities previously reserved for humans. "Strategic autonomy, where systems make high-level decisions and adapt objectives in real time, holds great promise," Gutierrez says. "This shift will significantly reduce the need for human intervention, allowing operators to manage larger fleets of systems while minimizing risk to personnel."

AI systems that combine general intelligence with adaptive decision-making have big potential, too, Burns says. "These could enable fully autonomous decision-making in novel or unpredictable situations, such as coordinating multiple unmanned systems in complex, dynamic environments," he adds.

"The AI required for advanced weapon-target pairing and optimization already exists, enabling systems to optimize execution based on adjustable parameters like probability of hit or kill, fratricide risk, cost, time to replenish and supply chain impacts," Puryear says. "The real challenge is linking the kill chain to the logistical chain."

The future aerospace factory likely will deploy advanced robotics that are set up and optimized using AI, Johnson says. "Given the current pace of development, the limiting factor for operational fielding will likely be the ability to synthesize new technology into highly rigorous production and design environments."

Giving AI greater autonomy also will require infusing it with morals, a task that may be difficult and "will require significant breakthroughs to address trust and accountability issues," Burns notes.

NASA says the state of AI in a decade is anyone's guess.

"AI research and deployment is moving so quickly that NASA isn't going to venture predictions about AI use in 10 years," Salvagnini says. "That's too far out to make reliable well-informed predictions in a rapidly changing field."

**What is the biggest misconception about AI?** AI is not likely to become "sentient," Lockheed's Baylor says. "AI algorithms allow for faster, more resilient decisions. These can be layered to imitate sentience, but not create it."

Another misconception is that AI will take all human jobs, multiple aerospace technologists say. "There may be some direct displacement in places like customer call centers, but the real risk is being replaced by someone who uses AI, not AI itself," Baylor says.

AI is not a general tool, but its uses can vary greatly, Northrop Grumman Chief AI Architect **Ebenezer Dadson** notes. "AI cannot simply be sprinkled on top as a garnish," he says. "AI, when deployed responsibly, presents as a system, subsystem or component. The operationalization of AI is both art and science, and requires significant expertise to be done effectively and responsibly."

DARPA considers it a misconception that AI would improve every system. "In reality, AI should only be used when it's the only suitable solution for a specific problem," says **Lt. Col. Ryan Hefron**, DARPA program manager for Air Combat Evolution and Artificial Intelligence Reinforcements. "If a simpler, more efficient approach works, use it."

It is important to establish appro-

## AN AI GLOSSARY

**Machine Learning** A basic building block of most other forms of AI, these systems learn and improve from experience without being explicitly programmed by a human. The software is enabled by algorithms that identify patterns, make decisions or predict outcomes based on the data input.

**Aerospace examples** Predictive maintenance, generative engineering, rocket trajectory optimization, weather prediction, target detection, collision avoidance.

**Neural Networks** Inspired by the human brain structure, these systems are made of layers of interconnected nodes, called neurons, that process information by adjusting weights and biases to learn and improve over time.

**Aerospace examples** Predicting aerodynamic properties, optimizing structural components for weight and strength, helping drones recognize obstacles.

**Natural Language Processing** A program that understands, interprets and generates human language by breaking text or speech into smaller components, analyzing their meaning and extracting patterns or insights.

**Aerospace examples** Voice-controlled cockpit systems, monitoring and analyzing air traffic control communications, analyzing maintenance logs to find potential problems.

**Computer Vision** A program that deciphers and interprets visual data from images and videos by detecting patterns, objects or scenes.

**Aerospace examples** Obstacle detection and avoidance, landing assistance, image-based navigation, target recognition, augmented-reality flight training, analyzing satellite images.

**Reinforcement Learning** A system that learns by trial and error to achieve its goals. The program's agent learns to make decisions by interacting with an environment, then receives rewards or penalties as feedback.

**Aerospace examples** Flightpath optimization, spacecraft navigation, air traffic control routing optimization, autonomous refueling, drone swarm coordination.

priate levels of trust with AI systems, adds Davison of The Aerospace Corp. "AI systems are inherently imperfect and often nondeterministic, so they will make errors," she says.

Indeed, there are other areas where AI is lacking. "While AI excels in predictable tasks and structured environments, it requires robust algorithms, extensive training data and adaptive methodologies to perform effectively in uncertain or rapidly changing conditions," says Gutierrez of Shield AI.

The U.S. Air Force does not see AI replacing human decision-making in high-stakes situations. "The primary goal of AI is to augment human decision-making, not automate it," the service says.

It is also problematic that AI has become a catch-all buzzword, says Rose of Reliable Robotics. "To advance the discussion on AI, industry should work through standards-developing organizations and trade associations to develop precise definitions for the types of AI being considered for aviation."

Finally, the idea that AI will achieve superintelligence and threaten an apocalypse is too speculative, says Puryear of L3Harris.

"While large language models (LLM) have demonstrated emerging capabilities, they are not steps toward [artificial general intelligence]," he says. "LLMs excel at tasks like predicting the next word but lack critical features necessary for [artificial general intelligence] such as reasoning, hierarchical planning and a deep understanding of the physical world."

**What areas will be difficult for AI?**

AI systems are only as strong as the data on which they are trained, and high-quality data can be hard to come by. For example, absent war, there is a lack of data on real-life military situations to train AI, aerospace technologists say.

**"While some AI systems have incorporated reasoning capabilities, they struggle with contextual reasoning."**

"Another challenge is understanding the nuances of human-to-human communication, like sarcasm, silence and words like 'fine,' where tone is as important as context," Baylor notes.

AI also lacks deeply human skills such as creative problem-solving in novel situations, Davison says. "Tasks requiring deep subject matter expertise, intuition or emotionally intelligent decision-making will be particularly difficult for AI," she explains.

As with technologies before it, adversaries will develop techniques to neutralize or impede AI-powered equipment. "As we increase utilization of AI technology in the battlefield, we will see advancements in evading those technologies," Gutierrez says. "Our challenge will be to overcome the current pace of fielding upgrades to the warfighter."

With all the ambiguity and complexity that come with operational use of AI, ethical boundaries in particular will be hard to establish and then integrate within the technology. "Frameworks like the [Defense Department's] Principles for Ethical Use of AI are helpful," Baylor says.

The U.S. Air Force notes that all those challenges come together on the battlefield. "Areas that may prove difficult for AI include human battlefield decisions, ethical decision-making and novel situations, among others," the service says.

Humans are likely to keep an edge on the battlefield, as they "excel at reasoning and planning because of their deep understanding of the physical world and its constraints," Puryear says. "While some AI systems have incorporated reasoning capabilities, they struggle with contextual reasoning, particularly in novel or dynamic situations."

Lastly, NASA points out that AI lacks the capacity for self-reflection. "Current AI models can have trouble determining their own biases or producing consistent answers and explaining how they sourced and derived their answers," Salvagnini says. "That's where it's critical to have humans serving as adjudicators and fact-checkers for the work these systems produce."

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AVIATION WEEK NETWORK

# Autonomy Software Evolves from Military Platforms to Missions

- ANDURIL DRONES PRACTICE AIR-TO-AIR ROLES
- COLLABORATIVE COMBAT AIRCRAFT AUTONOMY PROJECT MOVES FORWARD IN SECRECY

**Steve Trimble** Pecos County, Texas, and Washington

Four jet-powered drones take off in quick succession from a windswept, 8,000-ft. runway in the remote Chihuahuan Desert.

The drones coordinate among themselves and quickly form a perfect defensive counter-air patrol over the tumbleweed-filled sprawl of the Anduril Texas Test Site.

Then the plot thickens. A human test operator inserts a simulation of a Chinese Shenyang J-35 fighter into the digitized operational picture shared among the flying drones and their controllers on the ground. It is coming to attack the base.

The Anduril operator orders drone No. 3 to break away from the defensive pattern and intercept the intruder. Automatically, the other three drones adjust their flightpaths, filling the gap created by their missing partner. As the ground-based human controller observes, the interceptor drone acquires the J-35 and—after receiving the human operator's permission—fires a missile and kills the enemy.

Anduril recently staged this demonstration for journalists to show how far software-based capabilities have come. The scenario came from the company's Hyperion experimental series, which adapts the internal Lattice autonomy software to perform air-to-air missions. As one of the two companies building operational prototypes for the U.S. Air Force's Collaborative Combat Aircraft (CCA) program, Anduril's internally funded autonomy software experiments offer a glimpse into the future of air combat.

STEVE TRIMBLE/AW&ST


**Anduril's "clay pigeon" jets are helping the company refine its Lattice-derived mission autonomy algorithms for air-to-air combat missions.**

Autonomy software is no longer limited to enabling a single aircraft to execute the commands of a remote human controller. Software code can be trusted instead to orchestrate a mission involving multiple platforms. Anduril's Hyperion project focuses solely on coordinating aircraft, but other industry and military efforts are connecting platforms across multiple domains to carry out missions, with only policy dictating a human's explicit approval for the release of lethal effects.

The premise that "mission autonomy" is ready for combat guides several major U.S. Defense Department programs. The Air Force aims to introduce the first CCA by the end of the decade. The Navy's Project Overmatch is developing multidomain technology for sea and air platforms, mostly in secret. The Army's Project Convergence is pursuing a similar result on and over land, along with the Air Force Special Operations Command's Adaptive Airborne Enterprise. Meanwhile, the Pentagon's Project Replicator seeks to support all of those initiatives with a package of cheap drones and mission autonomy software.

As far as mission autonomy software has progressed, however, gaps are still apparent. Anduril's demonstration followed a tight script. When asked afterward about several contingencies—what if communications between the drones are disrupted? What if the J-35 shoots down the first interceptor?—Anduril's answer was clear: Software development is needed to address every possible permutation.

The capabilities of Anduril's choice of test drones also limited the realism of the demonstration. In April, the Air Force selected the company to develop the Fury as one of the first two operational prototypes for the CCA program. But the Fury is still months away from achieving first flight. Instead, the Anduril Texas Test Site operates Class 3-size—up to 1,320 lb.—"clay pigeon" jets as surrogates for the future CCA fleet. These aircraft lack the payload and computing capacity to be aware of their own surroundings. That would require carrying cameras and radars as well as a sensor fusion processor to interpret the data and a mission systems processor to act on it.

Several programs are underway to close the gaps in the software and computing resources needed to enable mission autonomy in combat. These programs are running in parallel to the more visible hardware prototyping efforts, but in some ways they are more important.

In the last year, the Air Force and DARPA launched separate programs, with each assigning several contractors to focus on developing mission autonomy software for future CCA. Meanwhile, industry heavyweights and small startups are working independently on their own software applications. Lockheed Martin's Skunk Works continues experiments of its

Enhanced Collaborative High-Frequency Orientation System. Startup companies also are refining software for mission autonomy roles, including Anduril's Lattice, Shield AI's Hivemind and EpiSci's Tactical AI.

**Mission autonomy software can orchestrate the behaviors of multiple platforms in combat independently of human commands.**

While the CCA operational prototypes catch public attention, the autonomy software that will define their combat capabilities is proceeding quietly. The Air Force selected five companies to develop mission autonomy software for the CCA program in July but withheld their identities as classified information. The project is being led by the Air Force Experimental Operations Unit, which is tasked with translating autonomy experiments into combat capabilities.

The program builds on the Air Force Research Laboratory's yearslong Skyborg program and DARPA's Air Combat Evolution (ACE) program. The latter produced algorithms that have been tested aboard various aircraft, including

**Anduril's leased test site deep in the remote desert of West Texas features an 8,000-ft. runway and test facilities.**

the Air Force Test Pilot School's X-62 Variable In-flight Stability Test Aircraft, General Atomics Aeronautical Systems Inc. MQ-20 Avenger, and Kratos XQ-58 Valkyrie and UTAP-22 Mako.

Slightly more visible are the contractors working on the follow-on to DARPA's ACE program. In June, the agency confirmed that six companies—Northrop Grumman Mission Systems, Lockheed Martin Missiles and Fire Control, BAE Systems, EpiSys Science, Systems & Technology Research and Strategy Robot—are working on Phase 1 of the AI Reinforcements (AIR) program. Whereas the ACE program was limited to one-on-one, within-visual-range dogfights, AIR is developing the algorithms to support engagements involving multiple aircraft on both sides in beyond-visual-range scenarios.

ANDURIL

STEVE TRIMBLE/AW&ST

To date, technology demonstrations have shown the limitations of state-of-the-art autonomous algorithms. The 2020 AlphaDogfight Trials showed that a simulated, autonomously piloted fighter could easily shoot down a human pilot at the controls of a simulated F-16. However, the simulator provided the autonomous pilot with perfect situational awareness of the location of the F-16 throughout each engagement. By the time the first CCA are supposed to be fielded—before 2030—situational awareness must migrate to the sensors and processors aboard each aircraft.

Anduril officials say they have a straightforward path to achieving CCA autonomy. The Lattice system is already used on the ground for base defense systems, which package a network of sensors with sensor fusion algorithms to develop a real-time situational awareness picture. The task now is to repackage those sensors and fusion processors into hardware compatible with the size, weight and power limitations of a small aircraft.

"Sensor fusion type problems was one of the original core problems that we were trying to understand," says Kevin Chlan, Anduril's senior director for air dominance and strike. "We just have really matured those capabilities. But it's also not to say that we solved sensor fusion, and now we will not have challenges. No, absolutely not. We're gonna continue to learn, but we're also not starting from zero."

# Generative AI 'Super Analyst' May Change How Airlines Set Prices

- ADVANCEMENTS IN AI PROVIDE NEW OPPORTUNITIES FOR AIRLINES
- PRICING, MAINTENANCE AND CUSTOMER SERVICE TOOLS ARE BEING TESTED

**Christine Boynton** Boston and **Helen Massy-Beresford** Paris

MARIO TAMA/GETTY IMAGES

Airlines are broadening their use of artificial intelligence to unlock efficiencies, profits and a more tailored customer experience. One application gaining traction lies in pricing, with active trials poised to evolve how carriers sell.

Eight airlines, six publicly, have begun tests with Fetcherr, an Israeli startup offering a pricing engine driven by generative artificial intelligence (GenAI). The company's first U.S. customer is Delta Air Lines. While the carrier generates nearly half of the domestic industry's profits, it sees room for improvement, so it is assessing a "full reengineering" of its pricing system, Delta President Glen Hauenstein said in November at an investor day.

At that time, about one year into a multiyear, multistep partnership, Delta was pricing 1% of its network with Fetcherr's GenAI technology. "The initial results show amazingly favorable unit revenues versus the beta," Hauenstein said, describing the potential for prices tailored to flight, time and individuals. "We're all in on this," he said.

Fetcherr's five other public customers are Azul, Royal Air Maroc, Viva Aerobus, Virgin Atlantic and WestJet. Founded in 2019, the company chose initially to specialize in the airline industry, with its three co-founders coming from algorithmic trading, e-commerce and advertising. Fetcherr sought out "the right customers willing to, let's say, break the glass ceiling of legacy," CEO and co-founder Roy Cohen explains.

"Me and my partners, we are not aviation people. . . . Our connection to aviation and travel is as any normal customer who is buying a ticket," Cohen quips. "We came up with the notion of our large market model without considering aviation because technology is agnostic. It can work in any industry."

For Fetcherr's launch, "we were looking for industries that are extremely legacy so we can showcase how our GenAI [large market model] can optimize the way companies or large organizations price," Cohen says. "We saw a big opportunity there [with the airlines] to bring a technology in that can basically future-proof the way these organizations work. At the end of the day, it's beneficial for the end customers because the prices are more flat throughout the booking calendar."

At the heart of Fetcherr's offering is a large market model, an AI engine able to forecast demand and market trends, learning as it goes. A demand-based system, it takes in airline schedules and inventory, public data from vendors including OAG, and weather and financial market data, acting as a "super analyst" to optimize the price until departure.

"The system recommends what to do, and the [airline] analysts can always overrule the AI," Cohen explains.

Although airline moves to test AI in pricing already have come under U.S. government scrutiny, carriers have pushed back, describing the focus as being on efficiency and optimization. A December U.S. Senate subcommittee hearing on ancillary fees questioned representatives from five airlines on their plans for the technology, seeking to understand whether AI use for that purpose could be exploited and harm consumers.

Delta Chief External Affairs Officer Peter Carter countered at the hearing that the AI push is "about the right offer at the right time, as opposed to a thousand different offers to a thousand different people."

Fetcherr stresses that it does not collect any customer's private data. "We don't price customers; we price fares," Cohen asserts. "We have zero private information."

Once implemented, Fetcherr says its GenAI solution can boost revenue 6-9%. Virgin Atlantic, its first customer in the UK, already has seen an impact, even if AI output initially had to fit in with legacy systems during a transition phase.

"It isn't about cost saving for us, but it does change how we work," Chris Wilkinson, vice president of pricing and revenue management at Virgin Atlantic, said during a podcast hosted by Fetcherr. "It's there to help you perform better, to do more."

Virgin set out to measure the technology's effectiveness by comparing new and old ways of pricing.

"There's no human putting a step between AI making a recommendation and it going into the market," Wilkinson explained. "Instead, we put our resources after the outputs have gone in to understand why it did what it did. We gave half of a route to Fetcherr, and we kept our existing systems and processes for the other half and then measured one versus the other."

As the airline has moved out of a proof-of-concept period and into implementation, "we think we've seen the benefit grow over time," Wilkinson said. "We think it keeps on learning."

## BEYOND PRICING

AI is not new to airlines. Traditional AI, which can analyze and predict, has been used for functions including revenue management, marketing and network planning. But the emergence of GenAI—capable of creating new

Delta Air Lines is testing a new pricing tool driven by generative AI it describes as a "super analyst" that works 24 hr. a day, seven days a week.

content based on what it learns—is broadening how the ever-evolving technology is deployed. And while airlines investigate its potential to shake up pricing, other operational areas are also benefiting.

One example is EasyJet, which opened a new operations Integrated Control Center (ICC) in Luton, England, to manage its daily program of about 2,000 flights, embedding AI into its day-to-day practices to speed up and improve decision-making.

The ICC, which opened in May, houses 250 specialists and operates 24/7, using AI for predicting standby crew requirements, including a crew planning tool that helps recommend and select the best crew options for the needs of EasyJet's operation and aircraft.

The new GenAI tool, Jetstream, gives the team "instant access to policies, procedures and information which will enable them to solve operational issues as they occur," EasyJet said in a press release at the time, noting that it planned to place AI-led technology in crewmembers' hands as well.

Air France-KLM also is using AI to improve its operations and offerings to passengers. In December, the group and Google Cloud announced a strategic collaboration. Through this greater use of data and AI, including GenAI, Air France-KLM wants to understand passenger preferences and travel behavior better to provide tailored options and services and to improve operations, including through predictive aircraft maintenance.

Air France-KLM has begun transitioning its three legacy data centers toward a multicloud strategy using Google Cloud's data and analytics tools, including BigQuery. The group calls the partnership with Google Cloud "a significant step forward" in its data strategy.

"Airlines generate massive amounts of data, much of which can be incredibly valuable in helping drive operational insights, build better customer experiences and—with the power of GenAI—create entirely new services and offerings," said Matt Renner, president of global revenue at Google Cloud.

Even before the that collaboration with Google Cloud, Air France-KLM was exploring the potential of AI to improve operations and offerings, as fleet renewal brings into play aircraft that communicate increasing amounts of data to their operators.

In early 2023, the group decided to embrace ChatGPT and see what it could offer, Julie Pozzi, head of operations research, data science and data strategy, said at a May briefing in Paris. "There has been a strong acceleration in recent years," Pozzi noted. "We have been focusing on data strategy, and we have launched data management programs to structure the way we manage data at Air France and KLM."

Conscious that GenAI is in its infancy and technologies that seem the latest thing today might be obsolete in a year's time, Air France-KLM is not developing its own solutions but is basing its GenAI experiments on existing market solutions.

While some 40 GenAI projects were underway at the time of the briefing, a select few were at the proof-of-concept stage, being tested or in use, Pozzi said, including Air France's own internal ChatGPT, Talia, which allows employees to familiarize themselves with the tool in a closed circuit. Another tool, Pamelia, provides Air France airport staff with quick answers to questions from customers via their tablets. One big advantage is the voice function, which can answer the customer in 85 languages.

Another GenAI tool, Charlie, aims to improve maintenance processes by quickly finding part numbers within reams of documentation and thereby speeding up the replacement process—good for the airline's punctuality stats and for passengers waiting on the tarmac as well as for technicians' stress levels, Air France said.

Fox, meanwhile, is a tool capable of automatically analyzing customer feedback—including picking up on humor—and ideal for helping the airline zoom in on passenger opinions of a given aspect of their journey, such as onboard catering.

"Generative AI is not really disruptive; it is more a continuation of the data transformation of the airline," Pozzi said, noting that it is suitable only for certain use cases—"the cherry on the cake."

AI also has a role to play in cybersecurity; carriers are using the technology to help safeguard their operations. Latvia's AirBaltic says it deploys multiple integrated AI tools for continuous monitoring of its network and applications, allowing it to identify and respond to potential threats in real time.

The carrier also is using AI-based technology to maximize ancillary revenue, including PROS' Dynamic Ancillary Pricing and Merchandising, which allows for personalized offers based on detailed customer segmentation. The system, introduced in late 2023, automates and optimizes the pricing of seat assignments, allowing AirBaltic to adjust prices dynamically based on demand and customer preferences. Customer interactions help determine the optimal price points for various segments and flights, enabling the AI algorithms to learn and improve predictions over time.

AirBaltic describes the results as promising and is considering extending AI-driven strategies to other ancillary products such as baggage.

# Physics-Based AI Promises To Speed Aerospace Design Optimization

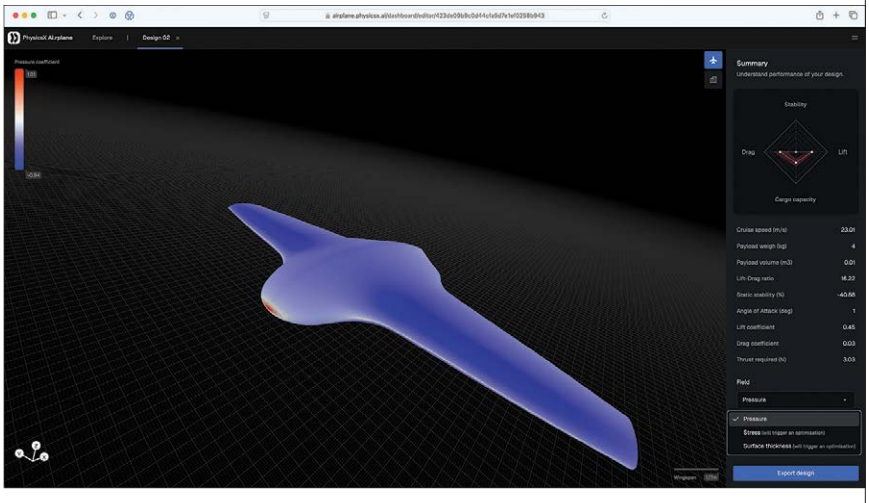
> AI MODEL IS PRETRAINED ON COMPUTATIONAL ENGINEERING DATA

> USERS WILL TUNE MODEL USING THEIR OWN SIMULATION RESULTS

**Graham Warwick** Washington

Numerical simulation has become an essential part of aircraft design, from aerodynamics and structures to aeroacoustics and thermal analysis. But the escalating use of modeling and simulation comes with a cost—the tens of millions of computational core hours required to develop an aircraft.

PHYSICSX




**PhysicsX's LGM-Aero AI-based analysis tool predicts performance of new shapes.**

Automated and ultrafast numerical simulation via cloud access to thousands of general processing units instead of hundreds of on-premises central processing units is one solution. Physics-based artificial intelligence (AI) is offering another approach.

London-based startup PhysicsX has launched a large geometry model, LGM-Aero, pretrained on tens of thousands of computational fluid dynamics (CFD) and finite element analysis (FEA) simulations of generic shapes, generated using tools from Siemens Digital Industries Software.

Rather than performing calculations to solve the mathematical equations governing fluid flow or simulate how a structure will behave under loads, LGM-Aero infers the results using a machine-learning model trained on that CFD and FEA data.

"What we're setting up to do with PhysicsX is change the way that engineering is practiced, starting with how physics simulation is carried out," cofounder and CEO Jacomo Corbo says. "The backbone of all of engineering is assessing different designs. And that involves physics simulation of some description.

"All of that involves solving partial differential equations explicitly, at some resolution on some mesh, and a lot of engineering is bottlenecked by these physics simulations," Corbo continues. "They're compute-intensive, and that stands in the way of optimization and end-to-end automation."

Numerical simulation entails the laborious process of generating a mesh of thousands or millions of simple cells that capture a complex geometry, simplify the calculations and allow computational power to be focused on high-resolution areas of interest to produce high-fidelity results.

"We're trying to change the form factor of that compute by moving to AI models that are very fast," Corbo says. "All the physics simulation now is a prediction step. It's happening by inference. That means speed-ups of $10^4$-$10^6$, so up to a million times.

"What that allows us to do, in turn, is to optimize things differently to how they're currently done," he adds. "So more algorithmically driven optimization, more end-to-end automation and, ultimately, greater creativity imbued in the whole engineering process."

Work on aeroelastic applications began in 2022. "There's no explicit calculation of the physics. They're not about solving the equations of physics," Corbo says. Instead, LGM-Aero infers aerodynamic performance, flight stability and structural stresses for a large class of flying shapes. It can operate as a zero-shot model, producing results out of the box without being trained on specific examples, PhysicsX says, but the model only needs tuning to capture the fine features required for a specific application like exterior aerodynamics.

The model comes pretrained, but customers can use their own data to further train it and produce a version "that's in the loop of an optimization process," Corbo says. "So we can search a large space much more effectively than if we have numerical simulation in the loop every step of the way."

LGM-Aero can be used in detail design but also, because of its speed, from conceptual design to process control. "[In detail design], we can unlock a lot of value by enabling much better optimization," he says. "We can also go upstream to concept design, where we are evaluating big architectural choices."

Computer-aided engineering (CAE) typically is not applied to concept design because of the complexity of building meshes. "We think we can get to CAE levels of accuracy but bring it into concept engineering because we've divorced physics simulation from the complexities of the mesh," Corbo notes.

"We can also go downstream of detailed design," he adds. "CAE is just too slow at the fidelity required to be in the loop of a control process. Now we can bring it there, and one of the things we're unlocking is an ability to bring a high-quality physics simulation to the entire product development life cycle."

PhysicsX is working with OEMs and Tier 1s to integrate physics AI into their tool chains. "We are building a new software stack for complex engineering and manufacturing—a platform and developer tools for our customers to build workflows based on this kind of physics simulation and these kinds of AI models and do optimization they otherwise are not able to," Corbo says.

# AI-Designed Batteries Are Unlocking Tailored Performance for New Markets

> ELECTROLYTE DETERMINES BATTERY PERFORMANCE ATTRIBUTES

> DROP-IN COMPONENT CAN TUNE BATTERIES FOR DIFFERENT MARKETS

**Graham Warwick** Washington

There are many requirements for electric air taxi batteries: high power for vertical takeoff, high energy for cruise, fast charging for quick turnaround, long cycle life for operating economics and safety for certification. Artificial intelligence is being applied to optimize these often conflicting needs.

In recent years, lithium-ion battery development has been focused on electrode materials that increase energy density for greater electric vehicle range. Now that the range challenge is largely conquered, attention has shifted to other battery attributes, such as safety, cost, power, charging and cycle life.

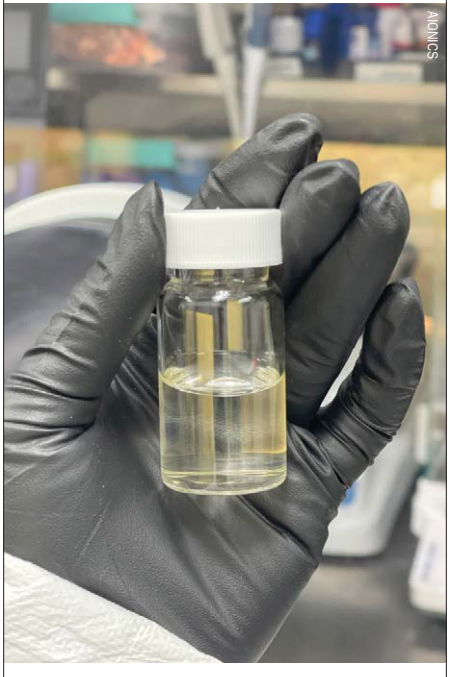
At the same time, batteries are finding new applications, from grid storage to electric aircraft, that require different mixes of these attributes—mainly determined by the electrolyte, a chemical solution that enables lithium ions to shuttle between the cathode and anode.

Researchers are taking a leaf from the drug discovery playbook and using artificial intelligence (AI) to analyze combinations of 10 billion available molecules in search of electrolyte formulations tuned to different customers' specific requirements, whether for high power, long life or both.

Californian startup Aionics was formed in 2020 by three postgraduates from Stanford University. "We were working at the intersection of materials science and AI," co-founder and CEO Austin Sendek says. "I was interested in the potential for accelerating the design of materials and especially batteries."

The seed-stage company based in Palo Alto, California, has secured investment from mobility-focused Trousdale Ventures and UP.Partners along with the University of Michigan's startup fund and Avila VC. Aionics has signed joint development partnerships with Porsche's battery subsidiary Cellforce Group and more recently with an undisclosed aviation company to "tweak" an off-the-shelf cell into an electric vertical-takeoff-and-landing (eVTOL) battery.

"The idea has been to discover and commercialize new battery materials," Sendek says. "We're focusing on optimizing electrolyte formulations around the various performance profiles that applications need." Aionics is mainly working with liquid electrolyte systems, the type most widely used in the battery industry.




**Aionics has provided customers small quantities of AI-tuned battery electrolyte for testing.**

"Every application area, whether it's eVTOL, automotive or grid-scale storage, needs something slightly different," he adds. "And batteries today are kind of one-size-fits-all.

"Reengineering the electrolyte can unlock a lot of changes in performance along with different unique properties that are determined by the electrolyte," Sendek explains. "And the marginal cost to change the electrolyte is close to zero. It's a drop-in component. You don't have to retool your factory. You can explore tons of combinations relatively easily, and the design space is huge."

The majority of electrolytes used in commercial batteries are different ratios of the same 11 molecules. "If you want more power, you add a little bit more of this, and if you want a little bit longer lifetime, then you can get a little bit more of that," Sendek says.

"But that's a tiny fraction of chemical space that's available," he notes. "There are about 10 billion molecules you can order and have show up in a couple weeks. We're searching through the same chemical design space that drug companies are looking through for therapeutics. And essentially any molecule you can buy that is stable—including some that are produced by generative AI and are feasible but have never been made—is a candidate for this process."

Aionics uses four or five layers of AI. "If I want to optimize the cell to give me high power for 5 min., I need to build a machine-learning model that can predict, based on formulation of the electrolyte, what the peak power of the cell is going to be," Sendek says. "And I need to apply that really specific model across this chemical space of 10 billion possible molecules. So it needs to be computationally fast, but it also needs to be accurate."

Such models can use a deep-learning potential neural network function that simulates interaction between atoms. This type of model predicts the potential energy of a system and is used in molecular simulations. Aionics also builds small data models that learn the response of the cell to changes in the electrolyte. "That's like a regressor-type model," he says.

Aionics uses a multimodal approach to data collection that combines large language models trained on textbooks, publicly available databases, simulations and experimental data from partner laboratories and customers. "I call this a semi-empirical approach," he says. "There's bottom-up science, and there's top-down data, and you want to find some way to bridge that."

Aionics has produced small amounts of electrolyte formulations that are being tested by customers. "Our commercialization strategy is not to become a manufacturer but to find companies with the right manufacturing capacity for the formulations," he says. "We're in the Pfizer-BioNTech model."

# Thales Bets on Hybrid AI for Future Automation

> DRONE FLIGHT TESTING ADVANCES AI-BASED NAVIGATION SAFETY

> AI MAY HELP PREVENT COLLISIONS IN AIR TRAFFIC MANAGEMENT

**Thierry Dubois** Paris

Thales is developing hybrid artificial intelligence approaches for commercial air traffic management and large drone control, thus taking steps toward eventual use on commercial aircraft.

Thales aims to harness the power of artificial intelligence (AI) in future commercial cockpits, with possible advancement toward autonomous flight. Engineers have found ways to circumvent AI's challenges for aviation: explainability, the system's ability to explain its decision or advice, and trustworthiness, or ensuring AI does not make the wrong decision. Whether crew members or air traffic controllers can maintain the current level of engagement remains to be seen. While the pilot or controller is making the final decision, they do not devise the solutions themselves.

Thales' progress on AI comes as the European Union Aviation Safety Agency (EASA) has issued rules intending to allow certification in 2025 of a Level 1 AI system, which provides assistance only while a human operator remains in command. A number of aerospace players are working on this. Daedalean and Leonardo have flight-tested AI tools to support helicopter pilots with traffic detection, navigation and landing. Daedalean's research in 2020-21 contributed to EASA's first guidance for Level 1 AI applications in aviation.

Thales recently launched its Autonomy Project, Baptiste Lefevre, Thales Avionics' technical lead for autonomy, said at the AI Applications in Aeronautics, Defense and Space conference organized by the Air and Space Academy here in mid-November. "We want to use the amazing optimization power of AI while keeping decades of experience in safety management and safety analysis," he emphasized. Thales has thus set a prerequisite to achieve the project's goal of full autonomy: a higher safety level than current aircraft.

Under a stepped approach, Thales engineers have started to mature solutions on a long-range UAS100 surveillance drone. They deem urban air mobility the logical next target due to the high relative cost of pilots in operating an aircraft carrying a small number of passengers. After 2040, Thales intends to pursue full autonomy of a commercial aircraft.

"That means maybe 2050 or maybe never, but it is still our horizon," Lefevre said. "Our deliberate choice for a long-term objective pushes us to find new concepts, new systems and new technologies that will drive future developments."

On the UAS100, Thales devised an AI system for a car-tracking mission. The drone's trajectory depends on a moving target and cannot be planned. "We decided to use a neural network to generate a trajectory, using reinforcement learning," Lefevre said. "We are calling the neural network every second, giving current positions as inputs. As the output, the system gives a direction and a radius of curvature."

The integrity of an AI system is below 99%, far from the required safety level on such an aircraft—the probability of a catastrophic failure should be one in 10 million or below, Lefevre explained.

To bridge that gap, Thales has adopted a hardware architecture relying on two onboard computers. The first uses high-performance processing units able to run a neural network, but it is limited to a relatively low reliability level. The second meets safety-critical criteria with a high design assurance level but has moderate performance, Lefevre said.

From the ground, the operator sends just a mission objective. The high-performance computer receives it and generates a trajectory using AI. It then shares the result with the high-design-assurance computer, which checks the trajectory. "The architecture unlocks free-route capability for the drone," Lefevre said, referring to the ability to choose a flightpath on its own, without an onboard program or ground control.


THALES

Engineers have been very careful about the type of trajectory the high-assurance computer accepts, he said. If it does not match with the drone's performance or the obstacle database, the trajectory is rejected.

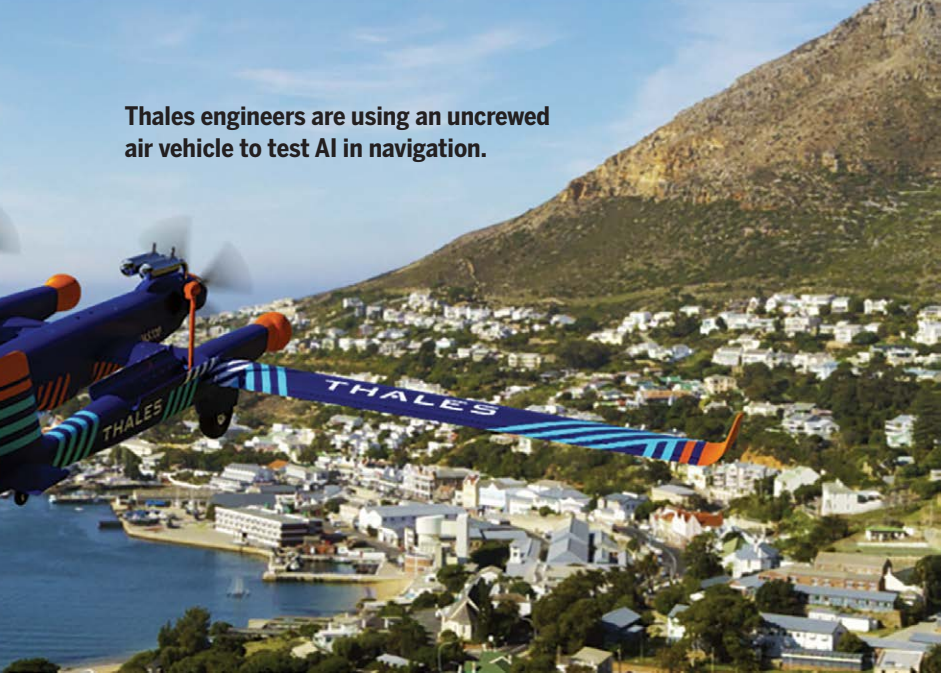
The first computer also generates contingency trajectories. In case of a failure, the second computer checks all the database's "what if" scenarios. "In the certified computer, at all times, we have this trajectory database for safe termination of the flight," Lefevre said. Flight tests in Canada included car tracking as well as power line detection and avoidance.

For air traffic management (ATM), Thales is investigating the combination of a neural network with a certified conflict-detection system to help prevent aircraft from flying too close to one another in a given airspace.

The emergence of such a hybrid AI system could reduce pressure on air traffic controllers, who would decide whether to use a proposed resolution advisory. It also could improve avoidance trajectories, for instance, by making them shorter. Thales says such a system might enter service around 2030, after further development and certification work.

Under the conventional procedure, when a trajectory conflict or potential loss of separation is identified, the air traffic controller steps in and identifies a new trajectory. They provide the crew with an instruction, or clearance, to alter their flightpath and avoid the conflict. Simultaneously, controllers make sure they avoid conflicts with other aircraft in the same airspace.

Regulations call for maintaining




Thales engineers are using an uncrewed air vehicle to test AI in navigation.

separations of 5 nm horizontally and 1,000 ft. vertically, although some variations may apply. "When traffic is very dense, this can be quite stressful," Thales Airspace Mobility Solutions Chief Data Scientist Andrei Purica said at the conference.

Thales already offers an automated resolver. Based on classical research algorithms, it works in the background, looking for an alternative trajectory, Purica said. The resolver shares the result with the controller, who can decide whether or not to use it.

The current model has computational power limits, however, and cannot analyze every single solution in the background. Thus, it may miss some, Purica pointed out.

Thales is exploring AI to address this—specifically, reinforced learning. The approach gives more exhaustive and faster results, and includes cost functions, such as the benefits and drawbacks of each solution. It can take into account criteria including $CO_2$ emissions and contrail reduction, Purica noted.

Safety concerns rank first among the limitations of AI for ATM. The system cannot guarantee a solution, and a solution may be difficult to explain. "In accuracy, 99% is not enough," Purica said.

Hence Thales' hybrid approach, combining AI and symbolic calculations. "If a conflict is detected, and we have a number of options to resolve it, we ask the neural network what it thinks of a certain option with respect to a certain cost function," Purica said. "We look at rewards and penalties. In a flightpath's deviation, the neural network may tell us one heading is better than the other, or it may suggest a certain range of angles is best." The classical tool then focuses the search and gives the controller a validated solution.

To train the AI model, Thales relied on 20-30 min. ATM scenarios and ensured it was learning from failures, Purica said. The company deemed the experiment successful. "We ran the system for several days," he said. "After 15 million clearances, the system began to understand and started to maximize the cost function we provided. After 20 million clearances, it not only solved 99% of the problems, it reduced the average length of the trajectories."

Thales tested the AI part of the system with controllers, who found it acceptable—sometimes comparable to a novice controller, sometimes more proficient.

# MRO Industry Expands Potential AI Use Cases

- AI TOOLS SERVE AS DIGITAL ASSISTANTS TROUBLESHOOTING MAINTENANCE ISSUES
- ENGINE BORESCOPE INSPECTIONS TAKE LESS TIME DUE TO AI TECHNOLOGY

**Lindsay Bjerregaard** Chicago

The maintenance, repair and overhaul segment has been using artificial intelligence for many years under the less assuming name "predictive maintenance," but technology startups, OEMs, airlines and aftermarket service providers have been developing a wide range of other use cases recently.

**AI-powered tools are enabling MRO providers to improve speed, accuracy and consistency of inspections.**

Beyond utilizing artificial intelligence (AI)-based simulation models to determine when assets are deviating from expected behavior or when they will need maintenance or should be scrapped, some companies have developed AI tech-


LINDSAY BJERREGAARD/AW&ST

nology to simplify the maintenance processes themselves.

For instance, GE Aerospace has created AI-powered tools for blade, borescope and fluorescent penetrant inspections of engines that are aimed at improving speed, accuracy and consistency. The OEM says these technologies simplify what is otherwise repetitive, manual work for technicians and reduce turnaround times considerably. For instance, GE says the AI-enabled blade inspection tool has cut times in half.

Dutch startup Aiir Innovations has been offering an AI tool for automated aeroengine borescope inspections for several years to customers such as KLM, GT Engine Services and TAP Air Portugal. The company says its software can analyze borescope video 75% faster than manual reviews.

Generative AI has been a particular area of interest in maintenance, repair and overhaul (MRO), and companies have developed applications aimed at simplifying maintenance technician work and customer access to pertinent information.

AIIR INNOVATIONS

In November, GE Aerospace, Accenture and Microsoft developed a new tool—tentatively called GenAI Assistant—that airlines and lessors can use to access critical maintenance records more quickly. The companies want to reduce the time spent searching maintenance records from hours to minutes.

Several companies—such as AFI KLM E&M, Amygda, LexX Technologies and Veryon—have been developing generative AI-powered apps built to function like a maintenance technician's personal assistant. These apps can provide answers to "what if" scenarios, troubleshoot issues based on data from maintenance logs or aircraft sensors or log and transcribe maintenance information via speech instantly.

LexX Technologies, an Australian tech startup, has an AI platform that can automatically process data from manuals, handwritten notes, photos, work orders and other sources. Technicians can ask the platform a question or describe a problem in their native language, and it provides what LexX says are accurate, data-based answers in simple language to help guide them through tasks. The company describes the technology as a cross between Apple's Siri virtual assistant and the C-3PO droid from "Star Wars," custom-tailored for the MRO industry.

AFI KLM E&M has launched more than 80 projects related to the use of generative AI across all Air France business sectors. For instance, it developed a tool called Charlie for its maintenance teams that lets technicians search and instantly pinpoint correct parts, tasks and essential documentation, which the company says is saving more than 1 hr. when repairing or replacing parts.

The MRO provider also has developed a natural language processing tool called Voice to Admin. A person using the app can speak into a device using their native language, and the app translates their words into English for a report in the company's enterprise resource planning software. AFI KLM E&M says the tool results in higher shop productivity and better data quality.

Some companies also are hoping AI can help the industry safeguard against parts with fake or improper paperwork, which happened

**One of AFI KLM E&M's many generative AI projects involves helping technicians find correct parts and documentation more easily.**

in the recent AOG Technics scandal. Aftermarket services provider GA Telesis recently partnered with tech startup Alitheon to develop technology that will improve traceability and provenance of aftermarket parts.

Alitheon's FeaturePrint technology applies optical AI to create unique digital fingerprints for parts using standard industrial cameras or mobile phones. The company says its technology detects minute surface details of physical items, augmenting elements such as removable tags, QR codes and paperwork to trace part history and authenticity. GA Telesis plans to integrate FeaturePrint into its Wilbur parts provenance and records platform.

Some companies are leveraging AI to improve maintenance-related customer service, recruiting and sustainability, too. For instance, Rolls-Royce is working with startup Aerogility to use its AI-based digital twins to model the environmental impact of its products and services, such as energy consumption at its MRO sites. United Airlines has been using AI to generate messaging around delays, and it is using an AI-based tool called Textio to eliminate potentially biased language in job listings so that it can tap into a more diverse applicant pool.

AVIATION WEEK'S 67TH ANNUAL

# LAUREATE AWARDS

*Since its inception in 1957, the Aviation Week Network's Laureate Awards have honored extraordinary achievements in aviation, defense and space. Each year, our editors review piles of internal and external nominations and choose exemplary individuals, teams and accomplishments. The winners epitomize the aerospace industry's outsize role in underpinning global economic and technological advances.*

*This year, we honor 28 individuals, companies and programs across five industry sectors—commercial aviation, defense, space, business aviation and maintenance, repair and overhaul—as well as Lifetime Achievement awards and a Pathfinder award for exceptional industry leadership. We also recognize two dozen university-level students and military cadets pursuing careers in aerospace or aviation. They join a long list of past luminaries extending back to the dawn of the space age and commercial jetliner service:* AviationWeek.com/Laureates-1957-2024

*The 2025 Laureates will be presented on March 6 at a black-tie gala at the National Building Museum in Washington. That evening, editors also will reveal five Grand Laureates selected from the winners in each of the industry categories.*

*For more information on attending or sponsoring the event, please contact Rob Howlett at rob.howlett@aviationweek.com. Queries on general event information should be sent to Allison Gold at allison.gold@aviationweek.com.*


CHRIS ZIMMER

**Digital Extra** *Read more about the Laureates and their history and view photos from last year's event:* **Laureates.AviationWeek.com**

# Commercial Aviation


AIRBUS

## Airbus A321XLR

Airbus received European Union Aviation Safety Agency certification of the CFM International Leap 1A-powered version of the A321XLR and delivered the first aircraft to launch operator Iberia in November. The long-range version of the A321neo will enable airlines to operate secondary long-haul routes at a much lower unit cost and has the potential to substantially change long-haul networks.

## Embry-Riddle Safety Center

Embry-Riddle Aeronautical University's safety center has established itself as a center of excellence for advancing research, education and industry collaboration on topics critical to improving aerospace safety globally. Launched in 2023, The Boeing Center for Aviation and Aerospace Safety supports safety-related studies by students on key topics including human factors and artificial intelligence.


EMBRY-RIDDLE AERONAUTICAL UNIVERSITY

NASA

## NASA's Electric Aircraft Testbed

Already used by GE Aerospace, MagniX and others, NASA's Electric Aircraft Testbed within the Neil Armstrong Test Facility in Sandusky, Ohio, is a unique asset providing an emerging industry with the crucial capability to test megawatt-class electric propulsion systems at simulated cruise altitudes, paving the way for the electrification of regional and single-aisle airliners.

## SAS Scandinavian Airlines CEO Anko van der Werff

After many years in crisis, SAS Scandinavian Airlines has been transformed into a profitable business by Anko van der Werff, who was appointed CEO in 2021. Emerging from a fundamental restructuring via Chapter 11 bankruptcy in mid-2024, the airline was acquired by a group of investors, including Air France-KLM, which can take majority control at a later stage.

SAS

WESTJET

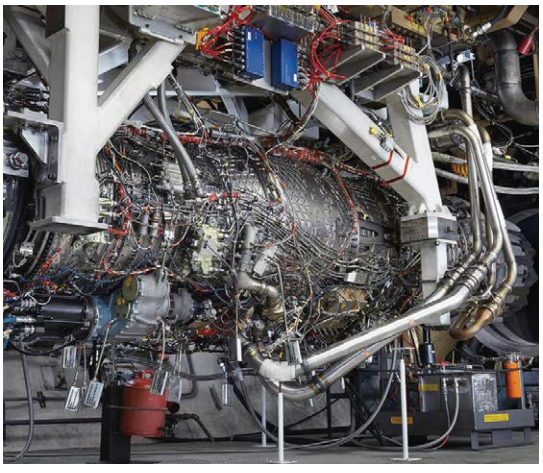
## WestJet Airlines CEO Alexis von Hoensbroech

Alexis von Hoensbroech joined WestJet as CEO in 2022 and pivoted to focus on the carrier's strength in Western Canada, capping widebody operations, building on its position as Canada's largest leisure carrier by acquiring Sunwing and maintaining a competitive cost base. His leadership has preserved WestJet's position as Canada's premier low-cost carrier.

# Defense

## Adaptive Engine Transition Program

Pioneering propulsion advances achieved through the U.S. Air Force's Adaptive Engine Transition Program led to the development and test of two three-stream engines—GE Aerospace's XA100 and Pratt & Whitney's XA101. With 10% more thrust and 30% higher efficiency than the Pratt F135, the engines will pave the way for future variable-cycle powerplants.



GE

AIRBUS

## Airbus Racer High-Speed Compound Rotorcraft

Just seven flights into its test program, Airbus' Rapid and Cost-Effective Rotorcraft demonstrator raced past its initial 220-kt. speed target. Developed under Europe's Clean Sky 2 research program, Racer's aim is to prove higher cruise speeds can be achieved for rotary-wing aircraft without a substantially higher operating cost or training burden.

## Air-Launched Rapid Response Weapon

Lockheed Martin's AGM-183A Air-Launched Rapid Response Weapon achieved the first end-to-end tests of a hypersonic glide vehicle with a high lift-to-drag design. Facing an uncertain future, the U.S. Air Force program battled numerous obstacles and a daunting schedule to demonstrate the viability of an air-launched hypersonic weapon with the ability to maneuver during the glide phase.


U.S. AIR FORCE


ANDURIL

## Anduril Industries

Demonstrating its ability to turn the idea of disrupting the defense industry into reality, startup Anduril in 2024 underscored its ascent as an industrial force by winning a U.S. Air Force contract to develop a Cooperative Combat Aircraft, snagging an order for more than 500 counter-drone interceptors and securing a $1.5 billion funding round.

## Hermeus

High-speed aircraft developer Hermeus completed initial tests of a full-scale precooler with a Pratt & Whitney F100-229 engine, marking a key step toward development of a production-relevant, turbine-based combined-cycle propulsion system and paving the way for flight tests of a low-cost, reusable air-breathing hypersonic aircraft.

HERMEUS

# Space

## Artemis Accords

A foreign policy initiative launched by NASA as part of its Artemis Moon program, the Artemis Accords establish key principles for global space exploration and development. Starting with seven signatories in October 2020, 52 participating nations have signed on to a shared vision of a safe and transparent environment for exploration, science and commercial space.


NASA

CNES/ESA/ARIANESPACE/OPTIQUE VIDEO CSG/S MARTIN

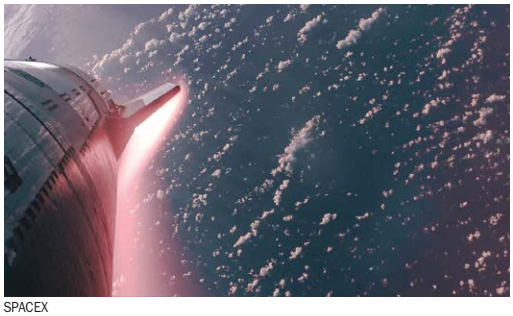
## Kourou Spaceport and CNES

Europe's spaceport in French Guiana is undergoing a metamorphosis with the arrival of the Ariane 6. French space agency CNES is welcoming private developers of small space launchers, repurposing the Soyuz launch facility left vacant because of Russia's invasion of Ukraine. The spaceport is simultaneously reducing its environmental footprint by upgrading buildings to higher energy standards.

## Space Development Agency and York Space Systems

Since November 2023, the U.S. Space Development Agency has demonstrated Link 16 connectivity from a York Space Systems satellite to ground radios in Australia, a carrier in international waters and an aircraft aboard that vessel. Space-based data relay to Link 16 receivers is a crucial enabler for the agency's proliferated satellite network in low Earth orbit.

YORK SPACE



SPACEX

## SpaceX Starship

SpaceX has demonstrated the viability of its Starship-Super Heavy space transport, a fully reusable, low-maintenance system that promises to reduce launch costs markedly. Milestones in 2024 included the spectacular launch tower catch of the Super Heavy booster on the first attempt and the on-target splashdown of the upper stage during the Oct. 13 fifth integrated flight test.

## Varda Space

After eight months in orbit, Varda Space's Winnebago space capsule landed on the Utah Test and Training Range on Feb. 21, 2024. On board was equipment for processing pharmaceuticals, including an experiment to reformulate an antiretroviral drug used to treat HIV, demonstrating a free-flying spacecraft and capsule using microgravity for life-sciences work.

VARDA SPACE

# Business Aviation

## Bombardier Aerospace

In a bid to lead sustainability in business aviation, Bombardier in April became the first business jet manufacturer to disclose the scientifically analyzed environmental impact of its entire aircraft lineup. By declaring each aircraft's $CO_2$ emissions from raw material to end-of-life, the goal is to take ownership of and drive down the environmental impact.

JEREMY KARIUKI/AW&ST

GARMIN

## Garmin Runway Occupancy Awareness

Garmin's Runway Occupancy Awareness (ROA) system is the first certified software using SURF-IA surface indications and alert technology. It is designed to help pilots navigate complex airports and avoid runway incursions. ROA analyzes aircraft GPS and ADS-B traffic information relevant to the airport's runways and taxiways to alert the crew visually and aurally to potential threats.

## Joby Aviation

In June, Joby Aviation took a prototype of its S4 electric vertical-takeoff-and-landing aircraft and fitted it with a hydrogen fuel-cell system that was developed by subsidiary H2Fly. The aircraft then completed a 561-mi. remotely piloted flight. This compares with the 155 mi. flown by the battery-electric S4 in 2021, demonstrating the potential of hydrogen-electric propulsion.

JOBY AVIATION

TEXTRON AVIATION

## Russ Meyer, Jr., Cessna Aircraft

In the almost 50 years since he was named chairman and CEO of Cessna Aircraft, Russ Meyer, Jr., has been a leader and advocate for the general aviation industry. His efforts were instrumental in passage of the 1994 General Aviation Revitalization Act, placing time limits on product liability and reviving single-engine aircraft production in the U.S. He is now chairman emeritus of Cessna.

## Zack Anglin, Spartan College

A certified flight instructor at Spartan College of Aeronautics and Technology in Oklahoma, Zack Anglin knows about overcoming obstacles. Born without hands and feet and abandoned in Nigeria, he was adopted by an American missionary family. Pursuing his dream to become a pilot, he was repeatedly denied an FAA medical certificate and turned away by schools but persisted until he found Spartan.

SPARTAN COLLEGE OF AERONAUTICS AND TECHNOLOGY

MRO

## Aerospace Maintenance Council

Marking its 12th year in 2025, the nonprofit Aerospace Maintenance Council Competition brings teams of five together at Aviation Week Network's MRO Americas show to compete in hands-on, judged and timed competitions. Elevating the profession, the energetic competition highlights the requirements of knowledge, skill and integrity to return an aircraft to a safe, airworthy status.


AVIATION WEEK

DELTA TECHOPS

## Aviation Supply Chain Integrity Coalition

Formed in February 2024 to find ways to prevent unauthorized parts from entering the market, the Aviation Supply Chain Integrity Coalition brought together Airbus, American Airlines, Boeing, Delta Air Lines, GE Aerospace, Safran, StandardAero and United Airlines. After a nine-month investigation, 13 actions were recommended to close gaps and add layers of safety to strengthen the supply chain.

## Embraer Aircraft Maintenance Services

Facing full hangars and rising demand, Embraer's heavy maintenance facility in Nashville, Tennessee, needed to do more with the same footprint. Among its tactics: shorten airframe check times by going paperless. Turning task cards into digital files has streamlined communication on issues such as nonroutine work approval, and a process that took days is finished in hours.

EMBRAER

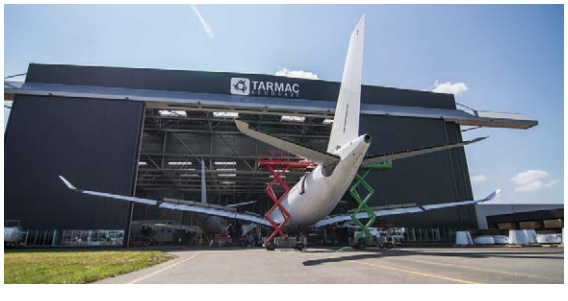
LUFTHANSA TECHNIK

## Lufthansa Technik AeroShark

AeroShark, a surface film technology that mimics shark skin to optimize airflow, is reducing emissions for passenger and cargo aircraft around the world. An adhesive riblet film codeveloped by Lufthansa Technik and BASF, AeroShark has exceeded its design expectations in both fuel burn and service lifetime and is being adopted by airlines outside of the Lufthansa Group.

## Tarmac Aerosave

Tarmac Aerosave's aircraft recycling process is helping Airbus recover some 90% of aircraft weight at the companies' recently opened Airbus Lifecycle Services Center in Chengdu, China. Tarmac Aerosave also is collaborating with ATR to enhance end-of-life dismantlement, increase recyclability of the turboprop manufacturer's aircraft and identify new recycling processes.




TARMAC AEROSAVE

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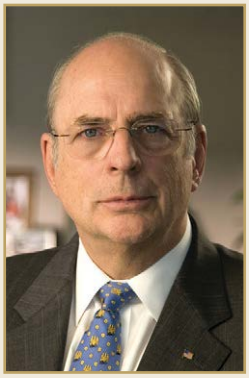
# Philip J. Klass Lifetime Achievement Award


U.S. NATIONAL SCIENCE FOUNDATION

**Norm Augustine** may have retired from the industry in 1997, but his outsize influence on the aerospace sector he joined as an engineer in 1958 did not end there. After a career split between industry leadership and public service, including roles as CEO of Martin Marietta and Lockheed Martin as well as undersecretary of the U.S. Army, Augustine has continued to help shape the industrial landscape as chair of blue-ribbon committees investigating the U.S. space program, human spaceflight plans and, most recently, NASA's uncertain future due to declining national investment in technology innovation. Famed for Augustine's Laws, which were published in 1984 and warned that by 2054 the entire U.S. defense budget would purchase just one aircraft, his wise guidance has continued to be invaluable to an industry facing unprecedented technological change.


EASA

**Patrick Ky** has made a lasting, positive impact on the field of aviation safety. During his 10 years at the helm of the European Union Aviation Safety Agency (EASA), Ky was instrumental in raising the profile of the European regulator and making it a strong reference for global safety matters. EASA led efforts to establish tougher standards for certification of the Boeing 777X and the 737 MAX return to flight in 2021 after two fatal crashes within six months in 2018 and 2019. To ensure sufficient fire protection, EASA also required Airbus to make substantial changes to the A321XLR. Under Ky, EASA led global moves to regulate the emerging advanced air mobility sector safely as well. A former aerospace engineer, Ky previously led Europe's SESAR air traffic management research project and is now CEO of the Singapore-based International Centre for Aviation Innovation.

# Pathfinder Award


GE AEROSPACE

**Larry Culp** transformed General Electric from a troubled, debt-ridden conglomerate into a pure-play aerospace and defense company, culminating in 2024 with the spinoffs of GE's energy and health care businesses. As chairman and CEO, Culp has reinvigorated GE Aerospace with a culture of candor and facing into problems along with a relentless focus on lean operations. His signature initiative, Flight Deck, partners leaders at the aircraft engine-maker with workers and suppliers to remove barriers to productivity and create a safer, more effective work environment. The company hired 900 new engineers and invested $650 million in manufacturing facilities and the supply chain in 2024. Culp, who had never run an aerospace company, has emerged as one of the industry's most consequential CEOs in recent years.

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AVIATION WEEK NETWORK

# TECH TAKE

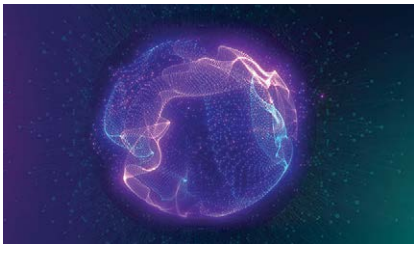
By **Graham Warwick**

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

## Airbus-BMW Challenge Shows Quantum Potential

Anticorrosion coatings, sustainable supply chains and aeroacoustic modeling are among the applications demonstrated by winners of Airbus and BMW Group's quantum computing challenge.

AIRBUS



**The quantum computing ecosystem is thriving, Airbus and BMW say.**

Launched in December, the Quantum Mobility Quest challenged developers to harness quantum computing technologies for real-world applications. Fifteen finalists were selected in June to benchmark their solutions using datasets provided by Airbus and BMW.

The challenge was designed to push quantum computing forward another step by identifying and maturing solutions for promising mobility applications. Five winners were announced on Dec. 10.

"The outputs of the teams show unprecedented quality," Airbus and BMW say. "All candidates selected as finalists have provided highly valuable solutions at the end of Phase 2." Both companies have run quantum challenges before and say they "observed a significant jump in maturation as well as specialization in the solutions offered."

Under the quantum simulation category, a University of Southern California team won for demonstrating that material behavior such as energy absorption and binding properties can be understood better by using quantum technologies.

The category focused on smart coatings and challenged teams to model the adsorption of corrosion inhibitors on an aluminum surface and understand the coating's binding properties using quantum methods. The team highlighted binding energy as a key parameter for identifying potential inhibitors.

UK startup 4colors Research won under the quantum-powered logistics track for using quantum optimization to minimize $CO_2$ emissions and other costs in supply chain logistics. The company proposed a pipeline that allows the user to swap quantum and nonquantum algorithms seamlessly. The solution combines a classical programming framework with novel application of quantum algorithms.

French startup Quandela won the quantum-enhanced autonomy category for exploring how quantum generative modeling could be used to improve image generation for training of machine-learning algorithms, such as transforming limited daytime data into precise and realistic nighttime conditions.

"Quandela showed a convincing analysis about the potential in scalability," Airbus and BMW say. "This is highly relevant for us as industrial end users and essential to bring quantum closer to industrial value."

Under the quantum solver track, a team from the University of Hamburg in Germany was selected for showing how quantum computing could be combined with classical computing solutions to solve complex aeroacoustic and aerodynamic equations to minimize aircraft noise and maximize efficiency.

The team demonstrated both as an efficient quantum-inspired classical method and a hybrid quantum method offering potential additional benefit. While still a long way from being deployable, the approach "offers a new path for solving equations using quantum computing," Airbus and BMW say.

The competition included a fifth category, the Golden App, for novel solutions that push the boundaries of quantum technology for mobility. This was won by Delft University of Technology in the Netherlands with an application addressing optimization techniques for the layering of carbon-fiber materials.

"[This is a] concrete solution for a relevant problem in the mobility sector, [one that is] linked to fuel efficiency and weight reduction and relevant to the key challenges of sustainability," Airbus and BMW say. "We see a promising path to move this example closer to the actual engineering units."

The companies say they were impressed with the "level of novelty, with solutions going beyond what exists today."

"Many solutions presented are just at the beginning of exploration but with high potential," Airbus and BMW say. "There was deep analysis on an algorithmic level but also strong adaptation to specific quantum hardware."

The door is starting to open to quantum computing, the companies say.

## Black Hawk Features Advanced Controls

Fifty years after its first flight, Sikorsky's UH-60 Black Hawk is at the forefront of developments in flight control and autonomy. Skyryse, a startup developing a fly-by-wire and touchscreen flight control system, has partnered with Black Hawk reseller Ace Aeronautics to equip the helicopter with its SkyOS system.

Separately, Sikorsky has cooperated with Rain, another startup developing an autonomous aerial wildfire containment capability, to demonstrate that its autonomous Black Hawk testbed could be commanded to take off, identify the location and size of a small fire and accurately drop water to suppress the flames.

Under their agreement, Ace's Guntersville, Alabama, facility will serve as the primary installation hub for retrofitting ex-military helicopters with Skyryse's SkyOS automated flight control system, enabling Black Hawks to be optionally piloted for high-risk or nonpassenger missions. Ace modifies surplus Black Hawks for civil missions, including public safety and search and rescue, as well as for sale to foreign customers.

RAIN

**Rain's wildfire containment system directed Sikorsky's autonomous Black Hawk testbed to extinguish a fire.**

Sikorsky already has modified an ex-U.S. Army UH-60 into an optionally piloted Black Hawk testbed using its Matrix autonomy management system, developed with support from DARPA's Alias project. This included a fly-by-wire upgrade to the helicopter.

In the October Rapid Wildfire Response Demonstration at Sikorsky's

Stratford, Connecticut, headquarters, the Matrix system was connected to Rain's wildfire mission autonomy system to suppress a fire in its incipient stage.

During the 30-min. flight demonstration, a tablet was used to command the Black Hawk aircraft to take off, search and find the fire, then drop water from an underslung Bambi Bucket. The Rain system adjusted the flightpath to account for an 8-10-kt. crosswind.

Each of three successive water drops extinguished a 12-in.-dia., propane-fueled fire ring producing a 3-6-in.-tall flame, demonstrating the precision of Rain's fire perception and targeting capability, the companies say. Safety pilots were onboard but hands-off until the aircraft landed.

"With Rain's wildfire mission software loaded onto the aircraft and a tablet, wildland firefighters in the field could deploy autonomous Black Hawk or Firehawk helicopters to search and attack wildfires before they spread out of control," says Igor Cherepinsky, director of the Sikorsky Innovations prototyping group.

## Bell Tunnel-Tests Stop-Fold Tiltrotor

Bell has completed wind tunnel testing of its proposed X-plane for a DARPA project to demonstrate a high-speed vertical-takeoff-and-landing aircraft. The company is competing against Boeing subsidiary Aurora Flight Sciences to build and fly the subscale demonstrator in 2027-28.

The scale model of Bell's stop-fold tiltrotor design was tested in the subsonic wind tunnel at the National Institute for Aviation Research at Wichita State University. The tunnel can conduct tests up to 200 kt., which covers the speed range for transition of the tiltrotor between vertical and horizontal flight.

Bell also has released a concept image of a potential operational stop-fold tiltrotor, showing a Lockheed Martin C-130-size crewed aircraft with two tilting proprotors that feature a faceted spinner design patented by the company and designed to reduce cruise drag at high speed.

Bell is designing the X-plane under DARPA's Speed and Runway Independent Technologies (Sprint) project to demonstrate technology for high-speed vertical-takeoff-and-landing (Hsvtol) aircraft able to cruise at 400 kt., well beyond the 260-280-kt. speed range of current tiltrotors.

In Bell's design, the aircraft takes off in helicopter mode with the nacelles vertical. As in a conventional tiltrotor, the nacelles tilt down during transition to forward flight. The aircraft then accelerates and transitions from turboshaft to turbofan propulsion, the rotors stopping and folding back along the nacelles.


**Bell's X-plane is subscale and uncrewed (foreground). The potential objective vehicle is crewed and C-130-size.**

The wind tunnel testing involved Bell's subscale uncrewed X-plane configuration and focused on stability and control of the vehicle through transition at representative speeds, the company says. The model included features that allowed for blade rotation, folding and nacelle tilt.

Previously, Bell conducted a proof-of-concept evaluation of the stop-fold rotor transition using the Holloman High-Speed Test Track in New Mexico. The sled tests in 2023 demonstrated the folding rotor, multimode turboshaft-turbojet propulsion and integrated flight controls at representative flight speeds.

Bell says the design combines jet speed with runway independence. "Bell's advanced Stop/Fold family of systems will revolutionize the speed, range and survivability of vertical-lift aircraft to enable operations in contested environments," says Jason Hurst, executive vice president of engineering.

While the X-plane model had conventional conical spinners with prominent fairings over the blade-fold joints, Bell's vision vehicle has a spinner design that incorporates flattened faces that meet at three chines aligned with the rotor blades. Designed to reduce drag, the chines help conceal the blade fold and pitch control mechanisms.

In a conventional spinner with large openings that provide clearance for rotor motion, the blade attachment, hub and controls can be exposed, resulting in a large drag increase at higher speeds. The chined spinner design includes drag-reducing fairings over the fold joints and nesting channels along the nacelles that provide a place for the blade edges to rest when folded back during forward flight.

Aurora and Bell are in Phase 1B of the Sprint program. Aurora is developing a fan-in-wing design. Its one-third-scale uncrewed X-plane demonstrator has a blended wing body design with twin vertical tails and three lift fans—two in the wing and one in the forward fuselage—that are covered by doors in cruise.

## Beta Demonstrator Goes to New Zealand

Air New Zealand is to lease a CX300 Alia CTOL from Beta Technologies for in-country familiarization ahead of its operation of the electric aircraft on a cargo-only service planned to begin in 2026.

Following an 18-month evaluation, the airline selected the conventional-takeoff-and-landing Alia CTOL in December 2023 as the first purchase under its Mission Next Gen Aircraft program. Air New Zealand placed a firm order for one aircraft, with options for two more and rights to a further 20 Alia aircraft.

The airline will operate the aircraft initially in partnership with New Zealand Post, flying between Wellington on the North Island and Marlborough on the South Island on a route over the Cook Strait.

The latest agreement adds the six-month lease of an Alia CTOL as a technology demonstrator to provide familiarization to pilots and maintainers as well as the airline's route planning, operations and ground support teams. The demonstrator will be a new-build aircraft off Beta's South Burlington, Vermont, production line. Beta is aiming for FAA type certification of the Alia CTOL in 2025.

Air New Zealand also has added Beta's electric aircraft chargers to its order, including one Charge Cube for permanent installation and several mobile Mini Cube chargers to expand the network footprint in New Zealand. The Alia is planned to be used on routes of about 150 km (95 mi.) at 270 kph (165 mph) and altitudes of 5,000-10,000 ft., with a full recharge expected to take 40-60 min.

Selecting the Alia CTOL, Air New Zealand said the aircraft would not replace anything in its existing fleet but would act as a catalyst for change and help accelerate the airline's decarbonization.

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## Aviation Week Network Events

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**Jan. 27**—Engine Leasing, Trading & Finance Americas. Fort Worth.

**Jan. 28-29**—AeroEngines Americas. Fort Worth.

**Feb. 4-5**—MRO Latin America. Panama City.

**Feb. 10-11**—MRO Middle East. Dubai.

**Feb. 10-12**—Routes Americas. Nassau & Paradise Island, Bahamas.

**March 6**—Aviation Week Network's 67th Annual Laureate Awards. Washington.

**March 12-13**—Aviation Week's SupplyChain Conference. Southlake, Texas.

**March 25-27**—Routes Asia. Perth, Australia.

**April 2-3**—GAD Americas. Grand Cayman, Cayman Islands.

**April 3-4**—CAPA Airline Leader Summit Americas. Grand Cayman, Cayman Islands.

**April 8-10**—Military Aviation Logistics and Maintenance Symposium. Atlanta.

**April 8-10**—MRO Americas. Atlanta.

**April 8-10**—Routes Europe. Seville, Spain.

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VIEWPOINT

# U.S. National Security in a Changed World

By **Howard A. Rubel**

Washington has an opportunity to reassess its military and diplomatic goals. By crafting an appropriate national security strategy, the U.S. can avoid costly policy errors and set the stage for proper long-term investment in its defense capabilities. The upcoming budget review should be about defining the threat, understanding the needed force to defeat it and ensuring that the industrial base is properly incentivized and capable of equipping the armed services. In an unpredictable world, a strong and innovative military is essential to protect the U.S. and its economic interests.

U.S. DEFENSE DEPARTMENT

**"EMPLOYING UNIT COSTS AS THE SOLE METRIC FOR VALUE DOES NOT TAKE INTO ACCOUNT THE NEED FOR LONG-TERM PREPAREDNESS."**

At $850 billion, the planned budget for fiscal 2025 is probably below ideal. Government outlays for defense are just under 3% of the $28.3 trillion U.S. GDP. A decade ago, the figure was 3.3%, and it was 4.1% in 1993, when the Cold War had just ended. So the cost to defend America is declining as a percentage of economic output.

Looking at it another way, the U.S. has a stronger defense with fewer troops. The total active-duty force is down to just under 1.4 million today from 1.8 million at the end of fiscal 1993. The Defense Department's civilian workforce of about 800,000 is 10% smaller. Could we find ways to be more efficient? Probably. Is there nonessential work being performed by the civilian workforce? Of course. Here are some ideas.

The Pentagon should spend more time on budget outliers while cutting paperwork on recurring buys and reducing bureaucratic costs. Find the levers in procurement laws that can speed up reviews and enhance oversight. Operation and maintenance claim 40% of the military budget, so invest in reducing recurring costs. Craft better proposals and raise the hurdle for bid protests. Deliver the budget on time. Delays cost money and harm readiness. It is in the national interest for all parties to work together.

The ability to deliver more for less has been driven by forward-thinking leaders who recognize that strategy drives outcomes. The adversary gets a vote, too, though, so the Pentagon needs to have a competitive fighting force while it evolves and deploys technologies to defeat new threats. For example, to down cheap drones, it should replace expensive interceptors with low-cost-per-kill directed-energy weapons or small projectiles.

In 2002, then-Defense Secretary Donald Rumsfeld set out a compelling framework in *Foreign Affairs*. He argued that our security challenges were not as predictable as during the Cold War. It was true then, and his argument remains relevant today.

Rumsfeld cited the need for more uncrewed and long-range systems as well as improved information networks. Those ideas have become reality with the Boeing MQ-25 drone, the Northrop Grumman B-21 bomber and significant funding for software-defined radios and cyberspace activities.

With the end of the Cold War, many companies exited the industry, leaving it to those with a vision of how to operate in a more constrained and volatile environment. Successful companies cut overhead, consolidated factories to match demand and transformed production lines to meet the next need. For example, demand for air-to-air missiles declined, but the requirement for long-range strike missiles rose. Today, Lockheed Martin's Joint Air-to-Surface Standoff Missile and its sister, the Long-Range Anti-Ship Missile, are built on one production line, sharing costs.

Other initiatives have delivered value to the Pentagon and shareholders. The use of multiyear contracting generated shared efficiencies, and to balance risk and innovation, the Pentagon embraced competitive development programs. The Army set up a process that scrapped lower-priority programs to free up about $35 billion to fund its modernization. The Pentagon has sought partners in Silicon Valley and created the Defense Innovation Unit in 2015 to help the U.S. military make use of commercial technologies more quickly. All that drove down procurement costs and renewed focus on competition.

There are many lessons from the war in Ukraine; funding was supplied and industry responded to battlefield needs faster than a budget cycle. In a related example, contracting terms could be revised further to pay for war reserve capacity—future contracts should have a war-related surge clause. Employing unit costs as the sole metric for value does not take into account the need for long-term preparedness.

Finally, Congress, with its control of the nation's purse strings, needs to support a concrete plan that delivers recurring and verifiable value to the public and to the Pentagon's suppliers.

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