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AEROSPACE & DEFENSE 2025

LOOKING AHEAD TO
UNCERTAIN TIMES



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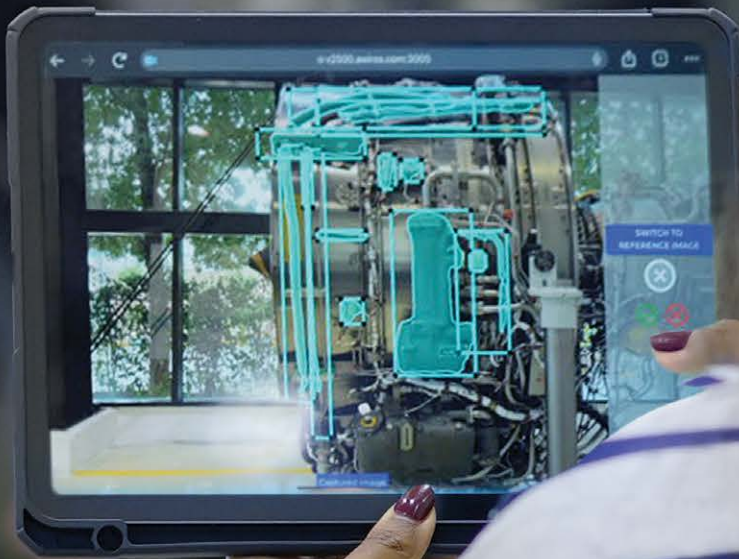
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ON THE COVER

The second Trump administration is poised to take power at a time when potential conflict with China looms closer and security cooperation deepens among China and Russia, Iran and North Korea. Our editors' analyses of what an uncertain world could mean for aerospace and defense in 2025 begin on page 24. Wang Guoyun/China Military Online photo.

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BEHIND THE SCENES

Aviation Week editors recorded 54 Check 6 podcasts this year. On the last of them, the executive editors and editor-in-chief—joined by Senior Editor Guy Norris, Business Aviation Managing Editor Molly McMillin and Space and Emerging Technologies Editor Garrett Reim—continued an annual tradition of making predictions for the year ahead and, in a new twist, grading themselves on how their predictions for 2024 turned out.

Listen in at: AviationWeek.com/Check6

LABOR DISPUTE

I am an Aviation Week subscriber and have been for years. I appreciate the great work Executive Editor for Commercial Aviation Jens Flottau put into the article published online titled “IATA Slams Manufacturers, Supply Chain For ‘Quasi-Monopoly’ Behavior,” regarding the International Air Transport Association and supply chain issues. I own an aerospace company that supplies piston and seal rings to the industry, Precision Rings Inc. We have been in business since 1949.

With all due respect, Director General Willie Walsh, quoted in the article, does not appear to know what he is talking about. The aerospace industry is and has been experiencing a labor shortage. It’s been coming for years, as reported by your excellent publication. Tens of thousands of highly skilled, dependable employees have aged out and retired, and the younger generation seems not to want to get their hands dirty. Unless Walsh can make tens of thousands of skilled workers appear instantly, he’s in for a long road ahead.

Joseph Crannell, Indianapolis

ALTERNATIVE RETURN

The mission architecture on the Mars Sample Return mission and the data that will be retrieved in 2033 at a cost of \$11 billion reported in “NASA Assessing Options To Return Samples From Mars” (Nov. 25-Dec. 8, 2024, p. 40) will do little to assist crewed landings on Mars or discovery of life on Mars.

I suspect by the time the samples are returned to Earth, Elon Musk and SpaceX probably will have walked on

the polar regions of Mars. If NASA would give some funding to SpaceX, Musk would gladly gather the 30 sample cylinders on Perseverance and the 10 cached samples and return them to Earth, bypassing the complex cislunar orbital path and landing them in South Texas at the SpaceX Boca Chica space base.

Jim Sherrard, Plano, Texas

FASTER PAST?

I’m pretty sure most of your readers already know the answer to this, but I’m a relative novice in the aviation business, so please tell me why “the scheduled transit times [for flights from New York to San Francisco] are 18-41 min. longer” than in 1959 (“65 Years Ago in Aviation Week,” Nov. 25-Dec. 8, 2024, p. 9).

Tom Curry, Seattle

Editor-in-Chief Joe Anselmo responds: Good question! While the two-engine Airbus A321 is much more efficient and environmentally friendly than the four-engine Boeing 707, its cruise speed is actually slightly lower. Today’s airlines also pad extra minutes to scheduled travel times so their “on time” statistics look better.

CAUSE ANALYSIS

In “Risky Debate” (Dec. 9-22, 2024, p. 14), Sean Broderick writes of the activation of the CFM International Leap load reduction device (LRD): “While this

helps slow fan rotation, it also opens an oil sump flange, releasing oil into the engine flow path.” This implies that activation of the LRD causes the oil sump flange to open. Can I assume contact of the fan blade fins with the “surrounding components” damaged the oil sump flange, which then caused oil to leak? Perhaps the wording should have been: “it also opened (damaged) an oil sump flange.” Assuming that damage of the oil sump flange was the cause for resultant smoke, perhaps more protection of the oil sump is in order. No oil, no smoke!

Jim Diffendorfer, Renton, Washington

Safety Editor Sean Broderick responds: Despite early reports to the contrary, damage did not cause oil to leak from the sumps in either of the two reported CFM Leap LRD activations. As information provided by CFM to operators and seen by Aviation Week explains, Leap LRD activation creates a gap between the No. 1/No. 2 bearing support and aft flange. This opens the A-sump and releases oil into the flowpath upstream of pneumatic bleed ports.

CORRECTION

The Photo Illustration First Place photo caption on page 47 of the Dec. 9-22, 2024, issue should have stated that the photo was made up of 257 10-sec. exposures, making a 43-min. exposure in total.

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.

A high-angle, rear-quarter view of an F-35 fighter jet in flight against a blue sky with scattered white clouds. The jet is dark grey with a distinctive orange and yellow flame-like graphic on the rear fuselage. The text "ADVANCED THERMAL MANAGEMENT FOR EXTREME ENVIRONMENTS" is overlaid in large, bold, white and dark blue letters. A small orange horizontal bar is positioned above the word "ADVANCED".

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Nico Neumann has been promoted to co-CEO from chief operating officer at *Deutsche Aircraft*, effective Jan. 1, when he will begin working with co-CEO Dave Jackson. Neumann has spent more than 18 years with *Deutsche Aircraft*.



Lockheed Martin has hired **Kevin O'Connor** as general counsel, senior vice president and corporate secretary, effective Jan. 13. He succeeds Maryanne Lavan, who is retiring. He was chief legal officer at Carrier and Point72, before which he worked at United Technologies, Bracewell and the U.S. Justice Department.

Bill Kircher has been appointed CEO of maintenance, repair and overhaul provider *CTS Engines*, adding to his role as executive vice chairman. He has held executive positions at Triumph Group and United Technologies. Kircher succeeds **Vesa Paukkeri**, who has been promoted to chief commercial officer after almost 12 years with



CTS. Paukkeri previously headed Finnair Engine Services.

Klaus Goersch has joined *Atlas Air Worldwide* as chief operating officer and executive vice president.

He was chief operations officer at Air India and before that worked at Air Canada and British Airways.

Roadable aircraft developer *Samson Sky* has hired **Michael Maxwell** as research and development chief as the company aims to launch production of its Switchblade flying car. A veteran program manager, Maxwell was composite manufacturing manager at SpinLaunch and before that worked at Boeing, Toyota, NASA and the U.S. Defense Department.

Justin Thompson has been promoted to vice president of information technology data and analytics from managing director at *JetBlue Airways*. He has been with the carrier in information technology and customer service with some breaks since 2004 and also worked at MaritzCX and Zions Bancorporation.

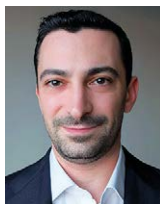


The International Aircraft Dealers Association has named **Louis C. Seno, Jr.**, executive director, succeeding Wayne Starling on Jan. 1. He is also chairman emeritus and special advisor to the board of directors at Jet Support Services Inc., where he had served as president and CEO, and he sits on the board of directors at the General Aviation Manufacturers Association and Experimental Aircraft Association.

Space infrastructure manufacturer *Redwire* has hired **Aaron Futch** as general counsel, executive vice president and secretary. A 20-year veteran of the industry, Futch was associate general counsel of corporate and regulatory at Virgin Galactic and before that was assistant general counsel at Intelsat.

Andrew Auerbach

has joined *Sierra Nevada Co.* as vice president of technology. He was chief technology officer for mission innovation at Amazon Web Services, overseeing platforms for the U.S. Defense Department and intelligence agencies. Before that, he helped found several tech companies and worked as special technologies architect at Juniper Networks.



The *UK Space Agency* has named **Adam Amara** chief scientist. He is a professor at the University of Surrey, working as director of space strategy and head of the School of Mathematics and Physics, and has also taught at the University of Portsmouth and ETH Zurich.

Carly Anderson

has been appointed chief legal officer, general counsel and chief strategy officer at *Jet Support Services Inc.* She was vice president of engineering, regulatory and FAA compliance in Boeing Commercial Airplanes' law department and before that worked in the U.S. Justice Department.



The *Aerospace Center for Excellence*, an educational nonprofit, has hired **Julie Ehnle** as chief financial officer. She succeeds Tracy Neal, who is retiring after 14 years with the center. Ehnle worked in finance and operations at the Schools of McKeel Academy charter system.

Low-Earth-orbit satellite communications provider *Skytrac* has hired **Shane Sullivan** as vice president of operations. He held the same title at Conair Aerial Firefighting and before that worked at AeroFlite Aerial Firefighting and ICON Aircraft. Prior to entering the public sector, Sullivan served in the U.S. Navy, from which he retired as strike fighter squadron commander.

Aviation artificial intelligence systems developer *Aerogility* has hired **Patrick Corrigan** as head of customer success. He was business development director at QOCO Systems and before that worked at Rolls-Royce and Spiff.

Greg Goodner has been named senior director and site manager at aircraft parts and services provider *Professional Aviation Associates*. He was director of business relations at Perfekta and before that worked at Global Parts Aero and Bombardier Aerospace.



Earth-observation satellite company *Satelogic* has appointed **Kelly Kennedy** as a member of its board and chair of the audit committee. She is chief financial officer at Willow Innovations and held the same role at the Honest Co., Bartell Drugs and Sur La Table, among others.

Mac Curtis has joined the board of directors at the *Virginia Spaceport Authority*, formerly the Virginia Commercial Space Flight Authority. Curtis is board chairman at defense and public transport equipment manufacturer Cubic and before that headed government services companies including Perspecta, Vangent and Vencore. 📧

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.:

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SECOND TAKE

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2024 in Review



DEFENSE

The first prototype of Turkish Aerospace Industries' Kaan combat aircraft made its initial flight on Feb. 21.

The U.S. Army canceled the Future Armed Reconnaissance Aircraft program in February, before competing prototypes could fly.

Iran launched more than 320 missiles and attack drones at Israel on April 13. Almost all were intercepted.

Sierra Nevada Co. in April won a \$13 billion contract to replace the U.S. Air Force's command-and-control Boeing E-4Bs with modified Boeing 747-8s.

NATO in July began the process to procure six Boeing E-7s to replace its fleet of 14 E-3 airborne early warning aircraft.

Lockheed Martin F-16s transferred to Ukraine by the Netherlands and Norway made their combat debut against Russia in August.

In November, Romania became the 20th country to buy the Lockheed Martin F-35, ordering 32 aircraft.

COMMERCIAL

The FAA ramped up oversight of Boeing after a door plug blew off an Alaska Airlines 737-9 in flight on Jan. 5.

Boom Supersonic flew its XB-1 on March 22, a 1/3-scale demonstrator for its Mach 1.7 Overture airliner.

After one flight of its 12.5%-scale AV1 demonstrator on June 5, blended wing body startup JetZero plans to fly AV2 in 2025.

Boeing on June 30 agreed to reacquire struggling aerostructures manufacturer Spirit AeroSystems for \$4.7 billion.



Airbus' long-range A321XLR received European Union Aviation Safety Agency type certification on July 19, with CFM International Leap 1 engines.

After blocking the JetBlue-Spirit Airlines merger, forcing Spirit into Chapter 11, the U.S. Justice Department cleared the Alaska-Hawaiian merger, which completed in September.

A seven-week strike that idled Boeing's 737, 767 and 777 lines in the Puget Sound region ended Nov. 4.



GENERAL AVIATION

Airbus Helicopters' Racer high-speed compound rotorcraft demonstrator made its first flight on April 25.

China certified Shanghai startup AutoFlight's CarryAll uncrewed cargo electric vertical-takeoff-and-landing (eVTOL) aircraft in March.

Joby Aviation flew an S4 tiltprop eVTOL prototype 561 mi. on hybrid hydrogen-electric propulsion in June.

Daher, Airbus and Safran completed flight testing of the EcoPulse distributed hybrid-electric propulsion demonstrator (page 18).

Airbus conducted the first hover flight of its CityAirbus NextGen eVTOL prototype in Germany on Nov. 6.

Gulfstream certified the ultra-long-range G700 in March and flew the large-cabin G400 in August.

German eVTOL startup Lilium filed for insolvency in November after failing to secure additional funding.

SPACE

Two key rockets debuted in 2024: United Launch Alliance's Vulcan on Jan. 8 and Arianespace's Ariane 6 on July 9.

Tilted touchdowns for two lunar landers: Japan's SLIM landed Jan. 19 but ran out of power in August, and Intuitive Machine's IM-1 failed to wake up after landing Feb. 22.

China's Chang'e 6 lander and rover touched down on the lunar far side on June 1, returning samples to Earth on June 25.

After experiencing thruster issues, Boeing's CST-100 Starliner returned to Earth Sept. 7, leaving its crew on the International Space Station.



SpaceX captured a returning Super Heavy booster at the launchpad on the fifth Starship integrated flight test, on Oct. 13.

The SpaceRISE consortium in December won a 12-year, \$10.8 billion contract to build and operate a sovereign, European 262-satellite secure communications network (page 21).

UP FRONT

RICHARD ABOLAFIA



SPECULATION THAT EGYPT IS reconsidering a purchase of Chinese Chengdu J-10 fighters may turn out to be nothing. So why even talk about it?

Because if it does come to pass, the order would mark a historic breakthrough for China as an arms exporter. Beijing has never sold a combat aircraft to a significant military power except Pakistan. Expanding its export market to Egypt would mean big changes in a fighter market driven by geopolitics.

Fighter Market Intrigues

Have Russia's woes opened the door for China?

Egypt has long been a nonaligned military market. Unlike all of Europe and most of the Middle East and Asia, Cairo has sourced from both Western and non-Western providers. One year after the 1979 Camp David peace accords, Egypt began ordering General Dynamics F-16s, breaking with decades of reliance on Soviet equipment, and ultimately becoming one of the biggest F-16 customers, with 240 purchased. It stayed with Western aircraft until 2015, when it ordered 46 Mikoyan MiG-29Ms. It almost ordered Sukhoi Su-35s, too, but the threat of U.S. sanctions canceled that deal. In the 2010s, Egypt also ordered 54 Dassault Rafales and tried to order Lockheed Martin F-35s.

The events of the Arab Spring and other factors resulted in Egypt returning to an East-West sourcing strategy. With a fleet of more than 300 combat jets, the Egyptian military is the second-largest nonaligned market after India. But politics and economics have delayed recapitalization of its aging fleet.

For nonaligned markets such as Egypt and Moscow-aligned customers like Algeria, Russia has become a very problematic weapons source. Russia has gone from being tied with the U.S. for the top exporter position to sixth place, according to the Stockholm International Peace Research Institute (SIPRI) Arms Transfers Database (see chart).

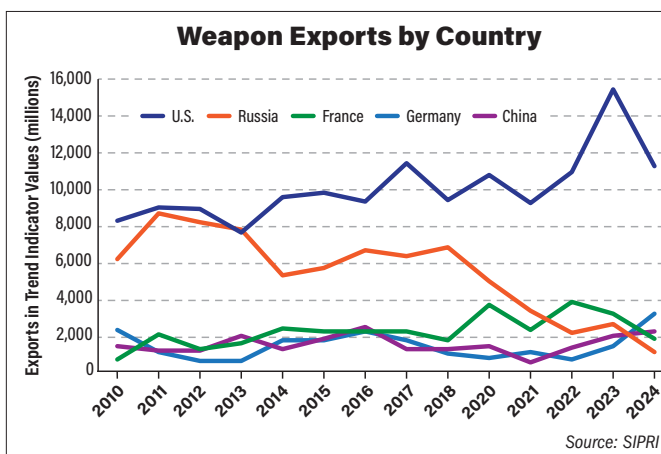
Russian military exports have suffered an unprecedented decline in the last five years. Some of this is due to sanctions imposed by the U.S. on Russian arms customers following the full-scale invasion of Ukraine. But Russian jets also have had serious performance and production issues, exacerbated by Western technology embargoes. On top of that, Moscow was dependent on countries that have destabilized to the point of being unable to buy new jets (Syria, Libya and Venezuela) or that have gone with their own aircraft programs (China).

Weapon production difficulties—coupled with the severe depletion of the country's own military inventories—mean that Russian industry will not be able to recover its export share any time soon. That leaves

a big gap in the market. What country could fill it?

France, the Western power that offers weapons with the fewest strings attached, has seen a very steady run-up in demand. The backlog for Rafale fighters is now more than 200 aircraft, but, as with all its defense products, France is having a very hard time scaling up supply. Rafale output is now just more than one per month, with plans to triple that uncertain. Any new customer would need to wait until the 2030s to receive jets.

Then there are the new producers, building fighters for indigenous and export customers. South Korea has led the way here, followed by India and Turkey. Buying from these countries might seem to entail fewer conditions than buying from Western producers, but all of them use systems



and components that are themselves from Western producers. Thus, in the event of a disagreement between the customer and the subsystems provider country, they would be vulnerable to a support cutoff.

This leaves China. Chinese fighters have become considerably more capable over the last decade or two. But their export market standing is miserable. Again, after many years of trying, China has sold fighters to only a small group of impoverished countries.

One big problem for China is that weapon-buyers want a strategic relationship with the producer country, and many of the likeliest customers for Chinese jets, such as the Philippines and Vietnam, are in an adversarial relationship with Beijing. India, which would be the perfect nonaligned customer, will not buy Chinese weapons because of their standoff in the Himalayas.

An Egyptian purchase of considerable numbers of J-10s would imply that China is making progress replacing Russia as the provider of choice for nonaligned producers. But further progress would depend on China's ability to convince customers that it is a power with which they want to be friends. ☺

Contributing columnist Richard Aboulafia is managing director at AeroDynamic Advisory.

QUANTUM LEAP

GARRETT REIM



IT WAS SUPPOSED TO BE CHINA.

This moment was theirs. A technocratic tyranny—with zettabytes of surveillance data and no qualms about exploiting and feeding it to the machine—was best suited to usher in a new era of artificial intelligence.

Yet in 2022, about a week after Thanksgiving, it was the U.S.—again—that jumped into the technological lead with the unveiling of OpenAI's enigmatically named ChatGPT. Since then, an artificial intelligence (AI) arms race has exploded across the world.

Starting with the invention of the integrated circuit in the late 1950s, U.S. engineers and scientists have invented or been at the forefront of nearly all software innovations, including operating systems, the internet, graphical user interfaces, email, cloud computing and AI. Indeed, six of the 10 largest corporations globally are U.S. computer companies—Apple, Nvidia, Microsoft, Alphabet, Amazon and Meta Platforms—and predominantly software businesses or have hardware closely integrated with software.

There is an enduring truth in that pattern of success: Software is America's superpower.

With that in mind, a growing number of startups are embracing a software-defined aerospace strategy to aid the U.S. Defense Department's attempts to match China's manufacturing might. Their approach is a twist on 19th-century economist David Ricardo's comparative advantage maxim: Do what you do best and adapt the rest. That is, the U.S. may manufacture fewer units of hardware relative to China, but the U.S. aerospace industry can use software to adapt the smaller lot to a greater number of purposes.

Take, for example, Salient Motion, a startup that has developed generalized motion control software for commercial off-the-shelf actuators to cut development time and nonrecurring engineering costs. Or Theseus, which built a drone that calculates its GPS coordinates without a signal by using an algorithm that matches satellite images from Google Maps to images from a basic camera. And last—but certainly not least—Hadrian Automation, which is attempting to use sensors, servers and software to codify and automate the craftsmanship of hundreds of thousands of U.S. machinists into a hyperproductive smart factory that oth-

erwise uses standard CNC machines and robotic arms.

It is still early days for these companies. Indeed, making such a strategy work across the U.S. military-industrial complex requires building more hardware—a lot more hardware—that readily accepts third-party software instructions or can be quickly plugged into a larger system. That means the U.S. industrial supply base still needs to make a lot more

actuators, cameras, batteries, lidar, radios, computer chips, gyroscopes, accelerometers and whatever else guides modern weapons of war. In addition, more manufacturers need to develop platforms—whether they are drones, missiles, aircraft or satellites—with open systems architectures, a construct that emphasizes modularity, interoperability and flexibility by adhering to widely accepted design standards.

The U.S. Defense Department has been pushing open systems architectures for years, with mixed success. Many incumbent prime manufacturers see the “open”

part of the concept as an invitation for upstarts to compete for what otherwise would be decades of guaranteed government business for replacement parts and upgrades. They are not wrong.

Yet for a software-defined aerospace strategy to work, there needs to be open and constant competition to drive down costs and push up unit production and systems performance. The good news is software, unlike hardware, can be rapidly developed and scaled, especially thanks to innovations like cloud computing and AI co-pilots that can rapidly generate new code for small teams. Those traits lower the bar to entry for startups with good ideas, injecting competition into Pentagon programs that previously were tedious, slow-moving affairs.

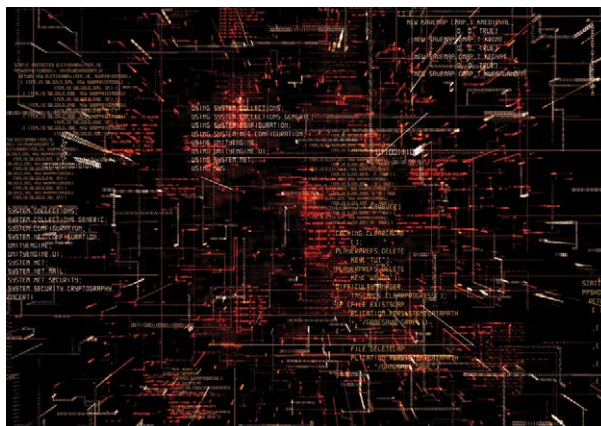
Software-defined hardware also plays at the speed of modern warfare.

In the Russia-Ukraine War, technology cycles for a variety of military kits only last 3-4 weeks before they become obsolete. Agile development methods and other fast-moving software engineering tactics will help the U.S. military keep pace.

Making a software-defined military-industrial complex work will not be easy. However, if it succeeds, the U.S. may have found a cheat code in its competition with China. 🇺🇸

America's Superpower

Unlike hardware, software can be developed rapidly and scaled



EDUARD MUZHEVSKYI/ALAMY STOCK PHOTO

HYBRID THEORY



> AFWERX AGILITY PRIME TURNS AWAY FROM BATTERY-POWERED eVTOLS

> BETA FLIGHT-TESTS HYBRIDIZATION OPTIONS FOR ELECTRIC ALIA

> ARCHER AND ANDURIL TEAM ON HYBRID MILITARY eVTOLS

BETA TECHNOLOGIES

Garrett Reim Seattle

In a significant shift of strategy, the U.S. Air Force's AFWerx Agility Prime program has acknowledged that the battery-powered electric vertical-takeoff-and-landing aircraft it has been funding and testing during the past four years lack the range necessary to be useful in operational theaters such as the Pacific.

"We're always balancing priorities and budgeting, but certainly the future is going to be in hybrid systems," says Prime Division Chief Lt. Col. Jonathan Gilbert. Hybrid-electric vertical-takeoff-and-landing (eVTOL) aircraft would give the Air Force the additional range and payload capacity needed for the service's logistics, he says.

AFWerx does not have any specific requirements, a program of record or impending contracts for hybrid eVTOLs, Gilbert says. Instead, the Agility Prime accelerator program would look to piggyback on the existing hybridization efforts of commercial eVTOL developers, he notes.

Developers of eVTOLs typically have designed their battery-powered aircraft with short-range air taxi operations in mind. But at least two eVTOL developers, Beta Technologies and Archer Aviation, said in December that they are developing hybrid aircraft for military missions.

Beta has two hybrid eVTOL aircraft in development, founder and CEO Kyle Clark told Aviation Week on Dec. 16. The company has flown its Alia A250 eVTOL with a reciprocating engine-powered range-extension kit installed in its cargo area multiple times since the fall of 2023.

The diesel-fueled generator was developed to validate hybridization engineering and design work for the Alia. But Clark says the system could be sold as a range-extender kit that would allow the battery-powered aircraft to ferry itself in conventional takeoff-and-landing (CTOL) mode—flying on its wing using its pusher propeller—more than 3,000 mi. The range extender is mounted to a cargo pallet and plugs into the aircraft's electrical power. A standard cargo door is swapped for a door with an intake for aspiration and cooling, as well as an exhaust port.

The range extension kit could allow

the U.S. military to self-deploy an eVTOL, Clark says, noting that the equipment also has a ground-based function. "That whole system comes out and becomes a generator on the ground to charge the aircraft," he adds.

Beta Technologies says it first flew a hybrid version of its Alia eVTOL in the fall of 2023.

Beta also is developing a turbogenerator version of its Alia that would provide power through all modes of flight, including vertical takeoff and landing. The company says it has adapted a turbine typically used for low-altitude helicopters into a turbogenerator.

The startup has developed its own electromagnetic generators and controllers and has integrated the hybrid system into the Alia nose. The company declines to say specifically where in the nose the turbogenerator is located but says the location was chosen for cooling and aspiration reasons. Exhaust comes out of the nonpassenger and cargo side of the aircraft. Fuel is stored in the Alia's wing.

The turbo-electric Alia would have a 500-mi. range, including military reserves, when carrying 2,000 lb. of payload, Clark says. Beta is ground-testing the aircraft ahead of a planned first flight.

Beta has "hybrid-related contracts with AFWerx and [U.S. Army Combat Capabilities Development Command] to support the development and testing of hybrid concepts," Clark says. The contracts are for delivering test data and reporting other information to the branches, he notes.

Beta's disclosure comes after Archer and Anduril Industries said on Dec. 12 that they had signed a "strategic partnership" to develop "next-generation aircraft" for defense applications starting with joint development of a hybrid-eVTOL aircraft for a potential Defense Department program.

The aircraft would be developed using Archer's eVTOL expertise and existing commercial parts and supply chains as well as Anduril's expertise in autonomy, artificial intelligence (AI), military missionization and systems integration, the partners said.

Archer's Midnight eVTOL air taxi, designed primarily to shuttle passengers between downtowns and airports, has a range of 100 mi. Performance

and the configuration of Archer's hybrid eVTOL were not disclosed, and the company declined to elaborate beyond its initial announcement.

The company's hybrid eVTOL development project will be run within the new Archer Defense program. "To support this initiative and for other general corporate purposes, Archer raised \$430 million in additional equity capital," the company says.

Joseph Pantalone will lead the Archer Defense unit as head of advanced projects. He was Sikorsky's director of special programs and operations analysis from 2020 to November 2024.

Joby Aviation, another prominent air taxi developer and participant in the Agility Prime program, did not respond to a request for an interview about its interest in hybrid eVTOLs. However, Joby said in a statement that it is "supportive of any efforts to decarbonize flight."

The company also emphasized its participation in the Agility Prime program and noted that it is developing hydrogen fuel cell technology as a means to extend eVTOL range. In July, Joby demonstrated a preproduction prototype version of its S4 flying 561 mi. using liquid hydrogen and a fuel cell.

Air Force generals have repeatedly

stressed the logistical challenges of resupplying forces across the Pacific theater, noting the "tyranny of distance." The service's leadership also has chosen a dispersion strategy, called Agile Combat Employment, to prevent its aircraft from being wiped out while on the ground by missile attacks from China. But spreading aircraft across landing strips on islands in the Pacific Ocean makes the Air Force's logistical challenges more difficult.

AFWerx hopes new smaller aircraft could help reduce the Air Force's reliance on its workhorse Lockheed Martin C-130 transport aircraft for delivering parts over "the last tactical mile," Gilbert says.

Toward that goal, AFWerx's Agility Prime program is funding a variety of advanced air mobility projects, including test-flying autonomous Cessna Caravan 208s, such as a version developed by Joby's Xwing, and Electra.Aero's hybrid-electric short-takeoff-and-landing (eSTOL) EL2 prototype aircraft.

"What we haven't done is a true analysis of alternatives and looked at: 'OK, well, do I care more about runway independence? Or do I care more about getting there faster? Or do I care more about the range? Or do I care more about the payload?' I think

that's some work that's going on right now to refine requirements for that Next-Generation Airlift concept," Gilbert says. "From an AFWerx perspective, VTOL right now is desired, but not required."

Fighter aircraft in need of replacement parts are likely to be found on an 8,000-ft. runway, he adds. A long airstrip also should accommodate conventional aircraft for resupplying parts.

"If that runway has been under attack and cratered out, then likely there's some room to land an aircraft still," Gilbert says. "If you look at an Electra [eSTOL aircraft] or a [Cessna Caravan] 208 or something like that, if I can do it in 1,500-2,000 ft.—land and take off—there's likely that room available on that runway."

Gilbert says the Air Force's ideal vehicle is a high-speed vertical take-off-and-landing (Hsvtol) aircraft. DARPA is taking the lead on that aircraft type with its Speed and Runway Independent Technologies project. That effort aims to demonstrate technology for an Hsvtol aircraft that is able to cruise at 400 kt. (460 mph). But with that aircraft still years in the future, AFWerx is weighing what it can do in the shorter term with hybrid eVTOLs, eSTOLs and autonomous fixed-wing aircraft, Gilbert says. ☛

Stopgap Boeing Defense Head Pushes Changes to Culture and Programs

➤ STRIKE HAD "SLIGHT" EFFECT ON KC-46 AND E-7 PROGRAMS

➤ INTERIM CEO SAYS SPACE IS FUNDAMENTAL TO COMPANY'S PLANS

Brian Everstine Simi Valley, California

Boeing is in the midst of cultural change ordered by its new CEO and coming on the heels of a strike that shut down major manufacturing facilities for weeks.

This also comes as Boeing's defense unit is looking to improve its performance on large fixed-price development programs with continued, substantial cost overruns. For now, all of this is on the shoulders of Steve Parker, who has been interim CEO of Boeing Defense, Space and Security (BDS) since September.

Parker, a 37-year Boeing veteran,

told Aviation Week in a Dec. 7 interview that he is leaning on his status as a "known entity" within the company—particularly in design, development, test and production—to help refocus on delivering critical programs.

"When organizations are in a crisis or things aren't going too well, it's easy to push blame around," Parker said on the sidelines of the Reagan National Defense Forum here. "This is really about owning where we are and coming through it to turn the corner, so that's been the focus. Unashamedly, it's down to program execution."

BDS was the first target for new CEO Kelly Ortberg's management change; in September, then-BDS CEO Ted Colbert was directed to step down immediately. The announcement of Colbert's departure also named Parker as interim replacement. Ortberg at the time said Boeing needed to "restore the trust of our customers and meet the high standards they expect of us."

Parker led the T-7A Red Hawk trainer and F-15 programs and served as vice president and general manager of vertical lift, vice president of bombers and fighters, and he had been BDS chief operating officer since November 2022.

As chief operating officer, Parker focused on making progress on major development programs that have been mired in delays, including the KC-46 tanker, uncrewed MQ-25 Stingray, T-7 and VC-25B Air Force One. Collectively, these programs have contributed to \$13.4 billion in reach-forward losses since 2014.



BOEING

Boeing and the U.S. Air Force want to improve the T-7A's schedule while the program is in the early stages of flight testing.

"We bid some contracts years ago, in a different time, a different world, pre-COVID, fixed-price," Parker said. "My personal view is these complex development programs should be cost-type, and it's something where the customer and industry need to work together."

For example, he said Boeing could not have predicted the COVID-19 pandemic-induced inflation and spike in supply chain demand. "When we locked into a contract for 300-plus [aircraft] and a training systems contract for T-7, we couldn't have foreseen that," he said. "It's something we have to work through and deal with, and that's what we're doing."

One of the biggest bets BDS made under Colbert—although it was Parker's idea—was investing heavily in air dominance manufacturing. This includes \$4 billion in new construction of a \$2 billion classified advanced manufacturing facility in St. Louis and multiple other facilities, such as a new composites manufacturing site in Mesa, Arizona, and a production site at MidAmerica St. Louis Airport in southern Illinois.

"That's an . . . investment we're making ahead of contract award, which is very unusual for Boeing," Parker said. "And it's a decision I made myself a couple years ago to go down this path because I do think, if you are going to bid this work, you have to make sure you've got the capabilities to actually execute it."

However, the company has slowed some of this work because of uncer-

tainty in the air dominance arena. BDS is one of three disclosed competitors for the U.S. Navy's F/A-XX program and also widely assumed to be a finalist for the U.S. Air Force's Next-Generation Air Dominance (NGAD) program, although companies are precluded from confirming publicly.

In July, Air Force Secretary Frank Kendall paused the NGAD crewed fighter program pending additional analysis. Meanwhile, the Navy has pulled almost all funding from the F/A-XX but says it will make a contract award in 2025.

Boeing also was not selected for the first round of the Air Force's Collaborative Combat Aircraft program.

"We've slowed down a little bit because we've got some flexibility in the schedule," Parker said. "But our intention there is to build those facilities. We're well-positioned to

win a number of new contracts across the portfolio, and we're going to reestablish ourselves."

The KC-46 tanker has been among BDS' most public struggles, amounting to \$8.1 billion in total cost overruns as of the third quarter of 2024. The company is bullish on the aircraft's performance, even ahead of the long-awaited delivery of a reworked Remote Vision System, and has said it expects the service to award an option that would bring the total fleet size to 188.

For the first time, Boeing in 2024 met the delivery target of 15 tankers in a one-year span expected by the Air Force. Parker predicts that will be the cadence for the rest of the KC-46 pro-

gram. No tankers have been delivered since 33,000 of the company's factory workers went on strike in September, although they returned to work in early November.

That strike had a slight effect on the KC-46, but deliveries are expected to return to pace in 2025. While it also affected the U.S. Air Force's E-7A Wedgetail prototypes, Boeing and the service have not detailed the extent of the schedule change.

Following the strike, Parker said he was pushing to speak to employees and getting other leaders into factories, engineering labs and design spaces to assess any issues and how they could be addressed.

They are doing "simple things like getting down and talking to the mechanic, the person who is building it, and asking, 'Hey, is this the reason we have a problem?'" he said. "'Did the supplier have turnover? Did they miss a requirement? Did we miss something on the buying side?' It's that real, honest view of looking in the mirror and working out what's really working well . . . and if it's not working well, what's the cause? And let's go fix it and fix it for good."

Boeing's space business made headlines through the summer and early fall of 2024 during the CST-100 Starliner Crew Flight Test. Issues with the spacecraft's reaction control system thrusters prevented the capsule from returning two astronauts to Earth, leaving them at the International Space Station to await a trip home on a SpaceX Dragon in February.

Mounting losses have led to speculation that Boeing might sell its space business—but that is unfounded, Parker said.

"Space is fundamental to what we do in defense, and you're going to see continued investment there," he said.

He pointed to wins such as the U.S. Space Development Agency's secretive Fire-control On Orbit-support-to-the-war Fighter (FOO Fighter) award to the company's Millennium Space Systems in April and continued successes of the Space Force's X-37B Orbital Test Vehicle spaceplane as examples of where BDS wants to go.

"We've just got to keep chipping away and just put one foot in front of the other, and we're going to get back to normal and back to being better than we have ever been," Parker said. "But it's going to take a bit of time." 🚀



BOEING

Steve Parker was chief operating officer of Boeing's defense and space arm before being named interim CEO.

Israel-Hamas War Drives Changes to Israel's UAV Operations

➤ TARGET SELECTION HAS BEEN A CONSTANT CHALLENGE

➤ ISRAEL RAMPS UP USE OF MINI-DRONES TO IMPROVE SITUATIONAL AWARENESS FOR GROUND TROOPS

Robert Wall Tel Aviv

Drones have been a cornerstone of Israeli military operations for decades, but with each round of fighting the Israel Defense Forces has adapted their use. In the wake of Hamas' Oct. 7, 2023, attack on the country, the Israeli military is again tweaking operations and scaling up its inventory of small systems.

One of the operational lessons from this round of fighting: Noisy uncrewed air vehicles (UAV) have value. Israeli Air Force (IAF) operators realized that when they employed higher-flying, quieter UAVs, insurgents felt safe to operate in the open. While that made them easier to spot, it increased the risk of ambushes of Israeli troops, and soldiers felt less safe, an IDF official said Dec. 10. The IDF has since decided at times to employ lower-flying, noisier systems to scare insurgents away and make the operating environment less hostile for its own ground forces.

"Planes sometimes need to be loud," the IDF official said.

The adversary also has adapted, the official added, resorting to greater use of underground infrastructure built up over recent years and eschewing operations in larger groups that were easier to spot and strike.

Israel also has been increasing its emphasis on fielding battlefield quadcopters to give ground troops more direct access to intelligence collection from the sky. UAV use that had expanded to the battalion level has widened further to the platoon level, another IDF official said.

The use of small drones has more than doubled, he noted. The government has scaled up the purchase of such systems in part to deal with shortages early in the war, when some soldiers used privately acquired commercial systems to gain an intelligence edge in combat.

The IDF's mini-drone use gained prominence when it released a video from one of the systems confirming

the lethal strike on Hamas leader Yahya Sinwar in October, a little more than a year after he had orchestrated the attack on Israel.

Israel has ordered more mini-drones to satisfy growing demand for such systems.



ELBIT SYSTEMS

The Israeli defense ministry disclosed plans on Dec. 3 to buy some \$40 million in UAVs and related communications gear from Elbit Systems to support the war effort. It did not

Around 80% of IAF flight hours logged in the conflict

have been amassed by uncrewed systems, reflecting in part the higher endurance of such platforms.

identify what systems it is acquiring but noted that they include drones that give combat forces an attack capability.

The acquisitions are the latest of several contracts placed with Elbit and others to "ensure that troops can optimally execute their battlefield missions," Brig. Gen. Yehuda Almakias, head of the ministry's Directorate of Defense Research & Development, said when placing the order on Dec. 3.

Elbit got into the small UAV busi-

ness in a big way when it took over full ownership of manufacturer Flying Production in 2019. The company has been doubling production in recent years to respond to local and overseas demand. Flying's mini-UAVs can be equipped with laser designators. More recently, the company has developed a mechanism to drop small munitions from some Thor mini-UAVs.

In the latest round of fighting, UAVs accounted for by far the biggest proportion of IAF activity. Around 80% of IAF flight hours logged in the conflict have been amassed by uncrewed

systems, reflecting in part the higher endurance of such platforms.

While Israel has long employed armed UAVs, the country has become more open about conducting such missions. In the current fighting, many of the precision strikes on individual vehicles, often using weapons designed to eliminate a driver or passenger but avoid wider damage, are being conducted by UAVs. Strikes using combat aircraft have largely focused on deploying heavier weapons.

Target selection has been a constant challenge, especially in a conflict where the fighting has been as much about the international narrative as gaining tactical advantages. Israel has long accused Hamas of using ambulances to ferry troops and equipment around the Gaza Strip. But the IDF has ceased striking ambulances after an attack on one drew international uproar, one of the IDF officials said, while insisting that the vehicle in question harbored militants. Establishing the reality on the ground has been difficult for outside observers, given the strictures of the battlefield. ☛

FAA Enters Transition as Whitaker Steps Down

- > ATC SYSTEM FACES A RECKONING
- > WHITAKER ORDERED MORE OVERSIGHT OF BOEING
- > FAA CLASHED WITH SPACEX OVER LAUNCHES

Bill Carey and Sean Broderick Washington

FAA Administrator Michael Whitaker has announced that he will step down when the next U.S. presidency begins, departing early from an agency burdened by an aging air traffic control system and stepped-up safety oversight of troubled Boeing.

Whitaker informed the FAA's workforce Dec. 12 that he will resign as administrator more than three years early on Jan. 20, the day Donald Trump is sworn in as the 47th U.S. president. Trump will nominate the next FAA administrator, who must be confirmed by the U.S. Senate.

Respected by both Democrats and Republicans in an otherwise polarized capital, Whitaker did not explain why he is leaving.

"As I conclude my time at the FAA, my confidence in you to meet our safety mission has never been stronger," Whitaker said in his message to employees, which the agency released to the public. "You have seen leadership come and go—and through every transition you have kept air travel steady and safe. This transition will be no different."

Whitaker left his job as chief operating officer of advanced

air mobility (AAM) vehicle developer Supernal to become FAA administrator in October 2023 for a term ending in 2028. A former airline executive and lawyer, he had served during the Obama administration in 2013-16 as FAA deputy administrator, the agency's second-highest position.

In his farewell message to employees, Whitaker called out FAA achievements during his brief but eventful tenure, among them beating its hiring goal for air traffic controllers. The agency hired 1,800 in 2024, up from 1,500 in 2023, but in July it was compelled to relocate some controllers and airspace responsibility to Philadelphia after failing to maintain staffing at its busy New York Terminal Radar Approach Control facility on Long Island.

Coinciding with Whitaker's announcement, the Government Accountability Office (GAO) in testimony before the Senate Commerce Committee on Dec. 12 reiterated its call for urgent FAA action to modernize the deteriorating air traffic control (ATC) infrastructure. The GAO's analysis of an agency operational risk assessment found the FAA had categorized 51 of 138 ATC systems (37%) as "unsustainable" and 54 (39%) potentially unsustainable due to spares shortages and deficient funding. Seventeen of those systems were deemed critical to airspace safety and efficiency.

The FAA launched the operational risk assessment following the January 2023 failure of its Notice to Air Missions system, which caused the agency to issue the first nationwide ground stop since the Sept. 11, 2001, terrorist attacks.

Whitaker will pass on to his successor the stepped-up oversight of Boeing that he ordered after the Jan. 5, 2024, door-plug blowout on an airborne Alaska Airlines 737-9. The FAA mandated a quality and safety improvement program for

Post-Strike, Boeing Shifts Focus to Production Output

- > BOEING 737 MAX PRODUCTION RESTARTED DEC. 6
- > SOUTH CAROLINA INVESTMENT WILL SUPPORT 787 RAMP-UP PLANS

Sean Broderick Washington and **Guy Norris** Colorado Springs

New fuselages moving into the first Boeing 737 MAX final assembly line positions Dec. 6 signaled day-to-day work on the company's most important product was back underway following the end of the machinists strike in early November. Boeing's new priority is ramping up production and factory capacity across its commercial programs while staying true to its pledge to maintain quality.

Like the post-strike restart, the ramp-ups will be slow. The official 737 production restart, signified by Spirit AeroSystems-built fuselages moving into Flow Day 1, the first 737 final assembly station, on the three active 737 MAX lines at Boeing's production facility in Renton, Washington, came ex-

actly one month after International Association of Machinists and Aerospace Workers (IAM) members began returning to work following a 53-day strike (AW&ST Nov. 11-24, 2024, p. 14). The walkout also halted Boeing 767 and 777 lines in Everett, Washington, as well as other facilities in the Puget Sound region. Production since has resumed in Everett.

"Our team has worked methodically to restart factory operations in the Pacific Northwest," the company says.

Boeing's restart processes included using its safety management system to develop risk-based plans for each aircraft program to ensure the correct parts and tooling were in place and ready for the workforce, the company



says. Workers also received training designed to support a trouble-free ramp-up.

Boeing is offering little information about the pace of its planned production ramp-up. Just before the strike, its 737 lines were combining to roll

the OEM and a production cap of 38 Boeing 737s per month.

In public pronouncements, Whitaker has repeatedly cast Boeing's need to improve its safety culture as a long-term process. "It has not been business as usual for Boeing," he assured FAA employees. "We have dramatically increased oversight, including more inspectors and closer scrutiny over production. We are also making sure the company implements a robust safety management system, which will be crucial to an enduring safety culture."

Overseeing the early release of a Special Federal Aviation Regulation (SFAR) considered critical to the success of the emerging AAM industry was among the achievements Whitaker noted in his message. The SFAR created the operating and pilot training basis for a new category of powered-lift aircraft, "the first new category of civil aircraft since helicopters were introduced in the 1940s," he said.

The agency had functioned without a permanently appointed leader since former Administrator Steve Dickson, whom Trump nominated during his first presidency, stepped down halfway through his five-year term in March 2022.

Though Whitaker has garnered praise from both major political parties, rumors of a leadership change at the FAA immediately followed Trump's victory in the Nov. 5 presidential election.

U.S. Rep. Sam Graves (R-Miss.), who will remain chairman of the House Transportation and Infrastructure Committee in the next Congress, introduced Whitaker at his Senate confirmation hearing. Speaking a year later at an SFAR signing ceremony, Graves said the FAA's ability to promulgate the AAM regulation ahead of schedule "is a testament to the leadership. This just reaffirms my support of Mike Whitaker."



BILL CAREY/AMAST

FAA Administrator Michael Whitaker unveiled a new regulation for advanced air mobility aircraft in October.

One prominent critic has been SpaceX CEO and Trump confidante Elon Musk. In September, after the FAA fined SpaceX \$633,009 for alleged violations of its launch license, Musk in social media postings accused the agency of "regulatory overreach" and called on Whitaker to resign. Trump later named Musk to colead a new so-called Department of Government Efficiency.

In his farewell message, Whitaker also announced a succession plan to replace FAA Deputy Administrator Katie Thomson, who will leave the agency on Jan. 10. Mark House, assistant administrator for finance and management, will succeed her as acting deputy administrator.

David Boulter, associate administrator for aviation safety, is stepping down at year-end, leaving a key oversight role. 🗞



SEAN BRODERICK/AW&ST

737 MAX production resumed as fuselages began moving through the first three final assembly line stations.

38 per month—a ramification of the Alaska incident. A recent RBC Capital Markets survey showed most 737 MAX suppliers do not expect the monthly production rate to reach 38 until 2026.

The latest projection of the Aviation Week Network Fleet Discovery database shows a similar ramp-up pace. This monthly 737 MAX rollout rate—as opposed to Boeing's definition, which is the supply chain's shipping pace. Fleet Discovery projects the rate will reach the mid-20s pace around the end of the first quarter of 2025, climb to 30 in the third quarter and end the year at 32. The figures exclude a handful of military variants that will be produced on a dedicated production line.

Boeing's past post-strike ramp-ups have taken time. Following a 58-day strike in 2008, factories needed nearly a year to reach pre-walkout levels. The current ramp-up will be more complicated, coming hand-in-hand with

implementation of an FAA-approved plan to address systemic quality control issues spotlighted by the Alaska incident and related audits of its production processes.

"As expected, Boeing has made progress executing its comprehensive plan in these areas, and we will continue to closely monitor the results as they begin to ramp up production following the strike," FAA Administrator Michael Whitaker said following a daylong visit to the Renton factory on Dec. 3.

Whitaker sees Boeing's deliberate approach as a positive departure from past post-strike plans. "In previous strikes, they've just come right back and started production," he told NBC News. "This time, following safety management principles, they've been very systematic."

Whitaker's opinion will not factor into whether Boeing is ready to produce more than 38 737s per month, as he is stepping down Jan. 20.

While the 737 ramp-up is a key watch item linked to improving Boeing's ailing financial health, the

out 25-30 aircraft per month—a figure that was climbing slowly after a dip into the low 20s in the aftermath of the Alaska Airlines 737-9 door-plug blowout on Jan. 5, 2024.

The 737 program remains under an FAA-imposed production limit of

company's to-do list extends beyond Renton (*AW&ST* Oct. 28-Nov. 10, 2024, p. 14). Work on a fourth 737 line, which slowed in the aftermath of the Alaska incident, is progressing in Everett.

Boeing unveiled a \$1 billion investment plan on Dec. 12 to bolster its 787 production operation in North Charleston, South Carolina. The investment supports previously announced plans to boost production capacity to 10 787s per month by 2026 and potentially higher volumes in coming years.

Boeing has confirmed that the expansion includes an additional final

assembly building and new flight line stalls. Other projects are to expand the interiors center and general infrastructure work such as parking and roadway improvements at different facilities.

At its previous peak, the Charleston plant produced a maximum of seven aircraft per month. Combined with the now-terminated line in Everett, the two sites generated a total of 14 aircraft per month before the COVID-19 pandemic and related production downturn.

Charleston is also the dedicated manufacturing site for the 787's aft

Sections 47 and 48, so parts of the facility already have demonstrated the ability to run at 14 shipsets per month—a figure Boeing is expected to target under the new round of investment.

The current 787 final assembly line can accommodate growth to 10 per month through lean manufacturing. Boeing's aspirations to exceed that figure again necessitate new production space.

Another watch item for Boeing's 787 production expansion plan is the overstretched supply chain—particularly the performance improvement cam-

PROPULSION

EcoPulse Strengthens Europe's Technology Basis for Future Aircraft

- > AIRBUS COULD BENEFIT FROM WING AERODYNAMICS PROGRESS
- > DAHER AND SAFRAN HONE THEIR UNDERSTANDING OF HYBRID-ELECTRIC PROPULSION CHALLENGES

Thierry Dubois Lyon

If commercial and business aviation's ambitious decarbonization goals materialize, future aircraft designs may find roots in the EcoPulse research and technology project.

Comprising Airbus, Daher and Safran, the distributed hybrid-propulsion program has proven particularly fruitful. Using a modified Daher TBM 900 single turboprop, all three companies gained knowledge that may contribute to program launches in the coming years.

Airbus may use the EcoPulse to improve wing efficiency, while Safran has overcome electric system architecture challenges. The engine-maker now knows where to focus its efforts if it decides to hybridize commercial aircraft, helicopters or regional aircraft.

Daher might be the first of the three to translate the demonstration into a product. The company's strategic plan calls for it to make a decision by 2027 about the launch of a hybrid-electric turboprop in the small business or utility aircraft category. Thanks to the EcoPulse, Daher has made progress on certification issues.

The proof-of-concept aircraft features six electric motors, with a total power of 300 kW, and associated three-blade propellers on the wing. Batteries



Daher's TBM demonstrator is large enough to integrate an 800-volt electrical system, turbogenerator and six motors.

can power four or all six of the motors; a turbogenerator can power two.

The EcoPulse demonstrator flew for 100 hr., including 55 hr. of all-electric propulsion testing, between November 2023 and July. French civil aviation authority DGAC funded 50% of the program through the France Relance and Next Generation EU budgets. Hybridization could improve aircraft efficiency 2-5%, DGAC noted in a 2024 report on 2023 activity.

"Collaborating on a concrete object has brought a wealth of information," Christophe Robin, Daher's head of air-

craft design, tells Aviation Week. "Unexpected difficulties were, in fact, good news: We discovered technology challenges no one had anticipated. If such problems emerge during a development program, it may be too late to solve them."

Using the right size of demonstrator may be an overarching lesson from the EcoPulse. The TBM was an

obvious choice for Daher, as it is a company product. It proved the right size for Airbus and Safran, too. The aircraft is large enough to integrate an 800-volt electrical system, turbogenerator and six electric motors but small enough to make the demonstration program relatively flexible, fast and affordable.

Airbus and Safran can now study larger designs. "Fine-tuning computational models in aerodynamics, propulsion and flying qualities is a crucial benefit of the program," Robin says. "Thanks to flight-testing, all three partners can now rely on validated models."

For its next-generation narrowbody, Airbus is considering two open-fan engines installed on the wing. CFM International—Safran Aircraft Engines' joint venture with GE Aerospace—is promoting that technology under its Revolutionary Innovation for Sustainable Engines (RISE) demonstration

campaign at Spirit AeroSystems, which produces the aircraft's Section 41 forward fuselage. Boeing's acquisition of Spirit, part of its broader effort to gain more control over its supply chain, is expected to close around mid-2025.

The airframer says delivery quantity and quality of Spirit-built fuselages have improved in recent months, and it no longer sees these core components restricting its 737 or 787 production ramp-ups. Further streamlining of the Spirit operation is expected throughout 2025 in preparation for more rate increases.

program for 20% greater fuel efficiency. In addition, Airbus is mulling a six-propeller layout for a future ZEROe hydrogen-powered 100-seater.

When asked about the main benefits of the EcoPulse, Jean-Baptiste Manchette, Airbus' head of propulsion of tomorrow, pointed to aerodynamics and the propellers' blowing effect. "When you blow the wing, the efficiency is different," he said at an EcoPulse press conference Dec. 10. "Performance improves at takeoff and during some maneuvers."

While not mentioning RISE or ZEROe, Manchette suggested Airbus could use the blown-wing effect in future developments. "We are working with Safran on how we move on with the integration of a propeller on the wing and see how we maximize both the efficiency of the engines with potential hybridization and the efficiency of the engine installed on the wing," he said. "We have quite an impressive demonstrator coming."

Safran learned from the installation and operation of a full electric propulsion chain, including a turbogenerator, electrical distribution, wiring and motors. In managing high-voltage wiring onboard, engineers solved the conundrum of installing 800-volt harnesses near the fuel system. The EcoPulse program may inform future hybrid-electric propulsion systems.

With a new product in the offing, Daher made substantial progress on certification issues. "To have the aircraft in flight, we had to demonstrate a level of safety," Robin points out. "As it is an unusual configuration, we had to develop new methods. That's a great asset for the future." ☛

While production affected by the strike is just now resuming, deliveries have been underway out of already-built inventory. Boeing handed over 13 aircraft in November, including nine 737 MAXs and two 777Fs produced in the strike-affected factories.

Boeing also delivered two 787s built at its South Carolina site, which was not affected by the strike. November's activity raised year-to-date 787 deliveries to 42—well below 2023's 73.

Supply chain issues, notably for heat exchangers and interiors, have slowed 787 deliveries for months. While new

production was not affected by the IAM walkout, pre-delivery rework in Everett of 787s stopped, holding up some deliveries.

Boeing has about 30 787s left from its pre-2023 production line inventory of 120 that required targeted inspections and repairs. Before the strike, Boeing was averaging four 787 deliveries per month in 2024, including one or two from the pre-2023 inventory, Aviation Week Network data shows. Since August, the company has handed over 10—or a little more than three per month. ☛

MILITARY SPACE > Europe's IRIS² satcom constellation **p. 21**

U.S. Space Force Plans Moves To Avoid On-Orbit Surprises in 2025

- > "KEEPING TRACK OF EVERYTHING ON ORBIT IS COMPLICATED"
- > CHINA'S SURGE IN SPACE CAPABILITY IS GEARED TO TRACK U.S. SPACECRAFT

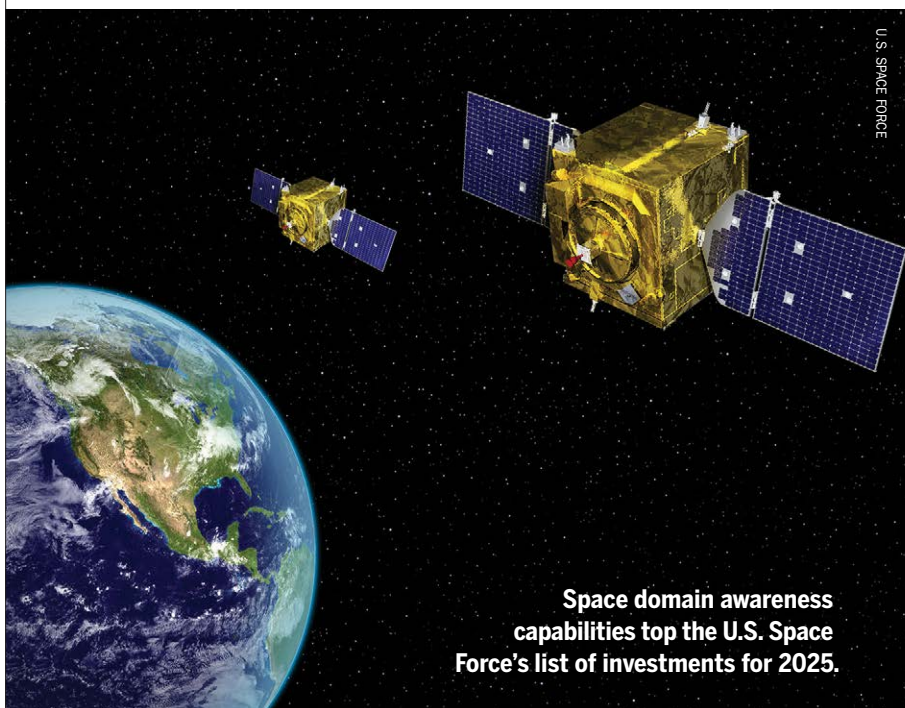
Vivienne Machi Orlando, Florida

The U.S. Space Force is racing to maintain a superior position among the stars as China and other nations are expanding their space fleets and fielding new satellites capable of zigzagging across orbits.

To do so, the service is laser-focused

on space domain-awareness technologies to characterize, track and attribute on-orbit activities considered necessary to avoid operational surprise.

The mission area is a top priority for Gen. Chance Saltzman, the chief



Space domain awareness capabilities top the U.S. Space Force's list of investments for 2025.

of space operations, going into 2025, he said at the Space Force Association's Spacepower Conference here Dec. 10-12.

"Keeping track of everything on orbit is a complicated affair, and we need more sensors to help us do that on a real-time basis," he said.

In 2010, when Hu Jintao was president of China, Beijing had only launched 36 satellites. But President Xi Jinping has overseen a dramatic increase in space-based capability since he rose to power in 2012. The nation now counts more than 1,000 spacecraft in orbit, including nearly 300 electro-optical satellites, 43 radar-imaging assets and 74 signals-intelligence spacecraft, Space Force Chief Master Sgt. Ronald Lerch said at the conference in an unclassified briefing on threats.

The Chinese host a robust network of space surveillance sensors that can search, track and characterize satellites in all Earth orbits, according to the Defense Department's 2024 China Military Power Report. It uses ground-based telescopes and radars as well as space-based sensors to perform missions including intelligence collection, counterspace targeting, ballistic missile early warning, space-flight safety, satellite anomaly resolution and space debris monitoring, according to the report.

Thanks to this surge in space-based capabilities, the Chinese Army is now the U.S. military's pacing challenge in the domain, capable of threatening its assets both in space and on the ground, multiple Space Force officials and industry leaders said at the conference.

The main goals are to track and target U.S. high-value assets, such as aircraft carriers, tankers and Airborne Warning and Control System aircraft "at the time and place of their choosing," the Space Force's Indo-Pacific commander, Brig. Gen. Anthony Mastalir, told reporters.

China is increasingly using maneuverable spacecraft to zip around geosynchronous orbit (GEO) to observe U.S. assets, said Clint Clark, chief growth officer at Exoanalytic Solutions. "China doesn't sit still," he noted, explaining how Beijing's spacecraft will "go up and down the belt," practicing tactics to hover above a positioned satellite, "and sometimes, they'll pick it up and move it away."

The Space Force cannot sit still either, officials stressed. The service must rapidly scale its capabilities "to meet and exceed what's required in the future," Mastalir said.

His command is forging a deeper partnership on space domain aware-



U.S. Space Force Indo-Pacific Commander Brig. Gen. Anthony Mastalir is forging closer ties with Japan on space domain awareness.

ness with Japan. The service's newest component field command, U.S. Space Forces-Japan, started up on Dec. 4 at Yokota Air Base, 25 mi. outside of Tokyo.

The Space Force will host a space domain awareness payload developed by the Massachusetts Institute of Technology's Lincoln Labs on Japan's sixth and seventh Quasi-Zenith Satellite System spacecraft, which are due to launch in 2025. Tokyo also will soon operate a new deep-space radar and is working on a free-flying space domain awareness satellite slated to be launched in the next couple of years, Mastalir said.

Next year, the Space Force expects to have additional inspection satellites operating on orbit. The first Silent Barker "neighborhood watchdog" spacecraft, jointly built by the Space Force and the National Reconnaissance Office, should begin operations in early 2025, the head of Space Com-

mand, Gen. Stephen Whiting, said at the conference.

An unrevealed number of spacecraft for the largely classified mission were launched in September 2023, and the full constellation is expected to include multiple payloads on orbit to keep watch on the GEO regime.

The next two Geosynchronous Space Situational Awareness Program (GSSAP) spacecraft also should be launched in 2025. The Northrop Grumman-built satellites operate near GEO and can perform rendezvous and proximity operations to check out other satellites or objects in space. United Launch Alliance is contracted to carry GSSAP-7 and -8 on its new Vulcan Centaur rocket once it completes the Space Force's certification process.

Meanwhile, the service hopes to field a major space data-processing application in 2025. The Advanced Tracking and Launch Analysis System (ATLAS) program may reach operational capability in the coming year, three years later than planned, following a spate of technical issues and schedule delays.

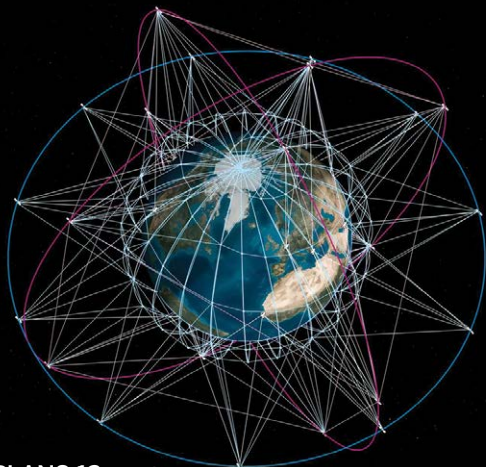
ATLAS will replace the U.S. military's 1980s-era Space Defense Operations Center (Spadoc) computer system to process and manage space-based monitoring data. But unlike Spadoc, which was built to track satellites the size of school buses, ATLAS will need to detect and identify assets that can fit in the palm of your hand.

The program recently was handed off from Space Systems Command (SSC) to the Space Force's Mission Delta 2 to complete testing and begin integration activities, SSC Commander Lt. Gen. Philip Garratt said at the conference. Mission Delta 2 conducts space domain-awareness operations as part of Space Operations Command, which is headquartered at Peterson SFB in Colorado.

Its commander, Lt. Gen. David Miller, told reporters he needs to be able to gather on-orbit data, consolidate access to it and integrate it into a "fused picture" that allows every level of command to use it to provide "combat-ready effects."

Miller said 2025 would be a "perfect year" if his command provides a common awareness platform that all units can use for training, planning and fighting while incorporating new automated intelligence tools. 🌌

Europe Greenlights Sovereign Satcom Effort



➤ EUROPE PLANS 13 ARIANE 64 LAUNCHES FOR IRIS² DEPLOYMENT

➤ THE CONSTELLATION IS TO FEATURE OPTICAL LINKS

Robert Wall London

Days after the European Union unveiled its ambition for a sovereign, secure global commercial satellite communications constellation in early 2022, Russia bolstered the case by launching a cyberattack on a commercial satcom system in the run-up to its full-scale invasion of Ukraine.

What has unfolded since is more than two years of difficult negotiations and program planning that on Dec. 16 finally led the European Commission, European Space Agency and SpaceRISE industrial consortium to sign a €10.6 billion (\$11.1 billion) 12-year concession contract to deploy and run the IRIS² satellite communications program. The constellation, which is due to reach initial operational capability in 2030 and full operational capability in 2031, would comprise about 292 satellites in low Earth orbit (LEO) and medium Earth orbit (MEO).

At the signing ceremony on Dec. 16 in Brussels, European Defense and Space Commissioner Andrius Kubilius said the program is vital in dangerous times. “Our connectivity communications are under threat,” he said. “IRIS² will give us the ability to connect even in a hostile environment, to keep communication lines open despite jamming by hostile forces, interference or cyberattacks.”

To create the service, the EU plans to spend about €6 billion on IRIS²,

with ESA contributing €550 million and industry €4.1 billion.

IRIS²—which stands for Infrastructure for Resilience, Interconnectivity and Security by Satellite—represents an effort by Europe both to bolster its space industry and to enhance its independence in the domain, avoiding reliance on foreign systems, such as SpaceX’s Starlink or Amazon’s planned Kuiper network. European officials have opted for a mix of LEO and MEO satellites to reduce the number required, saying they need fewer satellites than commercial vendors because their needs are more modest.

European officials acknowledge they face a tight schedule to mature key technologies as well as to build and deploy the system. But they also are signaling a sense of urgency. “We have no time to lose; we are already late,” Timo Pesonen, the European Commission’s director general for defense industry and space, said at the signing.

To jump-start the service, several governments have agreed to pool some of the capacity of their national satellite communications systems and make them available to others starting next year. Those services largely draw on geostationary satellites. France, Greece, Italy, Luxembourg and Spain are the initial batch of countries that are to make communications capacity available under the so-called Govsat-

com Initial Services. The full Govsat-com service is planned for 2028.

The SpaceRISE consortium—led by SES, Eutelsat and Hispasat—initially included satellite-makers such as Airbus and Thales Alenia Space. The two bowed out as full members this year, saying they preferred to act

The European IRIS² system is supposed to comprise close to 300 satellites in low Earth orbit and medium Earth orbit.

as vendors rather than take on the financial risk of being part of the group operating and selling the service.

The total system capacity of IRIS² and Govsatcom is slated to be about 3.3 Tbps. Much of the IRIS² capacity will be available for the SpaceRISE consortium to sell commercially. Customers are expected to include governments looking for more capacity, as well as nongovernmental users. About three-quarters of the system’s capacity should be available for commercial exploitation, although government members have reserved the right to use all available bandwidth in times of conflict.

Europe plans to deploy the IRIS² constellation through 13 launches using the heavy Ariane 64 rocket—three for the 18 MEO satellites and the rest for the 264 LEO spacecraft. The system also is supposed to comprise another 10 or more low-LEO satellites, deployed via a new generation of small-satellite launchers ESA is fostering and that are intended to use technology from small and midsize enterprises to advance European space startups.

The coming months could be pivotal to keeping the program on pace. Program officials have identified three key, low-technology-readiness-level technologies to mature: the onboard processor, onboard computer and digital beam-forming antenna. A decision on whether those are ready is due in about a year at a preliminary design review. Other contracts also are to be awarded in the coming months, including for the satellites’ electric thrusters and optical links designed to connect all the spacecraft to ensure data is beamed down in sovereign European Union territory.

“There is a lot of hard work in front of us,” SES CEO Adel Al-Saleh said at the event. 🌐

Airbus Future Fuselage Shows Weight Benefits

- THE FUSELAGE COULD BE 10% LIGHTER
- WINGBOX STATIC TEST IS PLANNED FOR THE FIRST QUARTER OF 2025

Guy Norris Colorado Springs

As Airbus eyes advanced fuselage and wing designs that could enable single-aisle production rates of up to 100 aircraft per month, the airframer is reviewing promising weight reduction results from its recently completed MultiFunctional Fuselage Demonstrator project.

Launched in 2014 under the European Union Clean Sky 2 research program's Large Passenger Aircraft effort, the Multifunctional Fuselage Demonstrator (MFFD) is an 8-m-long (26.2-ft.), 4-m-dia. section of an A320-size fuse-



lage produced largely from thermoplastic composites. Its construction uses multiple alternative forming and joining technologies, with the goal of reducing weight and recurring costs while enabling high-rate production.

Depending on the combination of technologies used on a fuselage, Airbus researchers say the MFFD shows the potential for structural weight that is more than 10% lower. That could mean up to 90 kg (200 lb.) less fuel used on a typical flight, which could translate into as much as 540 kg fewer CO₂ emissions per flight. "If you take into consideration that one single aircraft takes off and lands up to 1,600 times per year, this is a huge, huge saving of emissions we can look at here," York Roth, Airbus research and technology technical leader, said about the program at the International Council of the Aeronautical Sciences (ICAS) Congress in Florence, Italy, in September.

Unlike thermoset composite materials used in widebody aircraft, such as the Airbus A350 and Boeing 787—specifically carbon-fiber-reinforced plastics, which bind the fibers together with a thermosetting resin—carbon-fiber-

reinforced thermoplastic polymer composites do not form any chemical bond when curing, making them remoldable and recyclable. This enabled Airbus to explore innovative manufacturing and faster assembly technologies, such as thermoplastic welding.

A thermoplastic composite material called low-melt polyaryletherketone (LM/PAEK) was chosen for the program, which included developing and testing of upper and lower fuselage shells, a new cargo door concept and a crown module incorporating cabin functions, such as power, data, ventilation and passenger service units.

"We decided to use as much thermoplastic composite material as we could," Roth said. "And this was really to push the boundaries and to get a better understanding. When we discussed thermoplastics on one side, we saw a lot of opportunities. On the other side, we saw a high level of risks, and to bridge the gap, we said, 'Well, let's give it a try. Let's try it on a large scale.'"

Roth added that experimenting at large scale opened the door to welding structures rather than using conventional

rivets and fasteners. "If we have welding, we avoid drilling holes and chippings, so we have a cleaner manufacturing environment," he explained. "And if we have a cleaner shop floor, we can think about the different sequencing of our assembly processes in the final assembly line, which may be a game changer there as well."

Following final assembly by Fraunhofer, the largely thermoplastic fuselage demonstrator is now at the ZAL Center of Applied Aeronautical Research in Hamburg, Germany.

"Thermoplastic components really enable industrial change" as a result, he said. "Our ambition has been to look at weight and recurring costs at the same time as having high-rate production in mind. Ultimately, this year, the consortium delivered the world's largest thermoplastic composites fuselage demonstrator."

Although he had said at the American Institute of Aeronautics and Astronautics SciTech conference in January that the program was ambitious and that "we may have jumped too far," the overall effort exceeded weight- and cost-saving goals (*AW&ST* Feb. 26-March 10, p. 58).

The thermoplastic components were joined using a range of welding techniques—conduction, resistance, ultrasonic and laser, Roth said at ICAS. The upper and lower fuselage shells of the MFFD were joined together at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials in Stade, Germany, using an ultrasonic-welded overlap joint on one side and a laser-welded butt-strap joint on the other.

Spanish company Aernnova Composites developed the cargo door surrounding structure, upper-shell stringers, tapered butt straps and fuselage panels for the demonstrator from LM/PAEK. Meanwhile, Airbus Aerostructures and Premium Aerotec, based in Augsburg, Germany, and owned by Airbus, developed a manufacturing concept for making thermoplastic integral frames from tape provided by Toray Advanced Composites.

The upper-shell module skin was built using out-of-auto-

Ultrasonic welding was used to attach frames to clips and clips to the skin along with stringers in the lower shell module.

clave advanced fiber placement processes, such as in-situ consolidation, in which heat and pressure were applied to a specific location where carbon-fiber tape was placed on the tool rather than to the entire component. Although this eliminated vacuum bags and waste, maintaining the consolidation quality of the final laminate was challenging, researchers say.

The Aernnova stringers were attached using a continuous ultrasonic welding process. “We had an automated camera-based correction system, which was very useful,” Roth said. Forty-four stringers were automatically positioned and welded in place using a specially developed weld bridge. Structural welds were made at 1.4 m/min., with a net weld time of 11 min. per stringer. Resistance welding was used for frame and cleats, with 40 sec. required for both heating and cooling phases, resulting in 3 min. per weld, including robot movement and cleat pickup time.

GKN Fokker, the Netherlands Aerospace Center, Delft University of Technology, SAM XL and Diehl Aviation built the lower shell with a one-piece skin stiffened with omega stringers, also called “hat stiffeners.” Frames formed a sub-assembly with the cargo floor beams, and several systems—including electrical, water, air and fuel—were installed as preassembled modules. Most systems were installed in the floor structure so that the fully equipped unit could be integrated as a single assembly.

Airbus, meanwhile, is readying for a critical static test of a 17-m, full-scale, high-aspect-ratio composite wingbox in the UK as part of its Wing of Tomorrow program, which was launched in 2016. Focused on developing technology for an advanced longer-span/lower-drag wing that can be produced at a high rate, the program aims to tackle both industrial and aerodynamic challenges.

The static wingbox, which will be tested to failure starting in the first quarter of 2025, is one of three demonstrators involved in the program. The others include a fully equipped demonstrator to test installation technologies and next-generation wing systems, as well as a run-at-rate demonstrator to verify industrial capability and automation technologies required for build rates of up to 200 individual wings per month.

The static wingbox demonstrator, assembly of which began in 2022, will be used to validate engineering assumptions about the design, which incorporates highly integrated composite wing covers with several primary structural components combined into a single resin-infused structure to reduce fasteners and weight.

The fully equipped demonstrator has the systems installed inside the wingbox itself, with leading and trailing edges fitted “in a more streamlined fashion,” Martyn Cantrell, composites engineer and project manager at Airbus, said at ICAS. The run-at-rate demonstrator “will look at the industrial capabilities,” he explained.

“All three wings are built in an identical fashion, but when we come to this third wing, we’re going to have the abil-



ity to pause, take stock and review what we’ve been doing, and then maybe define some additional requirements or additional tests,” Cantrell said. “Then we will use those to develop the industrial capability and the automation that we have. So it’s very much learning on the fly and trying to develop the way forward.”

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The Great Decoupling

Graham Warwick Washington

Aerospace is an international business, with supply chains and security alliances that span the globe. But as U.S. President-elect Donald Trump prepares to begin his second term, the bonds that have shaped the industry over decades look set to be tested.

Whether it is Trump's determination to put America first, wield tariffs to punish unfair trade, promote fossil fuel production, end wars in Ukraine and the Middle East or deny U.S. protection to NATO nations not paying their share for Europe's defense, change is coming to the aerospace industry.

Trump's decision to use tariffs as a weapon presents an immediate concern for the industry. He has vowed to impose a 25% tax on imports from trade partners Canada and Mexico and up to 60% on goods from superpower rival China. While Europe may escape immediate attention, it may have to respond with its own tariffs on China to stave off a flood of goods displaced from the U.S. market.

China is certain to fight back. Even before Trump takes office a second time, Beijing has responded to the Biden administration's restrictions on exports of semiconductor technology to China by banning the supply to the U.S. of critical materials for advanced electronics, such as antimony, gallium and germanium.

When Beijing retaliated against the first Trump administration's tariffs, Boeing aircraft escaped the penalties. The same may happen this time, as China desperately needs Western airliners. Boeing is less exposed now, with 368 orders to Airbus' 453, but China's domestic industry cannot make up any shortfall. Despite an orderbook for 1,437 aircraft, Comac will not produce more than 40 C919s per year over the next decade, the Aviation Week Network forecasts.

But Trump's tariffs could accelerate the decoupling of Western and

Chinese supply chains that is already underway as Beijing strives to achieve independence in commercial aviation. This distancing is in no one's interest, Safran CEO Olivier Andries warned Dec. 5, as China is still 20% of the global market. Tariffs on Canada and Mexico, meanwhile, could affect suppliers that have placed bets on nearshoring production within North America to be closer to the U.S. market.

If Trump's second presidency is a clarion call to Europe to take more responsibility for its own defense or risk losing U.S. protection, it comes when EU powerhouses France and Germany are in domestic political and budgetary disarray. Trump has vowed to end the war in Ukraine, but there are fears his solution will leave Russia emboldened and Europe weakened.

NATO Secretary General Mark Rutte on Dec. 12 called on member states to "shift to a wartime mindset" and "turbocharge" defense spending and production, urging them to spend "considerably more" than the current target of 2% of GDP. Andrius Kubilius, the EU's first defense and space commissioner, has called for a "big bang" on defense spending by 2030.

Both leaders want effective defense spending. Rutte is calling on nations to place "big orders and long-term contracts" with their industries, which have been hollowed out by decades of underinvestment. At the same time, Trump's tariff threats could undercut those efforts, since some EU nations see orders for U.S. defense equipment as a way to appease Washington.

On the issue of sustainability, it is not yet clear whether a climate-skeptical Trump administration 2.0 will

The Chengdu J-20 stealth fighter is a flagship of Chinese military modernization and is fueling rising geopolitical tensions.

spell challenges for aviation's aspirations to achieve net-zero emissions by 2050. The president-elect has promised to promote oil and gas production and roll back incentives for electric vehicles, but the Republican stance is to embrace all forms of energy, including renewables.

So far, sustainable aviation fuel (SAF) has enjoyed bipartisan support in Congress, but there are concerns that Trump's dismantling of the clean energy incentives in the Biden administration's signature Inflation Reduction Act, including tax breaks for SAF and green hydrogen, could give the big energy companies another reason not to make the investments in SAF production the aviation industry is demanding.

Since establishment of the U.S. Space Force under the first Trump administration, concerns about the militarization of space have only grown, and the U.S. could shift in his second term from its current defensive posture to a more offensive strategy to counter rising space threats from China and Russia.

At the same time, SpaceX co-founder Elon Musk's closeness to Trump, and his charter to improve government efficiency, could accelerate the use of U.S. commercial space capabilities to meet national security requirements.

Meanwhile, Europe is concerned that Trump's "America first" approach could weaken transatlantic cooperation on civil and military space. This has sparked calls for greater European spending to reduce reliance on U.S. capabilities, a move that could risk another decoupling. 🌐



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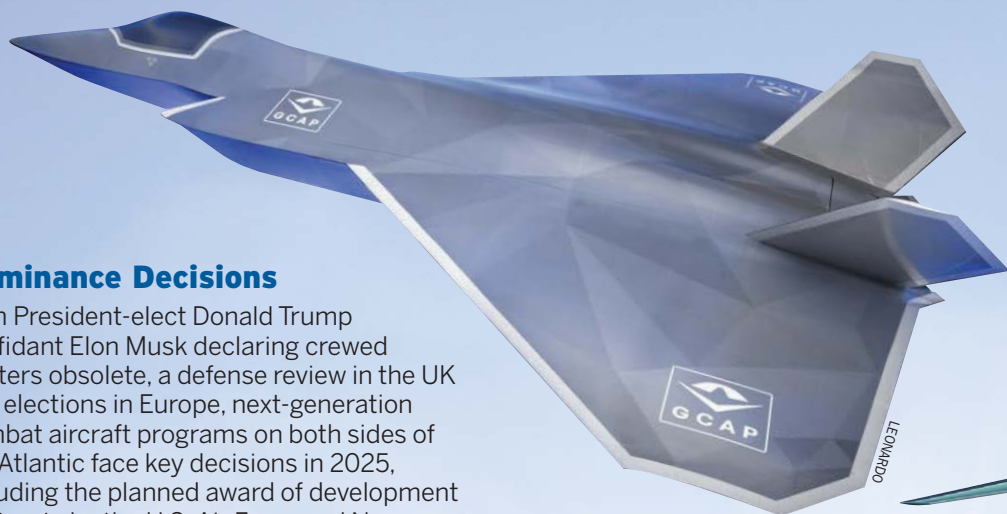
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Aerospace & Defense 2025 incorporates data from the Aviation Week Intelligence Network. For more information, visit awin.aviationweek.com

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Dominance Decisions

With President-elect Donald Trump confidant Elon Musk declaring crewed fighters obsolete, a defense review in the UK and elections in Europe, next-generation combat aircraft programs on both sides of the Atlantic face key decisions in 2025, including the planned award of development contracts by the U.S. Air Force and Navy as well as a UK-Italian-Japanese alliance.

WHAT TO WATCH FOR IN 2025

Challenges will abound in the coming year, whether in progress toward sustainable aviation, developing a new generation of combat aircraft or transforming commercial and military space.

Graham Warwick Washington

Heavy Metal

The top rung of private aviation will fill out in 2025 with planned certification of the competing Bombardier Global 8000 and Gulfstream G800 high-speed, ultra-long-range business jets and Dassault's rival flagship Falcon 10X entering flight testing. The big question: Will Bombardier's secret Challenger replacement break cover?

Rebuilding Boeing

Boeing faces a pivotal year. New CEO Kelly Ortberg is focused on stabilizing the company, slimming its workforce and stemming its losses; rebuilding 737 and 787 production; finally certifying the 737-7 and -10 and possibly the 777-9; completing the reacquisition of Spirit AeroSystems and—above all—transforming Boeing's safety culture.



BACKGROUND IMAGE: DAYTO BALIKOVITV/SHUTTERSTOCK

JENNIFER BUCHANAN/THE SEATTLE TIMES POOL PHOTO

Electric Ambition

Five years after a two-seat trainer became the first battery-powered aircraft to receive type certification, Sweden's Heart Aerospace plans to flight-test the X1 full-scale demonstrator for its 30-seat hybrid-electric ES-30 regional airliner from Plattsburgh International Airport, New York, as fragile progress in electric aviation continues.



Call an Air Cab

FAA type certification of one or more electric vertical-takeoff-and-landing air taxis looks unlikely in 2025, but rivals Archer Aviation and Joby Aviation continue to hold out hope of being able to launch commercial operations by the end of 2025 in Abu Dhabi and Dubai, respectively, ahead of certification in the U.S.



Space Tanking

SpaceX plans to take another giant leap with its first space-to-space propellant transfer in 2025. Crucial to the planned use of the Starship to land astronauts on the Moon with NASA's Artemis II mission in 2026, the demonstration will involve docking two Starship upper stages in orbit and pumping fuel between them.



Networked Space

After years of talk about ending reliance on expensive and increasingly vulnerable large satellites, the U.S. Space Development Agency is preparing for the operational debut of a proliferated space architecture, with the launch of 154 tactical communications and missile-tracking satellites into low Earth orbit expected to begin in early 2025.



SAF Harbor?

The U.S. is on track to produce more than 3 billion gal. of sustainable aviation fuel (SAF) a year by 2030, exceeding its SAF Grand

Challenge goal. That could change, unless bipartisan support in Congress protects SAF from a Trump administration targeting clean-energy incentives enacted under the Biden administration.

Uncrewed Competition

While Anduril Industries and General Atomics prepare to fly prototypes in 2025 under Increment 1 of the Collaborative Combat Aircraft program, the U.S. Air Force is developing requirements for Increment 2. Boeing, Lockheed Martin and Northrop Grumman are marshaling resources to compete again, hoping for better results. 🚀



ANALYSIS



The Window of Conflict Opens

Robert Wall London and Steve Trimble Washington

THE TRUMP ADMINISTRATION IS POISED TO take power at a time when—at least in Pentagon planning terms—conflict with China could be on its doorstep and security cooperation is deepening between Beijing and Moscow, as well as Tehran and Pyongyang.

In the early days of the Biden administration, the Pentagon started worrying that Chinese President Xi Jinping wanted his military to be ready to invade Taiwan this decade, accelerating that goal from 2035. Adm. Phil Davidson, who was then commander of U.S. Indo-Pacific Command, warned lawmakers in the spring of 2021 that conflict might loom as early as 2027. The timeline has become known as the Davidson Window.

The second Trump administration will release a budget request soon after taking office. But the reality of financial planning means that sweeping changes will not occur until the subsequent fiscal 2027 funding request. Effectively, the programs on the books now thus will define what will be available, should that war scenario play out.

National security preparations for confronting China have been in the works for years, spanning multiple administrations and predating President-elect Trump's first four years in the White House. That could suggest that Biden-era efforts to contain China may endure, such as key pieces of the AUKUS partnership with Australia and the UK in areas such as nuclear submarines and hypersonic weapons.

To some extent, Russia's full-scale invasion of Ukraine in February 2022 has become a catalyst for the Pentagon to prepare for military confrontation in Asia. The fighting has highlighted the need for deep stocks of weapons and informed key investments in areas such as higher solid-rocket motor output and increased missile interceptors. Lockheed Martin, for instance, plans to bring production capacity of its latest Patriot PAC-3 interceptors to 650 units per year in 2027 from under 400 in 2023.

The war in Ukraine also has put into even sharper focus the utility of swarms of low-cost loitering attack munitions and similar systems for imposing heavy costs on an adversary. The U.S. and countries like Taiwan have put more emphasis on adding those to their arsenals, although there are still questions about how applicable those relatively short-range systems would be in a fight spanning a 110-mi.-wide waterway.

China, for its part, has been routinely flying military aircraft close to Taiwan. In one case in October, China

flew 153 aircraft near Taiwan, 111 of which crossed the median line of the Taiwan Strait, Taipei said.

Beijing used the China International Aviation & Aerospace Exhibition in Zhuhai to showcase its advances, displaying systems such as the Cloud Shadow CS-5000T stealthy combat uncrewed aircraft system and disclosing that the CH-7 uncrewed combat air vehicle prototype is flying.

The Pentagon sent B-2 bombers to Guam in June as part of the U.S. effort to bolster military capacity in Asia.



AIRMAN 1ST CLASS MANASSEH DEMISSIE/U.S. AIR FORCE

The Philippines are emerging as another potential flash point with China, as Beijing is contesting territory that Manila considers its own. The tensions have strengthened ties between Washington and the Philippines, leading the U.S. Army in April to deploy its Mid-Range Capability, which can launch a land-based version of the RTX Tomahawk cruise missile and the Standard Missile 6, in the country for the first time.

Washington's desire to focus more on Asia is not novel, however, and hot spots elsewhere have a record of reasserting themselves—including in the Middle East. The continued fighting between Israel and some of its neighbors suggests that will not change in the coming year.

Europe, too, is not likely to recede entirely as a strategic issue for the Trump administration, even if the White House ends support for embattled Ukraine, as Trump has threatened. European countries have pledged to sustain their backing for Ukraine, which would create a competition for production resources that could challenge Washington's ability to increase inventory depth for a standoff with China. 🌐



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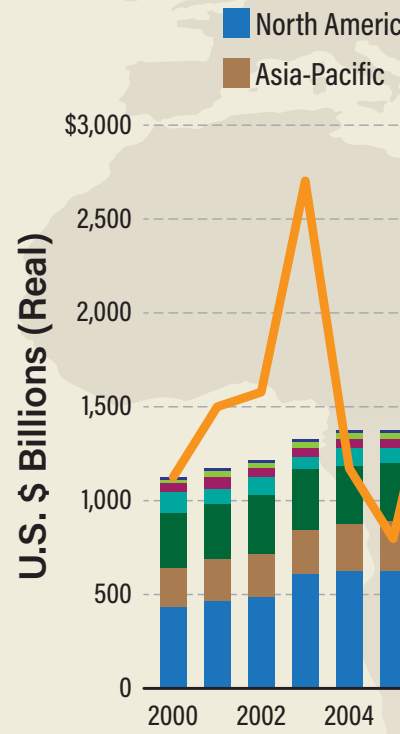
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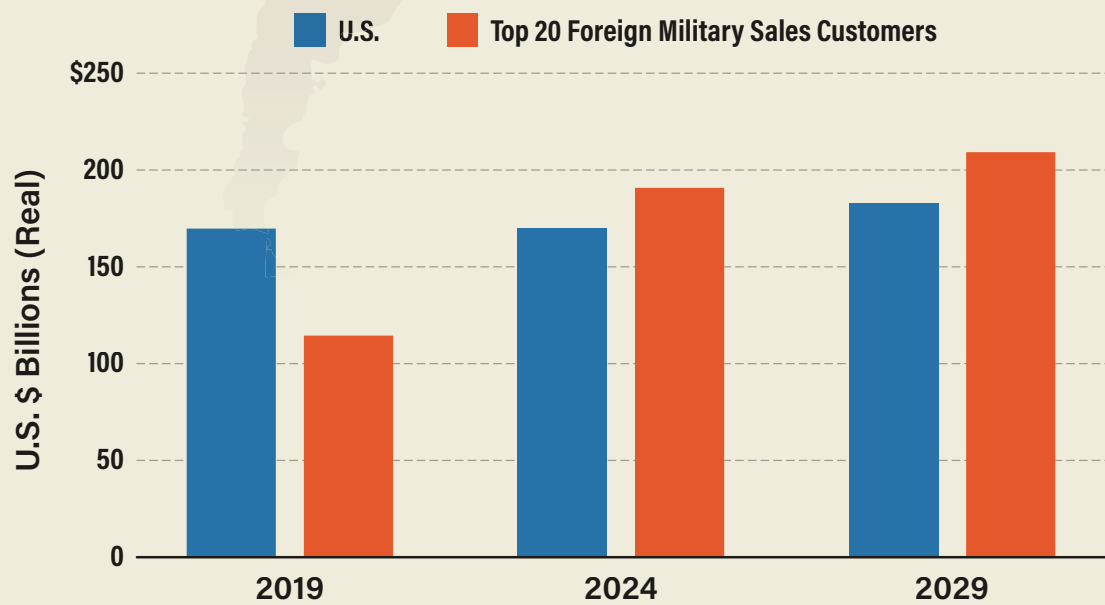


GLOBAL DEFENSE OUTLOOK

The period between 2022 and 2024 represents the third-biggest boom for the defense sector since the end of the Cold War. Driven primarily by the full-scale Russian invasion of Ukraine in February 2022, renewed instability in the Middle East and longstanding concerns about Chinese intent in East Asia, military spending increased 16.7%—\$327 billion in real terms. The difference between this period of expedited growth and the ones that followed the Sept. 11, 2001, terrorist attacks and the Iraq War surge is that for the first time since World War II the boom is being driven from outside the U.S., mostly by America’s closest allies. Over the past five years, U.S. procurement spending has remained largely static, at about \$170 billion, while among the 20 biggest U.S. Foreign Military Sales customers, spending has risen to \$191 billion from \$114 billion. Although growth is projected to slow marginally in 2025, the elevated levels of spending appear to be here to stay as governments around the world respond to growing instability.

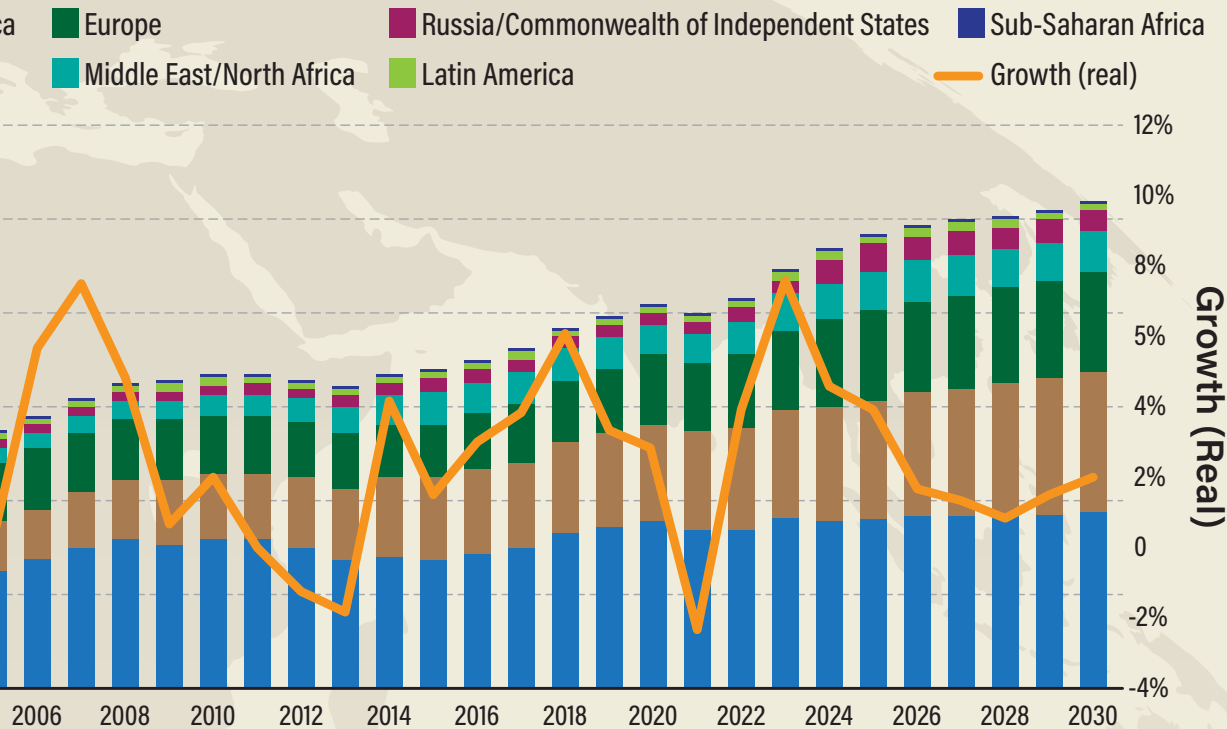


U.S. and U.S. Customer Spending Compared

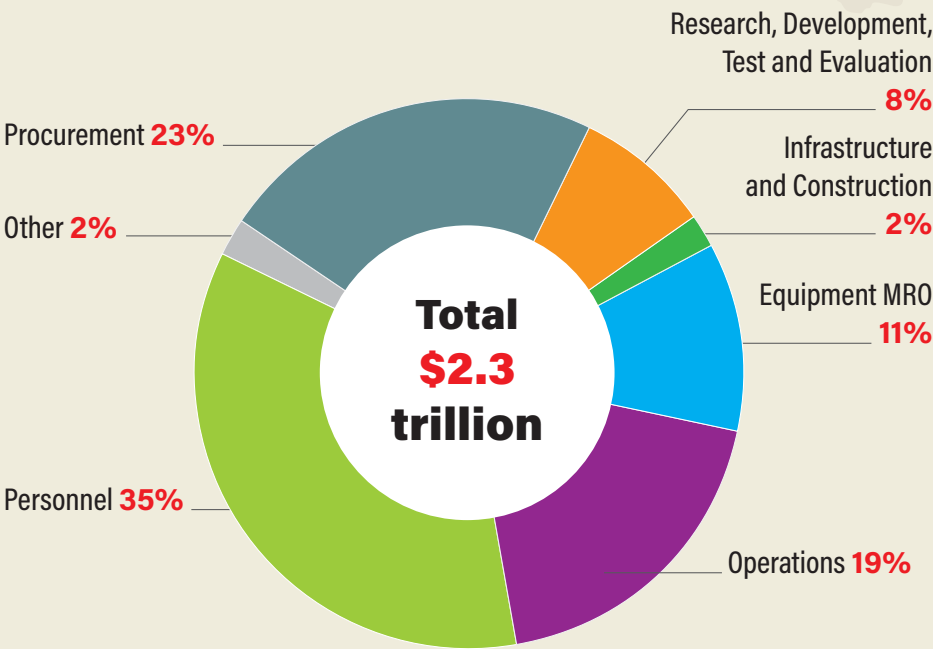


Source for all charts: Craig Caffrey/Aviation Week Defense Market Analyzer

Global Defense Spending by Region, 2000-30



Global Defense Spending by Function, 2024



Asia-Pacific Countries Adapt Their Military Modernization Plans



➤ AUSTRALIA EXPECTS TO START FIELDING JOINT STRIKE MISSILES

➤ INDIA AND SINGAPORE SHOP FOR TRANSPORT AIRCRAFT

Chen Chuanren Singapore

Defense modernization efforts in the Asia-Pacific region are entering a new phase as countries there start introducing new equipment to counter an increasingly aggressive China and look for tools to bolster their defenses further.

Gaining priority on the agenda are uncrewed aircraft systems (UAS), asymmetrical warfare and missile acquisition and production, reflecting lessons from the war in Ukraine and the realization that any conflict with China will require deeper inventories.

More critical in the near term may be armament efforts implemented in recent years that are now bearing fruit. Australia expects to start domestic production of guided rockets in 2025 as part of the country's push to ensure a sovereign ability to meet its weapon needs. Canberra also expects to receive Kongsberg Joint Strike Missiles in the new year after fast-tracking the acquisition. Taiwan plans to build up its air defense capability as it fields delayed Lockheed Martin F-16V fighters.

Perhaps one of the clearest indicators of how much regional security has evolved over the past few years is how Japan is distancing itself from its decades-long national security policy of focusing exclusively on self-defense.

The Japan Maritime Self-Defense Force soon will enter a new era of operating aircraft carriers, fielding the capability for the first time since

the end of World War II. Japan has completed Lockheed Martin F-35B integration tests on its two Izumo-class carriers, and the first Japanese short-takeoff-and-vertical-landing-variant Joint Strike Fighters are due to arrive before April. The navy also is exploring UAS for maritime domain awareness, with the potential for these platforms to operate from the Izumo-class carriers.

Japan stands out for its sizable defense budget, which it is underlining with a record request of ¥8.5 trillion (\$55.1 billion) for fiscal 2025.

Tokyo's rapid investment in advanced technologies is yielding results. Japan successfully test-fired its first hypersonic missile in June, with further developments planned through 2025 and beyond.

Other countries across the Asia-Pacific region also are pursuing hypersonic missiles. India joined the club on Nov. 17 with the test of an unnamed system.

The U.S. and Australia continue to collaborate under the Southern Cross Integrated Flight Research Experiment and have airborne tests scheduled in Australia. The program now includes the UK, thanks to a new Hypersonic Flight Test and Experimentation Project Arrangement under the second pillar of the AUKUS agreement. The trilateral group aims to complete six flight tests by 2028.

The effectiveness of loitering munitions against personnel and armored vehicles in Ukraine has influenced Asian militaries, particularly those preparing for large-scale land and littoral warfare. Taiwan was among the first in the region to take note, ordering 291 Anduril Altius 600M-V drones and 720 AeroVironment Switchblade 300 systems. Australia followed with an acquisition of an unspecified number of Switchblade 300s, and South Korea purchased some 180 WB Electronics Warmate 1 drones from Poland.

A Lockheed Martin F-35B landed on the JS Kaga carrier to prepare for its introduction into Japanese service.

Japan has indicated a strategic pivot by reducing its fleet of armed helicopters in favor of UAS and loitering munitions. Its fiscal 2025 budget allocates ¥3 billion for loitering munitions, emphasizing their anticipated role in protecting the country from invasion.

Deliveries of these munitions will commence in 2025, spurring a new concept of operations within the Asia-Pacific region's air services and the acceleration of cost-efficient air defense systems.

The focus on introducing novel equipment does not mean the period of sizable new program commitments is about to end. The Philippines is shopping for new fighters, while Thailand still must finalize its purchase of Saab Gripen E/Fs. India and Singapore are shopping for tactical transport aircraft. Embraer hopes to maintain its C-390 sales momentum in the competition, and Airbus and Lockheed Martin are eyeing the opportunity for the A400M and C-130J, respectively.

As Singapore works to replace aging Fokker 50 maritime patrol aircraft, the main question is whether it will seek a high-end capability or lean more toward UAS to address at least some surveillance needs. Also on the buying agenda are South Korea's interest in more airborne early warning aircraft and Japan's in additional refueling aircraft.

The region's defense procurement agencies are keeping missiles high on their lists, too. Australia is looking at anti-radar missiles, and Taiwan is considering increasing its air and missile defense interceptors, while several other countries are assessing long-range strike options. 🌐

China's Military Flex Prompts U.S. Strategy Change

➤ OCTOBER EXERCISES DISPLAY UNPRECEDENTED JOINTNESS

➤ U.S. MILITARY LEADERS RESPOND WITH REPLICATOR, PREVAIL PLANS

Steve Trimble Washington

A newly released Chinese government propaganda clip, titled “For You,” dramatically re-creates one of the five incidents in the 1960s when Chinese S-75 Dvina interceptors shot down a Taiwanese Air Force Lockheed U-2, then snaps 60 years forward to the present.

I had ever seen, and with the widest geography,” remarked U.S. Navy Adm. Samuel Paparo, head of Indo-Pacific Command, at the Brookings Institution Nov. 19.

A two-decade modernization sprint has populated the Chinese Air Force inventory with an arsenal of advanced

Strait-facing Eastern Theater Command—have been working to connect and coordinate all modernized platforms deployed in the air, ground and sea domains, enabling joint operations designed to deliver a combined punch greater than the sum of its parts.

The Chinese military's growing strength has prompted a shift in Pentagon buying habits. Under the Defense Department's Replicator initiative, Indo-Pacific Command expects to receive thousands of cheap, autonomous systems by August that can transform the area around the Taiwan Strait into a “hellscape” for anything that moves (AW&ST Oct. 2-15, 2023, p. 14). The Pentagon acknowledges a handful of

GLOBAL TIMES



A taxiway lineup with two J-20s and several J-11B fighters highlights the growth in numbers and sophistication of China's air force.

“Will there be any chance of us being bullied by foreign aircraft in the future?” a Chinese boy worriedly asks his father, a pilot in China's Air Force.

“Don't worry—we will always be watching them from the sky,” the father calmly and firmly replies.

It was a brief but telling exchange in a 10-min. film released by the Chinese government in November to celebrate the Chinese Air Force's 75th anniversary. Nearly two years before President Xi Jinping's deadline for the military to be prepared for an invasion of Taiwan, the Chinese Air Force has never been more powerful.

During the Eastern Theater Command's Joint Sword-2024B exercise in mid-October, Chinese fighters, bombers and surveillance aircraft swarmed over and beyond the Taiwan Strait, flying above a demonstration of a simulated amphibious invasion by more than 200 warships, with 43 brigades of ground troops maneuvering on Chinese soil.

The Joint Sword-2024B maneuvers were the “most joint exercise from the People's Republic of China (PRC) that

fighters, uncrewed combat air vehicles (UCAV), airborne early warning platforms, interceptor missiles, transports and tankers. The Chinese Air Force indeed is able to watch for aerial intruders, as the propaganda video asserts.

Many of China's most advanced capabilities have been put on display. The navy's Shenyang J-35 stealth fighter joined the air force's Chengdu J-20s at the China International Aviation & Aerospace Exhibition in Zhuhai in November. The Chengdu CS-5000T UCAV stood with the Hongdu GJ-11 UCAV on the static line. The propaganda film released on the eve of the air show revealed Xian YY-20A tankers refueling Shaanxi KJ-500s, along with a Xian H-6 bomber toting a CM-400AKG anti-ship ballistic missile under its wing.

Other capabilities still remain hidden from public view. The Chinese government acknowledges a program to field the Xian H-20 stealth bomber but has kept the design secret. A rumored replacement for the Xian JH-7 fighter-bomber also remains under wraps.

In a less visible development, military leaders—especially in the Taiwan

China's 2025 Planned Defense Spending

\$313.5 billion
1.5% of GDP

these Replicator systems, such as the AeroVironment Switchblade, but the details of a larger inventory of autonomous undersea and surface vessels remain secret.

The Pentagon announced the Replicator concept in August 2023 during the tenure of Paparo's predecessor, Adm. John Aquilino. Aquilino had launched the “Seize the Initiative” policy for Indo-Pacific Command in 2021, seeking to reenergize alliances and partnerships and to stem China's growing influence throughout the region.

Since assuming command in May, Paparo has promoted a new strategy that builds on Seize the Initiative. Simply titled “Prevail,” the plan seeks to leverage security partnerships and the influx of new technology, such as the Replicator systems. The new approach signals a more aggressive response to Chinese military moves in the Western Pacific region, from the Taiwan Strait to the South China Sea.

The new strategy's focus on swarms of autonomous systems does not replace the presence of other military capabilities in the Indo-Pacific region.

“The PRC has got 2,100 fighters. They've got three aircraft carriers. They have a battle force of 200 destroyers,” Paparo said at the Brookings Institution. “But air and maritime superiority are going to be important over wide expanses.” 🌐

Melting Ice Is Spurring Strategic Competition in the Arctic

- INCREASED ACTIVITY IS EXPECTED AS SHIPPING LANES OPEN UP
- THE PENTAGON'S FIRST REGIONAL STRATEGY IN FIVE YEARS AIMS TO TACKLE GROWING RIVALRIES

Vivienne Machi Los Angeles

In 1935, a former U.S. Army officer and World War I veteran named Billy Mitchell pleaded with the House Committee on Military Affairs to take seriously the strategic importance of Alaska.

pabilities for satellite communications (satcom), surveillance and reconnaissance activities.

After the collapse of the Soviet Union, eight countries established the Arctic Council: Canada, Denmark,

The Pentagon must “actively invest” in its Arctic satcom architecture, which historically has been limited, Iris Ferguson, deputy assistant defense secretary for Arctic and global resilience, said when the report was released. Satellites based in geostationary orbit have struggled to communicate past the Earth’s curvature.

The U.S. and Norway launched two polar satcom spacecraft in August as part of a joint program known as the Arctic Satellite Broadband Mission. The Northrop Grumman-built GEO-Star-3 spacecraft are following a highly elliptical orbit to provide continuous broadband coverage and protected military satellite communications north of 65 deg. Lat.

The two spacecraft in the Norway-operated constellation carry an Enhanced Polar Satcom-Recapitalization payload for the U.S. Space Force, an X-band payload for the Norwegian defense ministry, a Global Xpress K_a-band payload for Viasat and a European Space Agency-commissioned radiation monitoring payload.

NATO also is exploring new satcom capabilities in the High North. At the annual gathering of defense ministers in Brussels in early October, 13 member nations signed a letter of intent to establish a dedicated commercial satcom service over the Arctic called Northlink.

Officials proposed that allies could provide sovereign capabilities to other NATO members and develop a contracting mechanism to tap into commercial multi-orbit satcom services.

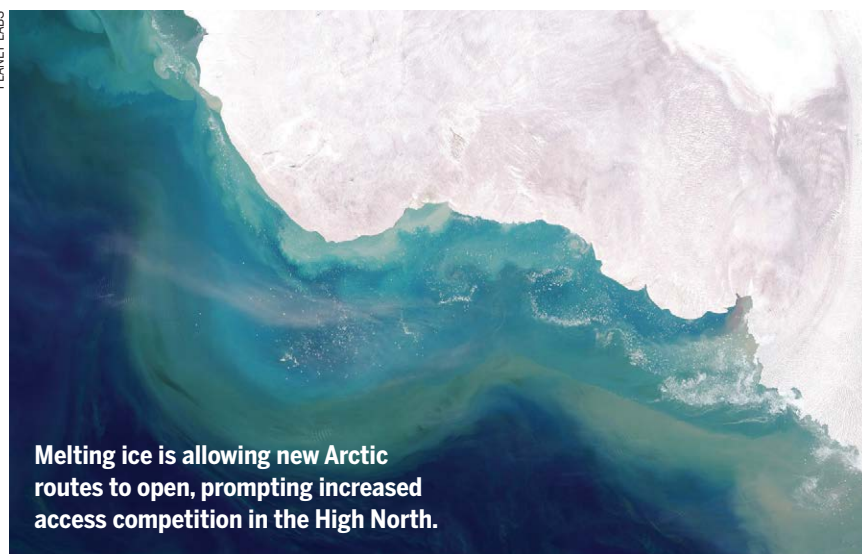
Northlink also could enable partnership with non-NATO allies like Japan, said Giorgio Cioni, the alliance’s armaments director, in October at the Japan Aerospace conference in Tokyo.

Canada is investing in a new ground-based satellite station to improve communications over the Arctic, along with modern airfields to support fifth-generation aircraft like the Lockheed Martin F-35 Joint Strike Fighter.

But infrastructure in the region is “almost prohibitively” expensive, the Canadian Armed Forces defense attache, Maj. Gen. Michel-Henri St-Louis, said at the Center for Strategic and International Studies in July.

“Getting after that in the future will be a challenge, but it is required,” he said. “You can’t just fly from Toronto and go defend the Arctic.”

PLANET LABS



Melting ice is allowing new Arctic routes to open, prompting increased access competition in the High North.

In the nine decades since his resignation from the Army, Mitchell is better remembered for being court-martialed for insubordination as he advocated for increased airpower in the military. But as a civilian, he told lawmakers: “I believe . . . whoever holds Alaska will hold the world.”

The U.S. has held that territory since 1867. But the broader Arctic region—rife with oil and natural gas reserves as well as precious minerals and rare earth elements—has only grown in importance. Ice sheets and glaciers are melting at an accelerating pace, transforming international shipping routes and drawing the attention of governments with no physical links to the area.

The growing geopolitical and environmental challenges in the Arctic are expected to boost activity in 2025 among the U.S., its allies and competitors like Russia and China and to increase investment in space-based ca-

Finland, Iceland, Norway, Russia, Sweden and the U.S. But Moscow’s 2022 full-scale invasion of Ukraine and ongoing war froze council relations and prompted two members—Finland and Sweden—to join NATO.

China is now filling an economic investment and technological cooperation gap in Russia’s Arctic zone. Last year, China and Russia operated warships together off the coasts of Alaska and signed an agreement to enhance joint maritime security cooperation.

Beijing has two permanent research stations in the region—one in Norway’s Svalbard archipelago and one in Iceland—and has declared itself a “near-Arctic state” despite being nearly 900 mi. south of the Arctic Circle.

In July, the U.S. Defense Department released its first official Arctic Strategy in five years, addressing the burgeoning challenges to warfighters operating in and through the region.

Neighbors Monitor Russia's Rearming of Iran

> SYRIAN GOVERNANCE ENTERS UNCERTAIN PHASE

> REPORTS SUGGEST IRAN AWAITS SU-35 ARRIVALS

Tony Osborne London

After more than a year of bloody conflicts across multiple fronts in response to a Hamas attack in Southern Israel in October 2023, events in Syria appear set to transform the regional landscape.

With the attention of Syrian allies Iran and Russia elsewhere, the militant group Hayat Tahrir al-Sham (HTS) took control of major cities and in a matter of days captured Damascus, sweeping aside Syria's fatigued armed forces and forcing President Bashar al-Assad to flee to Moscow, bringing an end to the decades-long al-Assad family regime.

Israeli airstrikes have disarmed Syria of combat aircraft and warships. HTS leader Abu Mohammed al-Jolani says he wants to rebuild the country after years of civil war, but there are fears that ungoverned spaces could become a breeding ground for new Islamist militant groups.

Meanwhile, full-scale war between Israel and Iran has been avoided, in spite of Israel broadening its conflict against Iran's proxies. Israel waged extensive attacks on Hezbollah in Lebanon, targeted Iranian officials in Syria and launched long-range strikes on Yemen's Houthis.

In response, Tehran launched one-way attack-drone, ballistic and cruise missile strikes on Israel, twice testing the country's multibillion-dollar aerial defense array. Ultimately, Iran's two attacks were ineffective, as Israel responded with focused strikes on Iranian air defenses. Concerns about the prospect of war between Iran and Israel prompted the U.S. to ramp up its presence in the region rapidly. Washington deployed numerous combat aircraft, including Boeing B-52 bombers to Qatar.

Israel has achieved some of its goals: It has killed many Hamas leaders, struck decisive blows against Hezbollah and perhaps proved that Iran's heavy investments in ballistic missiles have not been as effective as Tehran's leaders would like to believe.

Israel's approach, however, has stirred global anger at the relentless and often unscrupulous bombing campaign over Gaza, where tens of thousands of civilians have been killed and wounded.

International governments that supported Israel's initial campaign against Hamas have become uncomfortable with the daily death and destruction. Several have instituted arms embargoes; others have accused the Israeli government of genocide. And the International Criminal Court has issued arrest warrants that charge Prime Minister Benjamin Netanyahu and former Defense Minister Yoav Gallant with war crimes.

Elsewhere in the region, there is intra-Gulf state competition to secure a foothold in the Horn of Africa.

Concerns remain about Russia's rearming of Iran after Tehran lent its support to Moscow for the war in Ukraine. Reports suggest Russia could soon deliver Sukhoi Su-35 fighters to Iran, following the arrival of Yakovlev Yak-130 trainers last year.

Gulf Cooperation Council nations, though, are more than equipped to deal with an Iranian threat, as many have increased the size and sophistication of their fleets in recent years. Deliveries of Eurofighters to Qatar are close to completion; the final aircraft are expected in early 2025. Boeing F-15QA Advanced Eagles are soon to be delivered as well, after Doha decided to purchase 12 more aircraft to bring the fleet to 48.

Uncertainty surrounds deliveries of Boeing F/A-18E/F Super Hornets to Kuwait after political turmoil there delayed their arrival. Saudi Arabia is looking to acquire more fighters through an unusual open contest among the Eurofighter, Dassault Rafale and F-15EX.



Qatar's much expanded fighter fleet is almost complete with the arrival of the last Eurofighter Typhoons (pictured) and Boeing F-15QAs expected in 2025.

The Eurofighter is believed to be the favorite, but the competition is seen as a means for Riyadh to score entry into a next-generation fighter project. This could be the Global Combat Air Program of Italy, Japan and the UK, access to which would help to boost the kingdom's Vision 2030 initiative to diversify its economy away from oil. Reports suggest that Chinese fighters also may become more common in the region.

Having already obtained the Chengdu J-10, Pakistan has signed up to acquire the Shenyang J-35 from China. Reports have suggested, but not confirmed, that Egypt also may purchase the J-10.

Drones and air defense systems were on shopping lists, too. Iraq and Saudi Arabia purchased the South Korean Medium-Range Surface-to-Air Missile II (KM-SAM II) system in 2024.

Work to build Turkish-made Baykar Bayraktar Akinci uncrewed aircraft systems (UAS) in Saudi Arabia is expected to begin in 2025. The UAE, which has acquired the Bayraktar TB2 UAS, also has looked to its national defense industry to develop tactical armed systems.

Israel, meanwhile, has ordered additional Lockheed Martin F-35 Joint Strike Fighters and is set to become the latest customer for the enhanced F-15I Eagle. 🇮🇱

Europe Steps Up Defense Agenda

> EU DEFENSE WHITE PAPER IS DUE IN EARLY 2025

> LONDON IS POISED TO WRAP UP DEFENSE REVIEW

Tony Osborne and **Robert Wall** London

Even before President-elect Donald Trump returns to the White House and brings his expected influence on the war in Ukraine, Europe is anticipating several big decisions in the opening months of 2025 that will shape the region's defense ambitions and industrial prospects for years to come.

The European Union's new commissioner—combining defense and space in one portfolio for the first time—is calling for an acceleration of plans to bolster the region's security agenda. Germany, Europe's largest economy, is headed for general elections, and the UK is due to wrap up a strategic defense review that was requested by the government that took power in July. Both events are likely to shape the region's military policies.

The tone for European defense probably will be set early in 2025. The

new European Commission, which took office Dec. 1, aims to publish a white paper on the future of the region's defense within 100 days under Defense and Space Commissioner Andrius Kubilius, a former prime minister of Lithuania.

"Our defense spending must increase," European Commission President Ursula von der Leyen said as she took office for her second term. "We need a single market for defense. We need to strengthen the defense industrial base. We need to improve our military mobility. And we need common European projects on defense. . . . We have no time to waste. And we must be as ambitious as the threats are serious."

European governments have ramped up investment in defense in response to Russia's 2022 full-scale invasion of Ukraine. EU member states' defense

spending is now equivalent to around 1.9% of the EU's GDP, the European Defense Agency's Coordinated Annual Review on Defense stated in November, estimating that spending would rise to about €326 billion (\$345 billion) in 2024 and continue climbing.

The funding is helping to address capability shortfalls, particularly in munition stocks and air defenses, and to finalize long-delayed projects. While concerns remain that many nations are far from prepared for high-intensity warfare, the report says this will improve as spending rises.

The UK has pledged to lift defense spending to 2.5% of GDP; the time frame is expected to be clarified as part of the ongoing defense review. The review is likely to identify investment priorities as well as steps to free up money in some defense areas to bolster spending in others. London has disclosed plans to trim several programs, including reducing its fleet of Boeing CH-47 Chinooks, retiring its remaining Airbus Puma helicopters and phasing out the Thales Watchkeeper uncrewed aircraft system.

European government decisions also are due to crystallize the outlook

The Lockheed Martin F-35 is becoming increasingly common in Europe, as 13 nations either operate or have ordered the type. Portugal and Spain are expected to follow.



ROYAL NETHERLANDS AIR FORCE

European NATO Member Defense Spending Trends

for several of the region's key-stone combat aircraft programs, such as the Eurofighter Typhoon, Franco-German-Spanish Future Combat Air System (FCAS) effort and UK-Italian-Japanese Global Combat Air Program (GCAP). France has solidified plans for the Dassault Rafale, endorsing the development of the F5 standard with a new engine and other features. In December, Spain signed for a second batch of Eurofighters; Italy also wants to purchase another 24.

Germany has said it wants a top-up buy of 20 Eurofighters, too. That decision will need to be reconfirmed once a new government takes office following general elections early in the new year. The outcome could shape defense spending issues more widely, as the conservatives, currently leading in the polls, have indicated they may be ready to take on debt to increase defense spending and sustain support for Ukraine.

Lockheed Martin's F-35 has

NATO Country	2016		2024	
	Percent of GDP	Percent of Equipment Spend	Percent of GDP	Percent of Equipment Spend
Albania	1.10%	16.65%	2.03%	47.7%
Belgium	0.89	3.52	1.30	15.16
Bulgaria	1.24	1.03	2.18	31.89
Croatia	1.59	5.56	1.81	24.20
Czech Republic	0.95	6.53	2.10	37.86
Denmark	1.15	10.99	2.37	29.80
Estonia	2.07	22.15	3.43	33.74
Finland	1.42	13.68	2.41	45.75
France	1.79	24.64	2.06	28.36
Germany	1.20	12.94	2.12	28.75
Greece	2.40	8.17	3.08	36.07
Hungary	1.00	7.76	2.11	47.81
Italy	1.18	10.92	1.49	22.08
Latvia	1.44	7.55	3.15	36.92
Lithuania	1.48	14.06	2.85	21.17
Luxembourg	0.38	22.61	1.29	43.68
Montenegro	1.42	7.46	2.02	35.76
Netherlands	1.16	10.68	2.05	36.20
North Macedonia	0.97	5.92	2.22	29.33
Norway	1.73	20.42	2.20	29.99
Poland	2.00	18.84	4.12	51.13
Portugal	1.27	8.43	1.55	21.88
Romania	1.43	15.77	2.25	30.85
Slovakia	1.12	11.12	2.00	27.24
Slovenia	1.00	0.66	1.29	27.27
Spain	0.81	13.49	1.28	30.30
Sweden	0.97	40.47	2.14	33.99
Turkey	1.45	25.08	2.09	34.18
UK	2.09	22.82	2.33	36.09

Source: NATO

become the preeminent combat aircraft in Europe; two more nations, Greece and Romania, committed in 2024 to acquiring the type. There are few European nations left for Lockheed Martin to pursue. The only real prospects remaining are Portugal and Spain, and procurement of the F-35 is highly controversial in Spain. Top-up orders from existing customers are likely: The Netherlands already has placed two, and Italy is interested in following.

Poland also is poised to continue its shopping spree, as a decision on buying additional combat aircraft is pending.

Also on the agenda in the coming months are European efforts on advanced uncrewed combat aircraft. While those are part of the two flagship future combat aircraft architectures in Europe—the FCAS and GCAP—air force officials in France, Germany, Italy, the UK and elsewhere

have voiced interest in fast-tracking work on such systems.

Among the hottest items over the past two years in Europe have been air and missile defense equipment. Those purchases are showing little sign of slowing down and may be further spurred after Russia's strike in November on a Ukrainian rocket factory. The new conventionally armed, medium-range ballistic missile Russia fired seemingly carried multiple independently targeted re-entry vehicles.

In response to Moscow's use of ballistic and cruise missiles, several European countries have sought to develop and acquire ground-launched deep-strike weapons through the European Long-Range Strike Approach (ELSA) in a bid to deter Russian aggression. France, Germany, Poland, Sweden and the UK have signed up to ELSA, and the Netherlands wants to join them. 🌐



Eyeing Export Opportunities, Russian Military Aerospace Throttles Up

➤ TACTICAL COMBAT PRODUCTION HAS RECOVERED FROM 2021 LOWS

➤ THE R&D SPENDING SLUMP COULD SPELL TROUBLE FOR THE COUNTRY'S INDUSTRY

Piotr Butowski Gdansk, Poland

Irrespective of how the war in Ukraine unfolds in the coming months, Russia is set to ramp up military aerospace activities and reassert its position in the export market.

situation. Deputy Prime Minister Denis Manturov in September said that after prioritizing its own military needs, Moscow is ready to rebuild its export sector. "There is currently a

face of Western sanctions. Algiers could become the first export customer for Su-34E fighter-bombers.

Russia's military aircraft production has recovered from a low in 2021 and is set to advance in 2025. Tactical aircraft production fell to about 14 aircraft in 2021 but has bounced back to roughly 3-4 times that number.

Moscow's decision to strengthen its war economy is aiding that revival. Russia now spends about three times more on its military than it did in 2021. The country's 2025 draft budget calls for national defense to make up 33% of all federal budget expenditures and 6.3% of GDP, although external sources estimate that number to be more than 8% of GDP.

A big issue for industry is Russia's high inflation rate. That makes it hard for companies to take out loans to build the export equipment and then to service the loans before buyers receive and pay for that hardware. There are also longer-term concerns about Russia's ability to develop next-generation systems and remain competitive.

In Ukraine, Russia is betting on both high-end and lower-end equipment. It is set to increase use of the Su-57 fighter and, despite an early loss, the Sukhoi S-70 Okhotnik stealthy uncrewed aircraft system. Moscow is also upgrading the UMPK bomb wing kits that give its aircraft standoff distance from Ukrainian air defenses, reducing losses.

Russia is poised to expand serial production of advanced missiles it has used extensively to strike Ukraine, such as extended-range Kh-69 cruise missiles. Another tactical aircraft weapon that might soon enter serial production is the supersonic Kh-41 air-to-surface missile, a higher-speed and longer-range version of the Kh-31. Moscow also appears close to introducing into service an improved version of the Vypel R-77M medium-range air-to-air missile.

The Russia-Ukraine war is also pushing Moscow to maintain mass production of loitering attack munitions, decoys and similar low-cost systems to sustain its waves of attacks on its neighbor. The conflict and pace of aircraft use are driving readiness spending as well. According to United Aircraft Corp. financial reports, production of spare parts for aircraft increased 80% in 2023 and 92% in just the first half of 2024. 🌐



The Sukhoi Su-57's international air show debut at Zhuhai in China in November signaled Russia's rekindled export ambitions.

Russia paused most arms exports after its invasion of Ukraine in February 2022 turned into a prolonged conflict. But increased military aircraft production coupled with sustainable—albeit not trivial—aircraft losses are allowing the country to shift its focus abroad again, as evidenced by the Sukhoi Su-57 fighter's international air show debut in November at the China International Aviation & Aerospace Exhibition in Zhuhai.

Alexander Mikheyev, director of Russian arms export agency Rosoboronexport, said at the Zhuhai show that the first Su-57E export contracts have been signed.

Some analysts and Western officials argue that the poor showing of Russian equipment in Ukraine could hamper those export ambitions, but Moscow puts a different spin on the

huge demand in the world for our military products that have been tested in real combat operations," he told a local newspaper.

Russian export efforts likely target countries that have backed its war in Ukraine, including China, Iran and North Korea. According to one observer, North Korean pilots are already in Russia learning to operate new combat aircraft.

Iran said in November 2023 that it planned to buy Sukhoi Su-35 fighters, Mil Mi-28 attack helicopters and Yakovlev Yak-130 jet trainers. The first trainer aircraft are already in the country, although the status of the remaining deliveries is uncertain.

Algeria, historically a top purchaser of Russian military hardware, could represent a test case of whether Moscow can regain export momentum beyond its closest war partners in the

Russia's 2025 Planned Defense Spending

\$127.7 billion
6.6% of GDP

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People To Watch



Mehmet Demiroglu

CEO of Turkish Aerospace Industries (TAI)

The new leader takes over TAI as it enters a critical period to bring the country's flagship Kaan fighter program to reality and pursues international opportunities with the Hurjet trainer.



Gen. Wang Houbin

Commander of the Chinese Army Rocket Force

China in September conducted the first ICBM test over the Pacific in more than two decades, signaling that the new leader—reportedly put in place because of corruption in the force—is trying to test the service's readiness. The general's advice on the preparedness of China's strategic and tactical missile forces could be instrumental in guiding President Xi Jinping's actions on Taiwan and the region more broadly.



Andrius Kubilius

European Commissioner for Defense and Space

The European Union's first commissioner for defense and space has been tasked with quickly developing a plan to bolster the bloc's defense industrial base and drive member states to cooperate more closely. Kubilius is calling for a "big bang" approach to address European military capability

TOP TO BOTTOM FROM TOP LEFT: TURKISH AEROSPACE INDUSTRIES, ZEYNURBABA/GETTY IMAGES, EUROPEAN COMMISSION, U.S. AIR FORCE, ELBIT SYSTEMS, ZUMA PRESS INC./ALAMY STOCK PHOTO, U.S. DEFENSE DEPARTMENT, NATO, BRYAN VAN DER BEEK PHOTOGRAPHY/AIRBUS, NORTHROP GRUMMAN

needs and has warned that "time is very limited" for the region to address them.



Maj. Gen. Joseph Kunkel

U.S. Air Force Director of Force Design, Integration and Wargaming

The service is drafting a sweeping strategic blueprint known as Force Design. The goal is to roll out a blueprint in 2025 that could shape deployment plans and equipment needs.



Bezhalet Machlis

Elbit Systems CEO

Elbit is trying to ramp up production to support Israel's war requirements and the needs of export customers while also driving an innovation agenda that includes taking a leadership position in directed-energy weapons. The first Iron Beam, being developed with Rafael, is due for delivery in 2025.



Masami Oka

Nominated to be Chief Executive of the Global Combat Air Program (GCAP) International Government Organization (GIGO)

The former Japanese vice defense minister will take the lead of GIGO as it issues the first global contract for the GCAP fighter's full-scale development, expected in the summer of 2025.



U.S. Navy Adm. Samuel Paparo

Commander, Indo-Pacific Command

A U.S. military command typically lasts for three years. Few could be

more consequential than Paparo's term in Asia that began in May. Paparo must manage the military response to China's approach to Taiwan and neighbors in the South China Sea through at least 2027, when the People's Liberation Army seeks to be ready to launch an invasion.



Mark Rutte

NATO Secretary General

The former Dutch prime minister will face the challenging issue of balancing European interests in continuing to support Ukraine with a stated desire by the incoming Trump administration to end the conflict abruptly, as well as possible disagreements over financial commitments to defense.



Michael Schoellhorn

Airbus Defense and Space CEO

After a long period during which Airbus earnings were dented by the A400M airlifter and more recently the space program, Schoellhorn needs to demonstrate that those problems are behind the company. He also must manage the tricky relationship with Dassault over the Future Combat Air System cooperation among France, Germany and Spain.



Kathy Warden

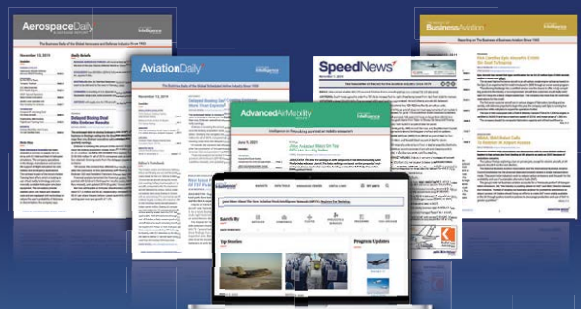
Northrop Grumman CEO

Warden pulled Northrop Grumman out of the U.S. Air Force Next-Generation Air Dominance (NGAD) program before it was derailed. In 2025, big decisions loom for the company over the size of the B-21 bomber program, Sentinel ICBM recertification, U.S. Navy F/A-XX fighter competition and, possibly, a decision on whether to reenter a revised NGAD competition. 🌐

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ANALYSIS

Next F-35 Upgrade Unfolds

Steve Trimble Washington

A BUSY AGENDA AWAITS THE

Lockheed Martin F-35 program in 2025. The building blocks for the next major round of upgrades will be set, paving the way for big advances in air warfare systems throughout the 2030s. The program also will rush to put orders, deliveries and testing back in order, while facing fresh scrutiny from newly empowered voices in President-elect Donald Trump's orbit.

A new round of upgrades may seem premature while the F-35 program struggles to deliver the full capabilities promised in the Block 4 follow-on modernization contract. But the requirements are already locked in for Block 5

The higher electric power demands of an onboard defensive laser help explain a new set of upgrades scheduled to enter development in 2025.

Lockheed expects to select a contractor to deliver the Power and Thermal Management Unit (PTMU) by the early 2030s. The candidates are the Collins Enhanced Power and Cooling System and the Honeywell Power and Thermal Management System. The winner must deliver a system with the capacity to handle up to 80 kW of heat shed by the F-35's electronics, a 150% improvement over the Block 3 requirement. The maximum cooling level for the PTMU far exceeds the 47-kW requirement for Block 4 electronics, underscoring the higher power output set for the Block 5 standard.

One feature that will not be part of the Block 5 standard is a brand-new engine. Instead, Pratt & Whitney plans to finalize in 2025 the design of the F135 Engine Core Upgrade (ECU), a higher-thrust modification selected over a proposal to reengine the F-35 with the GE Aerospace A100 or Pratt & Whitney A101. Both alternatives feature the ability to adjust the volume of fuel-efficiency-boosting bypass air during flight. But the improved version of the F135 is scheduled to enter service in 2032.

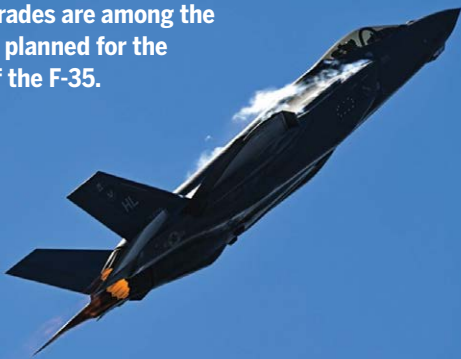
As the PTMU and ECU advance through early development, F-35 program officials face increasing pressure to deliver all Block 4 capabilities. The Joint Program Office (JPO) had expected Block 4 avionics to run on the 40P01 software baseline by the end of July 2023.

But development delays forced the program to halt all deliveries during the first half of 2024. Lockheed started delivering jets with software limited to training roles. A version of the code certified as combat-rated is scheduled for delivery by 2025. At that point, Lockheed can turn its focus to completing the rest of the Block 4 electronic upgrades, including an improved electronic warfare suite and the new Northrop Grumman APG-85 radar for U.S.-owned F-35s.

As the new upgrades flow into production, Lockheed is struggling to meet JPO cost expectations. Negotiations over prices for F-35s ordered in Lots 18 and 19 remain deadlocked, with Lockheed officials now expecting to operate under an undefinitized contract while talks continue.

The incoming administration could have mixed feelings. While Trump often praised the F-35 during his first term, hailing its "invisible" qualities, his advisors often seemed critical. Christopher Miller, the last acting defense secretary in the first Trump administration, insulted the F-35's capabilities with a rude expletive while still in office. Automotive and space entrepreneur Elon Musk, now a top advisor to Trump on a government reform plan, wrote on his social media platform X in late November that the F-35 was designed by "idiots" and should be replaced with drone swarms. 🤖

Defensive lasers, new weapons and power and cooling upgrades are among the new capabilities planned for the next standard of the F-35.



CAPT. NATHAN POBLETE/U.S. AIR FORCE

upgrades set to begin arriving after fiscal 2029. A contract awarded in 2023 calls for Lockheed to launch "initial Block 5 work," according to the F-35 selected acquisition report released by the Pentagon in October.

Details of the Block 5 plans are sketchy, but the overall goal is clear. The Block 4 upgrades focused on updating the F-35's electronics, sensors and software to modern standards while expanding the list of munitions the fighter can carry. The Block 5 program seeks to introduce new technologies onto any fighter and finally address the thrust, power and cooling shortfalls of the current configuration.

A prime example of the Block 5 program is a defensive system upgrade. A laser countermeasure system capable of jamming an infrared guided missile or perhaps destroying any incoming missile could be installed on a fighter for the first time.

Northrop Grumman revealed a company-funded program a decade ago to install such a capability on the F-35 Block 5. The proposed Threat Nullification Defensive Resource (ThNDR) includes a laser, beam-steering and a low-observable window. When it was unveiled in 2013, Northrop officials described ThNDR as more powerful than other directed infrared countermeasures, aiming to defeat a wider array of threats than heat-seeking missiles.

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ON HOLD

Adjusting the size of a future U.S. tanker could influence the design of a next-generation fighter.

- > STALLED U.S. FIGHTER PROJECTS SEEK BUDGET AND DESIGN CLARITY
- > POLITICAL AND ORGANIZATIONAL CHANGES INFLUENCE DEBATE
- > FLEXIBILITY PRIZED OVER SPECIALIZATION AND DURABILITY

Steve Trimble Washington

The plan seemed clear enough at the beginning of 2024, even if most of the details stayed classified. U.S. Air Force leaders would select a contractor around midyear to start developing a new air superiority fighter. Their Navy counterparts likewise would stay on track to pick a winning design for a new carrier-based fighter in 2025. After a decade of studies, prototypes and competition, the successors for the Lockheed Martin F-22 and the Boeing F/A-18E/F would finally fall into place.

To paraphrase the late Dinah Washington: What a difference a year makes.

The Navy was the first to blink. The Pentagon's long-term spending proposal submitted to Congress in March disclosed a staggering 67% cut for the F/A-XX program. Three months later, the Air Force halted the source selection process for the Next-Generation Air Dominance (NGAD) Platform. Facing new concerns about the program's proposed costs, the Air Force launched a sweeping review, challenging original assumptions about costs and threats. Then, instead of wrapping up that review by the end of 2024 as planned, Air Force leaders punted the final decision until after the inau-

guration of President-elect Donald Trump on Jan. 20.

Both programs—pursuing the first new U.S.-built, crewed jet fighters since the Lockheed F-35 entered development 23 years ago—will start 2025 with a starkly different outlook, clouded by uncertainty amid national political turnover in the White House and Senate as well as internal organizational change within the Air Force.

Similar questions hang over the Air Force's Collaborative Combat Aircraft (CCA) program, which aims to field autonomous fighters to operate jointly with crewed aircraft or independently. General Atomics Aeronautical Systems Inc. and Anduril Industries plan

to fly prototypes of the Gambit and Fury, respectively, in 2025 for Increment 1 of the program. But so far, both companies expect only a handful of orders to support a flight-test campaign. Decisions about the first batch of follow-on production for Increment 1 aircraft loom in 2026.

But the Air Force's concept is broader than merely buying one type of CCA. Following a model established by the Space Development Agency's incremental approach to procuring multiples of different satellites in 2-3-year tranches, the Air Force plans to acquire a diverse portfolio of autonomous fighters, with each increment optimized for different roles. Requirements for an Increment 2 series of CCA prototypes are in the works. If the Air Force follows the two-year pattern, contracts should be awarded in the spring, but it is not yet clear if the requirements are set.

The outcome of decisions made in 2025 for both programs will carry enormous risks for the future of the tactical aviation fleet. For more than a decade, a succession of Air Force leaders agreed to retire hundreds of

LOCKHEED MARTIN

fighters and reinvest the savings in the modernization budget, including the NGAD program. The strategy accepted lower combat capacity levels today in exchange for receiving advanced capabilities in the future. The Air Force can ill afford a result that eliminates or reduces those future capabilities while ignoring the erosion of capacity.

Meanwhile, the defense industry is waiting for answers. To keep design teams for the NGAD platform competitors intact, the Air Force extended technology maturation and risk reduction contracts for Boeing and Lockheed Martin. The same companies, along with Northrop Grumman, await a resolution to the Navy's budgeting shortfall for the F/A-XX. All three defense industry giants are expected to compete with smaller companies, such as General Atomics and Kratos, and Silicon Valley-backed rivals, such as Anduril, for the next round of CCA contracts.

The current indecision coincides with—or perhaps provoked—a range of outsider proposals. Elon Musk, the automotive and space launch entrepreneur Trump has tasked to recommend government streamlining options, tweeted on Nov. 25 that “some idiots are still building manned fighter jets like the F-35” and “manned fighter jets are obsolete in the age of drones.” Although his remarks targeted the F-35, the criticism applies equally to the NGAD platform and F/A-XX concepts, both of which are designed to be operated by humans on board.

Sen. Mark Kelly (D-Ariz.), a former Grumman A-6E pilot and NASA astronaut who currently chairs the Senate Armed Services Committee airland subcommittee, has made another provocative proposal. At the Reagan National Defense Forum Dec. 7, Kelly told Aviation Week that he inspected the candidates for the Air Force's classified NGAD platform and found “some really exciting things about it.” But he is skeptical of plans to acquire separate aircraft types for the Air Force and Navy. Kelly prefers the model of the F-35 program, with a common design adapted for the unique requirements of both services.

“I would ultimately like to see—and I've stressed this to the Air Force and the Navy—that when we consider what we build next, we do what we did with the F-35, with a caveat to that,” Kelly said. “It helps if we can jointly

build whatever the next system is. I think that would be a positive thing.”

So far, Air Force and Navy design choices offer little commonality. The Navy's F/A-XX, for example, will be powered by adapting a turbofan engine that is in production today. The Air Force's original requirement for speed and range, in contrast, called for developing a new engine capable of adapting the volume of bypass airflow midflight, using the GE Aerospace XA102 and Pratt & Whitney XA103 demonstrators funded by the Next-Generation Adaptive Program.

In another divergence from the Air Force's indecision over NGAD platform costs and requirements, Navy

for future aircraft. The Air Force activated the provisional Integrated Capabilities Command in September.

The new organization creates a clearinghouse for adjudicating overlapping requirements among Air Force Global Strike Command's bombers, Air Mobility Command's tankers and airlifters and Air Combat Command's fighters. Making a next-generation, stealthy tanker larger to carry more fuel, for example, could enable a future fighter to be smaller, since it would need to carry less gas.

The fate of any future Air Force aircraft also faces a far-reaching shift in design preferences. Air Force Chief of Staff Gen. David Allvin has called

The first wave of autonomous fighters remain in the prototyping stage, but serial production could begin in 2026.



AIR FORCE RESEARCH LABORATORY

leaders remain confident in the design and affordability of the future F/A-XX fighter. Moreover, requirements for the NGAD platform emerged from the Air Force's Penetrating Counter-Air concept, which called for a highly specialized design with the stealth, speed and endurance to sweep for enemy fighters deep inside contested airspace. Conversely, the Navy's requirements prioritized a multirole strike fighter with the endurance for long-range strike missions and ability to defend the carrier battle group from air and missile attacks.

But the extended Air Force review is challenging those original assumptions for the NGAD platform. The studies continue even as a wider reorganization revamps the service's internal process for setting requirements

for the end of platforms that are “built to last” for decades, which come with a costly and time-consuming approach to completing modifications and upgrades. Allvin instead wants future aircraft to be “built to adapt.” The design might not yield a fighter meant to fly for generations, but it could be swiftly altered as technology advances and new capabilities and threats arise. Allvin's preferred approach, if fully embraced, could result in a very different design for the NGAD platform in 2025. 🌐

—With Brian Everstine
in Simi Valley, California

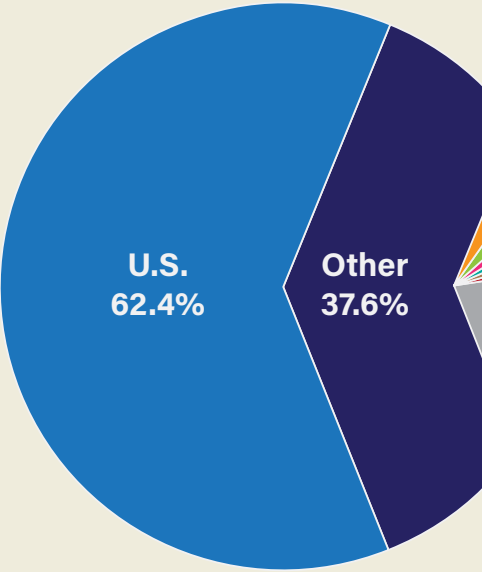
Gallery See more about defense sector developments in 2024: [AviationWeek.com/Defense2024](https://www.aviationweek.com/Defense2024)



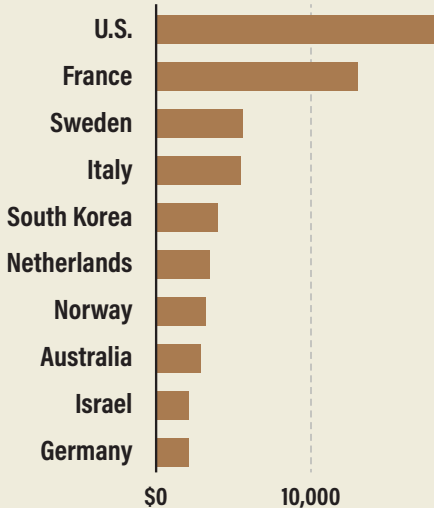
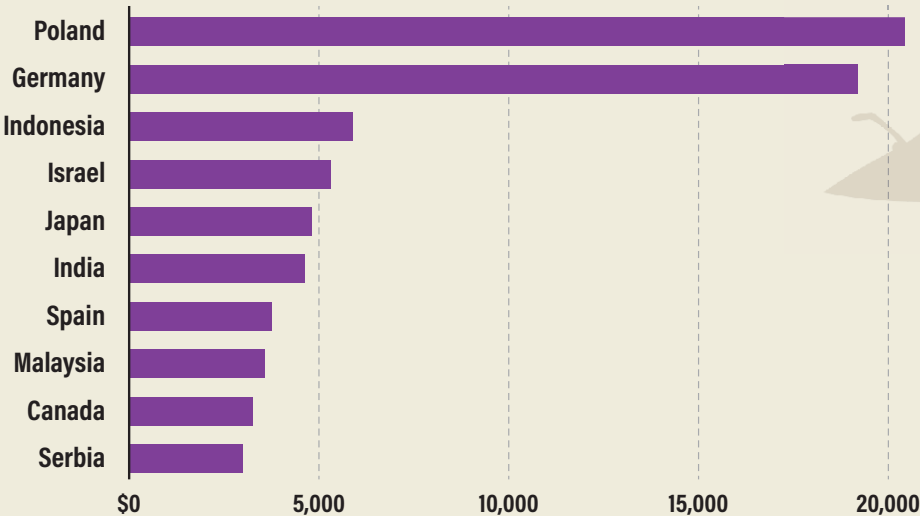
NEW THREATS BOOST AIRCRAFT DEMAND

Elevated global defense spending continues to drive a robust market for military aircraft, particularly in Europe and East Asia, with more than \$1 trillion expected to be spent on new and upgraded military aircraft in the next 10 years. Modernization plans have accelerated, and the increase in resources is allowing air forces to assess where capabilities can be expanded. With budgets still being built up, further requirements could emerge as governments reassess their airpower capabilities against a new range of threats, refocusing on survivability, mass and resilience. The clearest indicator of this shift in thinking is the rising importance of collaborative combat aircraft. Almost 700 are expected to be delivered in the next decade. Nevertheless, while collaborative combat aircraft account for almost 10% of the \$200 billion in open opportunities in the market in 2025-34, crewed fighter aircraft still dominate, with more than \$60 billion in unmet requirements identified over the same period.

Destination of U.S. Military Aircraft Sales, 2025-34

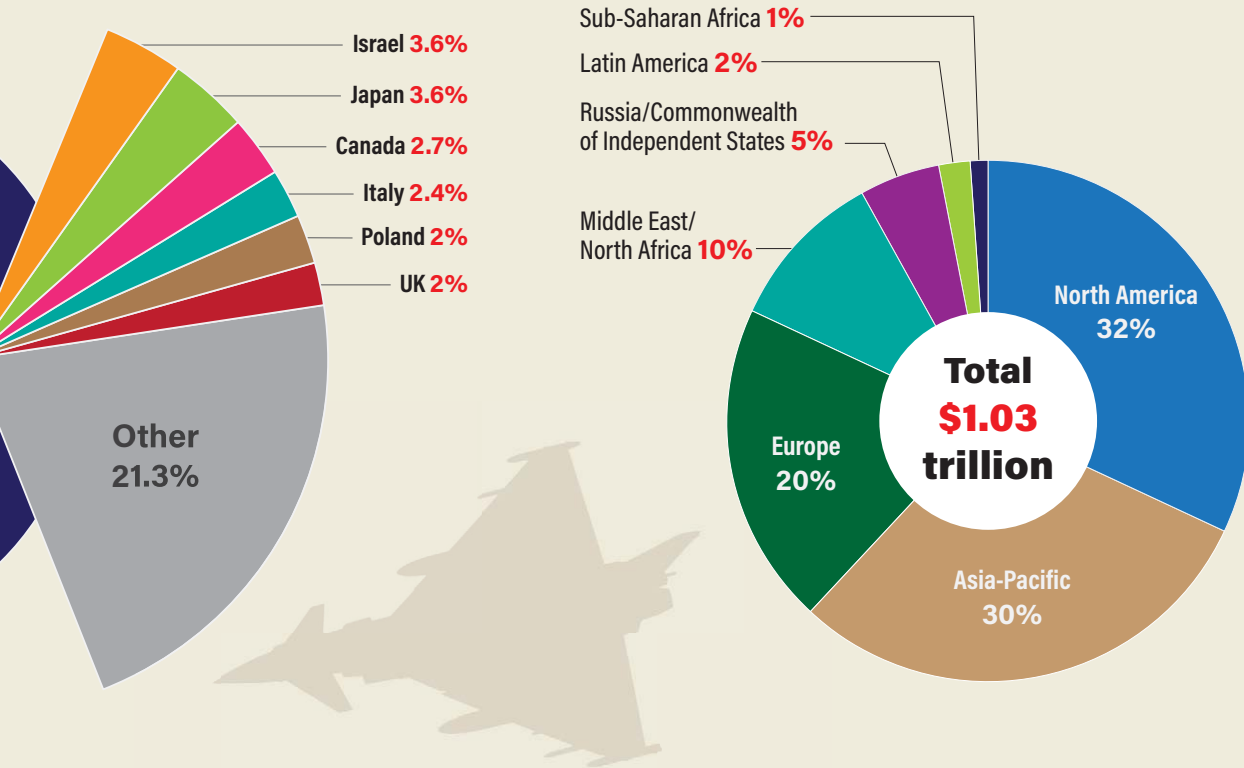


Top 10 Importers (U.S. \$ Millions)



Source, all charts: Craig Caffrey/Aviation Week Defense Market Analyzer

Value of Military Aircraft Deliveries, 2025-34

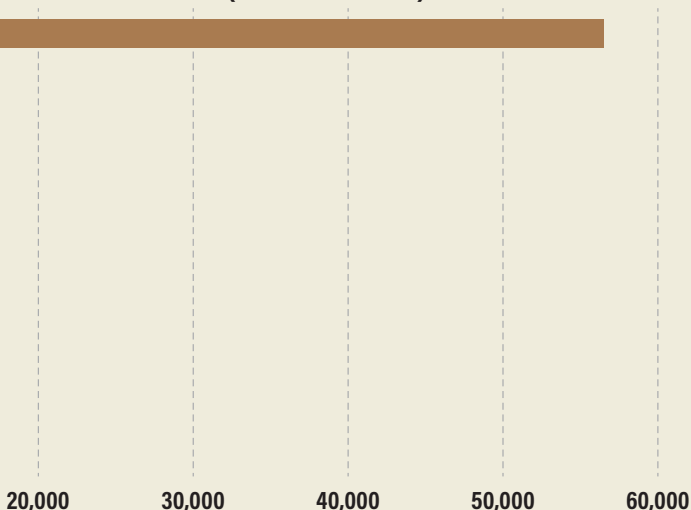


DEFENSE CONTRACTING SHIFTS

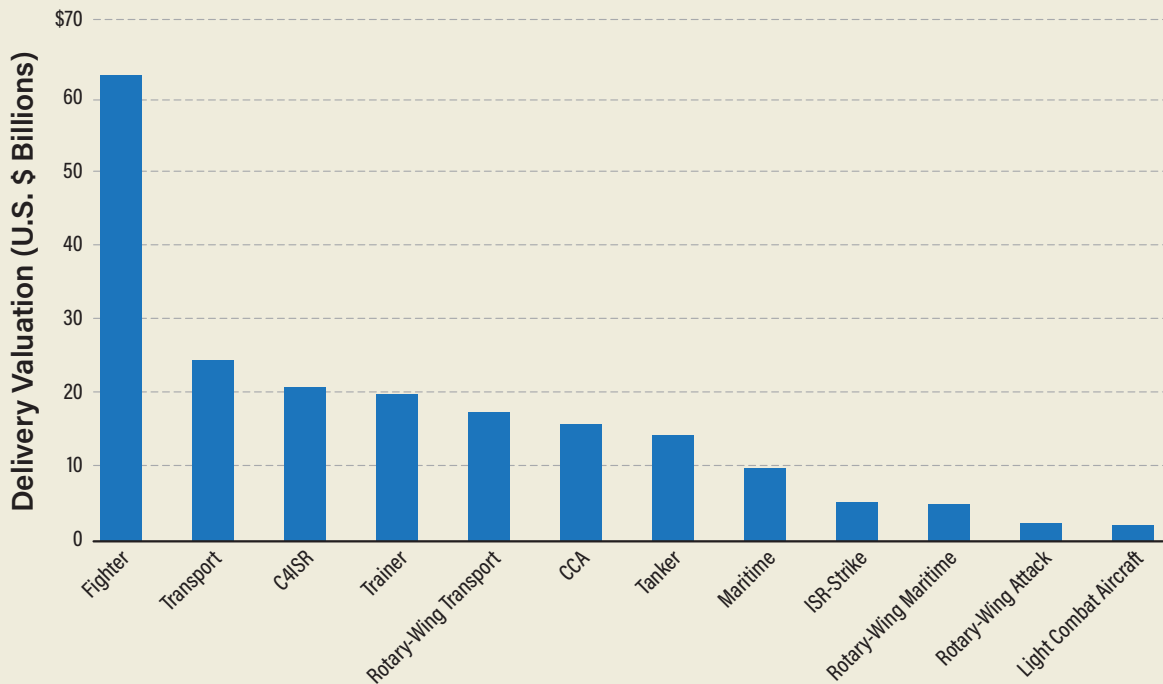
In 2024, Aviation Week tracked more than 1,300 major defense contracts finalized by governments around the world worth over \$400 billion. Air platforms represented the largest

market segment by value, accounting for nearly one-third of the total and marking a return to pre-2023 trends, when weapon systems temporarily became the dominant segment. European military modernization continues to be a key market driver; Poland and Germany emerged as the top global importers of defense systems in 2024, displacing more traditional leaders, such as Saudi Arabia and Qatar. Land platforms and weapon systems have been a key focus within this drive, accounting for 17% and 25% of the value of European defense contracts, respectively. Globally, these categories represented only 8% and 22%, respectively, of contracts by value. This shift underscores Europe's urgent response to the threat from Russia, with an enhanced emphasis on reinforcing conventional defense capabilities and highlighting the evolving defense landscape across the continent. A key beneficiary of the booming European market has been the U.S., which is expected to finalize more than \$100 billion in Foreign Military Sales in 2024; Aviation Week tracked more than \$56 billion in major new contracts during the year.

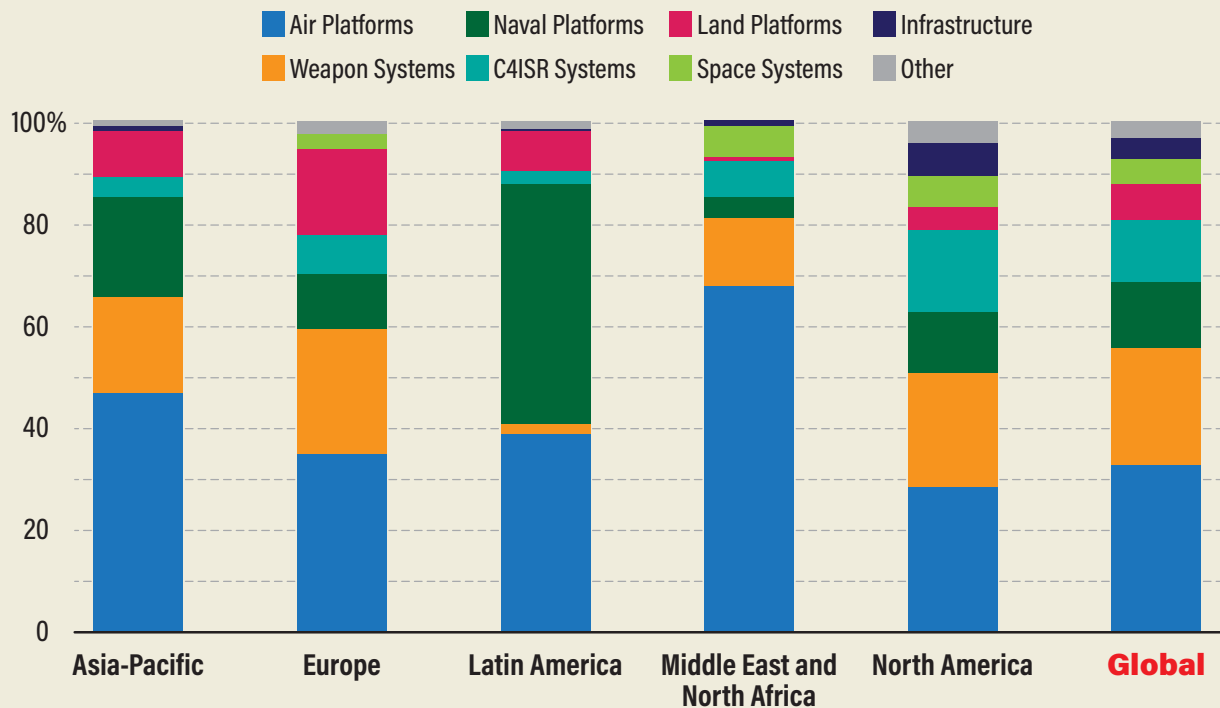
Top 10 Exporters (U.S. \$ Millions)



Open Opportunities by Mission Segment, 2025-34



Contracts by Segment and Region



Source, all charts: Craig Caffrey/Aviation Week Defense Market Analyzer



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SIEMENS

MILITARY AIRCRAFT COMPETITIONS

The Aviation Week Intelligence Network is tracking **\$193 billion in open opportunities for military aircraft over the next decade**. In that time frame, more than 15,500 new aircraft are due to be delivered to armed forces around the world.

One of the biggest expected to be decided in the coming year is the U.S. Navy's F/A-XX competition to replace the Boeing F/A-18.

Matt Jouppi



NAVEEN SHARMA/SOPA IMAGES/ZUMA WIRE/ALAMY LIVE NEWS

FIGHTERS

Competitions for fighter aircraft represent a market opportunity worth \$63 billion over the next decade. The lion's share of potential deals—\$24.8 billion—comes from the Middle East.

U.S.

After reviewing plans for the Next-Generation Air Dominance program to replace the Lockheed Martin F-22, the **U.S. Air Force** has punted the decision to the Trump administration. Source selection is still expected in 2025 for the Navy's F/A-XX despite a 67% cut to the program's budget.

INDIA

The **Indian Air Force** reportedly has been preparing a request for proposals for its Multi-Role Fighter Aircraft tender to be ready by mid-2025 or early 2026. Source selection is expected in 2026 or 2027. India's defense ministry, however, has been urging the service to prioritize indigenous equipment such as the Tejas Mk. 1A.

POLAND

Warsaw originally intended to buy two squadrons of air superiority aircraft (either the Boeing F-15EX or Eurofighter Typhoon) but is now considering the multirole Lockheed Martin F-16 Block 70 and F-35. Source selection is expected in early 2025. Poland also has shown interest in the Korea Aerospace Industries KF-21.

TRAINER/LIGHT COMBAT AIRCRAFT

Militaries are looking to buy \$21.6 billion in trainer and light combat aircraft through 2034. Egypt, with a 100-aircraft program valued at \$2.9 billion, represents the biggest market opportunity.

EGYPT

The **Egyptian Air Force** is evaluating replacements for its Dassault/Dornier Alpha Jets and Hongdu K-8s advanced jet trainers (AJT). Warming ties between Rome and Cairo may grant the Leonardo M-346 an advantage, while Korea Aerospace Industries (KAI) has been keen to offer local assembly work for the state-owned Arab Organization for Industrialization.

U.S.

The **U.S. Navy** seeks 145-200 Undergraduate Jet Training System AJTs to replace its aging McDonnell Douglas T-45s, but has delayed the contract award to fiscal 2028. Competitors include the KAI-Lockheed Martin TF-50N, Boeing T-7B and Leonardo-Textron M-346N.

INDIA

By the end of 2025, the **Indian Air Force** plans to replace its Hindustan Aeronautics Ltd. (HAL) HJT-16 Kiran intermediate jet trainers (IJT). The new aircraft would transition cadets from the HTT-40 basic flight trainer to the BAE Hawk. HAL's HJT-36 completed spin testing in 2022 but has yet to receive orders. The company also has proposed its HLFT-42 supersonic conversion trainer.



PAKISTAN

Islamabad is looking to replace its legacy K-8 and Cessna T-37 advanced flight trainers. Pakistan was reportedly in negotiations in November 2023 to acquire Hongdu L-15s from China for lead-in fighter training, which would complement its twin-seat Chengdu Aircraft Corp./Pakistan Aeronautical Complex JF-17Bs.

SPAIN

The **Spanish Air and Space Force** says it is looking at four existing AJT options and a possible new design to replace its Northrop F-5s around 2030. Airbus offered its Future Jet Trainer previously but is now partnering with Leonardo on the M-346, competing against the Boeing T-7A, KAI T-50 and Turkish Aerospace Industries (TAI) Hurjet.

ROTARY-WING ATTACK AIRCRAFT

The attack helicopter market is expected to reach \$2.4 billion over the next 10 years, with opportunities largely in Europe, the Middle East and North Africa.

BANGLADESH

The country's Forces Goal 2030 plan calls for acquiring attack helicopters. Bangladesh reportedly has considered the Boeing AH-64E, Eurocopter Tiger, Mil Mi-28NE and TAI T-129B. However, civil unrest that toppled the Sheikh Hasina government in August is likely to delay the tender.



MIQUEL MEDINA/GETTY IMAGES

MYANMAR

Since at least 2021, Myanmar has been interested in augmenting its fleet of eight Mil Mi-35P attack helicopters. As the junta is engaged in genocide against its Rohingya minority and a war against a broadly pro-democracy insurgency, Western arms embargoes limit options to Chinese or Russian aircraft.

UKRAINE

The country will need to replace its Mil Mi-24 fleet eventually with a Western alternative and has requested secondhand Bell AH-1Zs. The AH-64E would be ideal but is expensive. Leonardo may pitch its AW249. Any replacement is unlikely to materialize until hostilities with Russia conclude and then will be contingent on available funding.

ALGERIA

The longtime operator of Mi-24s upgraded to the Super Hind configuration by Advanced Technologies and Engineering will need to replace them in the next few years. In 2016-19, Algiers acquired 42 Mi-28NEs. Procurement of more Mi-28s would be sensible to replace the Mi-24s, and Russia is Algeria's primary security partner.

UNCREWED AIRCRAFT

The drone market has been growing rapidly and is set to reach \$27 billion through 2034, with most of the expenditure driven by Pentagon demand. More than 1,800 uncrewed aircraft systems (UAS) are to be delivered over the decade.



BAYKAR

ISRAEL

The country is almost certain to launch a major UAS recapitalization program by the end of the forecast period, as much of its fleet has been in service since the early 2000s. In October, a leaked U.S. intelligence document discussed the fielding of a low-observable long-range UAS, designated "RA-1," that enabled covert surveillance of Iran.

U.S.

The **U.S. Air Force** is looking to acquire at least 1,000 Collaborative Combat Aircraft (CCA) over at least three increments fielded in two-year cycles starting in fiscal 2028. Anduril's Fury and General Atomics Aeronautical Systems Inc.'s Gambit are the Increment 1 winners. The service is working to define its goals for the next iteration, subject to a review by the Trump administration.

TURKEY

Ankara is expected to field a fleet of CCA by the 2030s to complement the indigenous TAI Kaan fifth-generation fighter. Both the TAI Anka-3 and Bayraktar Kizilelma are undergoing flight testing.

TRANSPORT AND TANKER AIRCRAFT

The market in this segment is expected to reach \$38 billion, led by demand in North America, although Asia-Pacific buyers are not far behind.

SAUDI ARABIA

The country is looking to acquire 33 medium transports to replace its fleet of 43 Lockheed C-130Hs. In 2012, the Pentagon disclosed the potential sale of 20 C-130Js and five KC-130Js worth \$6.7 billion, but Riyadh ordered only two KC-130Js. Lockheed Martin is again offering the C-130J against the Embraer C-390 and Airbus A400M.

INDIA

The **Indian Air Force** is looking to replace some 100 Antonov An-32 light and 17 Ilyushin IL-76 heavy transports. The service issued a request for information in December 2022 seeking 40-80 transports with an 18-30-ton capacity. Competitors include the C-390, C-130J and A400M.

ITALY

Rome is seeking six tankers after rejecting a sole-source acquisition of Boeing KC-46As following its purchase of Boeing KC-767s. A Boeing representative tells Aviation Week the sale collapsed on industrial grounds rather than service requirements. Airbus plans to offer the latest variant of its A330 Multi-Role Tanker Transport.



DASSAULT AVIATION

SPECIAL MISSION AIRCRAFT

Market opportunities for these diverse aircraft types are set to reach a value of \$24 billion.

FRANCE

The **French Navy** is looking to replace its Dassault Atlantique fleet in 2030-40. Airbus is offering a modified A321XLR maritime patrol aircraft and Dassault a Falcon 10X derivative. Source selection is expected by 2026. The competition effectively supersedes the defunct Franco-German Maritime Airborne Warfare Systems program.

SOUTH KOREA

The **Republic of Korea Air Force** seeks four more airborne early warning and control aircraft by 2031 to complement its four Boeing E-7s. Seoul's defense procurement agency reportedly has been "struggling" in negotiations with Boeing over higher-than-expected costs. Additional contenders include the Saab GlobalEye and L3Harris-Korean Air Global 6500 CAEW.

SAUDI ARABIA

U.S. Air Force officials in August 2022 confirmed that Saudi Arabia had expressed interest in the Boeing E-7A. The **Royal Saudi Air Force** is undertaking a two-phase Boeing E-3 midlife update program worth \$2 billion. However, other E-3 operators, such as the U.S. and UK, have opted to retire their aircraft due to high operating and support costs. ☞



Tony Nicoli
Aerospace Senior Director
Siemens

Going forward confidently with speed: How Siemens is accelerating the design process

Q AW: What are the most challenging areas of design the A&D industry faces?

A Tony Nicoli: We see three prominent challenges when it comes to A&D design. The first is traceability of requirements, meaning ensuring that the design meets the requirements of the regulating authority and there is documented evidence. The second challenge is the communication of downstream and upstream changes between the program disciplines, i.e., engineering, software design, etc. – typically, when organizations get the “go-ahead” on a program, they don’t work in sequence; they work in parallel which creates risks of rework or escapes when changes occur and impacts to dependencies are not communicated. The last challenge is accelerating the development process – everyone wants to take on the most challenging missions, cutting-edge programs, and the like while being cost-effective and maintaining compliance. This means automating the routine systems that have been in place for decades so you can unleash people’s ability to focus on those things at the edge, where the actual development happens.

Q AW: Siemens is known as a leader in digital transformation and digital information systems. What is its approach to overcoming these challenges?

A TN: Over the last five years, we have successfully demonstrated our multidisciplinary design and optimization (MDO) approach, which leverages digital twin and digital thread technologies with tools and services from the Siemens Xcelerator business platform. It effectively removes the silos between program design and integration teams

by enabling access to a digital twin environment – that is connected by a digital thread - so they can validate design performance without it making a material impact on the program, thus generating faster, more iterative optimization. We want to create a reliable, single source of truth among the design team and create a digital twin of that “truth” so that teams can more quickly and efficiently iterate and evolve dynamic designs while having the context of the surrounding subsystems and components

For example, if Team A makes a design change, they can test and validate it in an environment where the other teams can see how the change will impact them well before it’s finalized. This increases communication and collaboration and minimizes rework and escapes that can cause material issues like program delays and financial implications.

Increased collaboration among design teams has enabled them to perform detailed analyses faster and earlier in the design process, which we’ve seen result in approximately a 25% decrease in detailed structural design time, a 30-50% reduction in analysis time, and more efficient use of engineering staff.

Q AW: Can you walk us through an example?

A TN: Our work on the Angel Owl drone is a great example. The systems engineer and the EE architect needed to integrate the new infrared camera capabilities. The team validated the new camera and software components against the mission requirements, ensuring complete test coverage for the new requirements. From

there, they imported the system functions into Capital Systems Architect to analyze the impact on CPU, memory, and network demand. Based on those results, they were able to update the network architecture to add a new network carrier and allocate the camera data to it to stay within bandwidth limits. That led to the generation of updated ICDs to reflect the changes needed for the electrical distribution system integration.

Q AW: How did this impact other members of the team?

A TN: In this case, the network engineer could implement the network changes quickly and confidently. Uploading the proposed network architecture changes from the systems architect, they added the new Ethernet bus and signals to the topology, ran a network consistency check, addressed errors, and automatically routed the messages between the LRUs. From there, they used virtual link synthesis to find the optimal and redundant paths and verified that the timing requirements were met, and the bus load was under the 80% target.

Q AW: What benefits did the automated software generation and testing provide in this scenario?

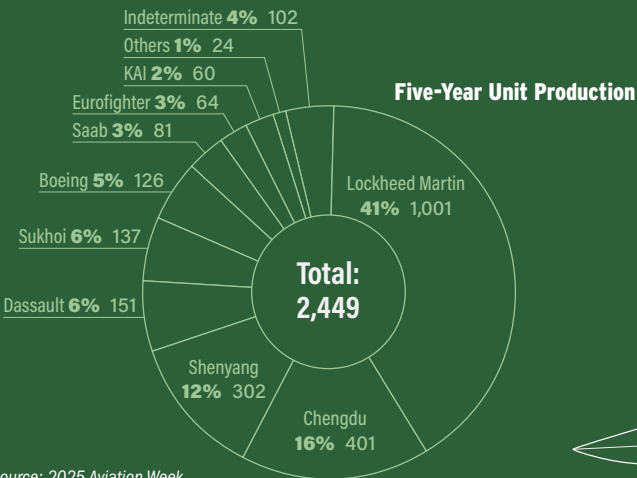
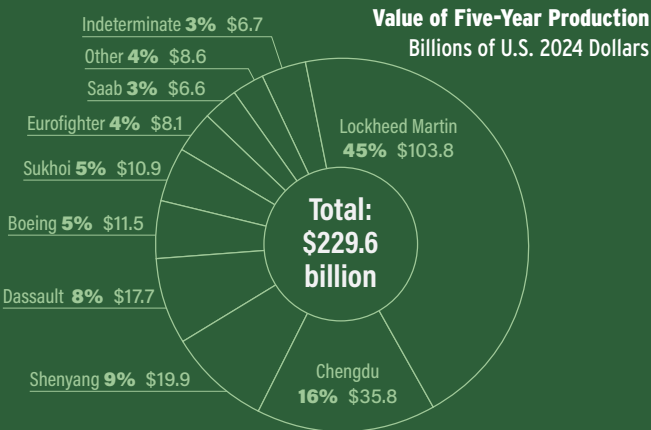
A TN: It goes back to the challenges I outlined earlier in our discussion. With software generated directly from the UML models, they were able to ensure traceability to the system requirements. They were also able to communicate and coordinate development quickly with external teams. By embracing automation, integration testing caught issues early, resulting in first-pass success.

Q AW: What would you tell an organization that might be hesitant to adopt this approach?

A JB: Adopting anything new can feel overwhelming, but we work closely and intimately with our customers on this journey. From the beginning, we are there to help assess and identify risks within their processes and determine where MDO can deliver early results. Siemens moves you forward incrementally, where you get gains every quarter, every year, and you've suddenly transformed everything over time. And we're also very transparent about the risks of keeping the old process and the benefits associated with what we're recommending. We are alongside our customers on this journey. While it might seem intimidating initially, the long-term results will transform internal processes and give you a competitive advantage unlike anything else in the market.



Fighter/Attack Aircraft Forecast, 2025-29



Source: 2025 Aviation Week
Network Military Fleet & MRO Forecast.
All numbers and percentages rounded.

Snapshot

Sukhoi Su-57E

At China's Zhuhai Airshow in November, Russia said it had signed up undisclosed first customers for the Sukhoi Su-57E export version of its fifth-generation fighter, possibly including Algeria. First flown in 2010, the Su-57 entered service with the Russian Aerospace Forces in 2022 with firm orders for only 78 aircraft expected to be delivered by 2027. Stealthy and supermaneuverable, with integrated multiband avionics, the Su-57's intended supercruise capability awaits the delayed availability of more powerful Saturn AL-51F-1 engines, expected after the mid-2020s.

Engines: **2X Saturn AL-41F1 @ 32,000 lb. each**

Max. Speed: **730 kt. (low alt.), Mach 2.0 (high alt.)**

Max. Takeoff Weight: **75,000 lb.**

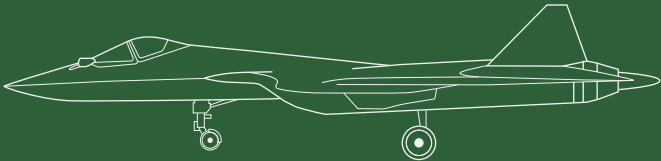
Max. Fuel Load: **21,400 lb.**

Combat Payload: **16,500 lb.**

Unrefueled Range: **1,500 nm**

Ceiling: **61,700 ft.**

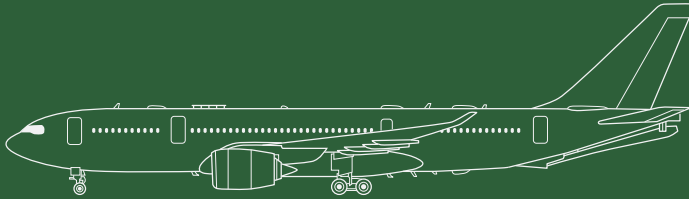
Stores Stations: **12 (6 internal)**



COMBAT AIRCRAFT TO WATCH

MODEL/ DESIGNATION	WING- SPAN (ft.)	MAX. LENGTH (ft.)	MAX. HEIGHT (ft.)	WING AREA (ft. ²)	EMPTY WEIGHT (lb.)	GROSS WEIGHT (lb.)	ENGINES (no./type)	THRUST (afterburning)	SPEED	LOADING	EIS
BOEING											
F-15EX Eagle II	42.8	63.8	18.5	608	—	81,000	2 X GE F110-229	29,000 lb. ea.	M 2.5+	12 air-to-air 24 air-to-ground	2023
DASSAULT AVIATION											
Rafale F4	35.8	50.2	17.4	492	22,000	54,000	2 X Safran M88-4E	16,860 lb. ea.	M 1.8	21,000 lb. external	2022
EUROFIGHTER											
Typhoon Tranche 4	35.1	52.4	17.4	538	24,250	51,600	2 X Eurojet EJ200	20,000 lb. ea.	M 2	16,535 lb. external	2025
KOREA AEROSPACE INDUSTRIES											
KF-21 Boramae	36.7	55.4	15.6	—	—	56,400	2 X GE F414-400K	22,000 lb. ea.	M 1.81	17,000 lb. external	2026
LOCKHEED MARTIN											
F-16 Block 70/72	31	49.3	16.7	300	20,300	48,000	1 X GE F110-229 or P&W F100-129	29,000 lb.		17,000 lb. external	2023
F-35A Lightning II	35	51.4	14.4	460	29,300	70,000	1 X P&W F135-100	43,000 lb.	M 1.6	18,000 lb. external/internal	2016
SAAB											
JAS 39E Gripen	32.4	49.9	14.8	323	17,640	36,300	1 X GE F414G	22,000 lb.	M 2	13,200 lb. external	2021
TURKISH AEROSPACE INDUSTRIES											
Kaan	46	69	20	67	—	>60,000	2 X GE F110	29,000 lb. ea.	M 1.8	6 AAM internal 6 stations external	2029

Military Transport Aircraft Forecast, 2025-29

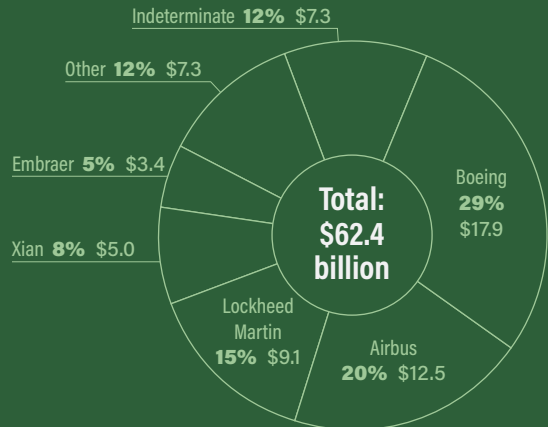


Snapshot

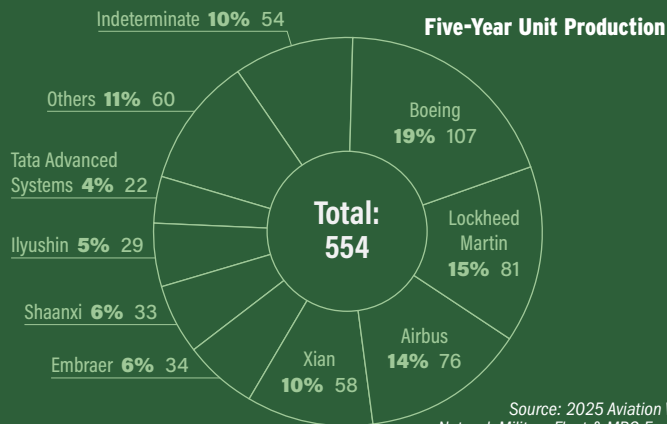
Airbus A330 MRTT+

Airbus unveiled the latest version of its A330-based Multi-Role Tanker Transport, the MRTT+, in July and plans to launch development with a customer by the end of 2024. With the original MRTT based on the out-of-production A330-200, Airbus is updating the design to use the current A330-800, the smallest member of the reengineered A330neo airliner family. Powered by Rolls-Royce Trent 7000s, with lower-drag nacelles and pylons and an improved wing aerodynamics and wingtip design, the MRTT+ has 8% higher fuel efficiency for increased range and fuel offload capability. Airbus says this boosts the range of the MRTT+ to 2,160 nm from 2,000 nm, further increasing its range lead over the rival Boeing KC-46.

Value of Five-Year Production Billions of U.S. 2024 Dollars



Five-Year Unit Production



Source: 2025 Aviation Week Network Military Fleet & MRO Forecast. All numbers and percentages rounded.

MILITARY TRANSPORTS TO WATCH

MODEL/ DESIGNATION	CREW	WING- SPAN (ft.)	MAX. LENGTH (ft.)	MAX. HEIGHT (ft.)	WING AREA (ft. ²)	EMPTY WEIGHT (lb.)	GROSS WEIGHT (lb.)	POWERPLANT (no./type)	POWER (SHP) or THRUST (lb.)	SPEED	PAYLOAD/ RANGE
AIRBUS											
A400M Atlas	2+1	139.1	148	48.3	2,384	169,000	310,850	4 X EPI TP400-D6	11,000 shp ea.	M 0.7	66,140 lb./ 2,450 nm
C-295	2+1	90.5	80.3	28.5	—	—	51,150	2 x P&WC PW127G	2,645 ea.	260 Kt.	13,200 lb./ 2,000 nm
ANTONOV											
An-178	2	100.3	108.1	33.3	—	—	—	4 X Progress D-436-148FM	—	405 kt.	22,046 lb./ 2,160 nm
BOEING											
KC-46A Pegasus	3-15	157.8	165.5	52.8	3,050	—	415,000	2 X P&W PW4062	62,000 lb. ea.	M 0.86	207,670 lb. (fuel transfer)
EMBRAER											
C-390 Millennium	2	115	115.4	38.8	1,513	—	178,570	2 X IAE V2500-E5	31,330 lb. ea.	M 0.80	50,700 lb./ 1,520 nm
LEONARDO											
C-27J Spartan	2+1	94.2	74.5	31.6	882.6	38,581	70,107	2 X R-R AE2100D3	4,637 shp ea.	325 kt.	22,046 lb./ 1,000 nm
LOCKHEED MARTIN											
C-130J-30 Super Hercules	3	132.6	112.8	38.8	1,745	87,667	164,000	4 X R-R AE2100D3	4,637 shp ea.	355 kt.	36,000 lb./ 1,700 nm

U.S. Aerial Logistics Programs Face Decision Points

- TANKER ANALYSIS IS TIED TO FIGHTER WORK
- ALL SERVICES ARE LOOKING FOR AUTONOMOUS PLATFORMS

Brian Everstine Washington

The U.S. military is reviewing how it will conduct airlifts in the future, focusing on refueling in contested environments with increased survivability for tankers and autonomy for smaller, more nimble airlifters—if the money flows.

The largest program for the U.S. Air Force coming down the pike is its Next-Generation Aerial Refueling System (NGAS), likely a clean-sheet refueling tanker intended to operate within threat ranges to top up advanced aircraft like the service's future Next-Generation Air Dominance (NGAD) platform. The service was in the final stages of its analysis of alternatives as of mid-December, although program results are not final, since that analysis is directly tied with the work on the now-paused NGAD program, said Andrew Hunter, the service's assistant secretary for acquisition.

"We've had insights that have come out of the work for the NGAS [analysis of alternatives] and insights for the rest of the tanker fleet and what capabilities it needs," Hunter said Dec. 10 at a Center for Strategic and International Studies event. "Some of those . . . will be pretty clear ideas of things we need to do to enable our tanker fleet to support the joint force for operations that we see in the coming decades. But nothing hard I can give you at this moment."

While Hunter said that analysis of alternatives—the in-depth study of the service's requirements for the future aircraft—is "very mature, definitely reaching kind of the final stages," he noted that the plan will be outlined in

the upcoming fiscal 2026 program objective memorandum. That long-term funding plan will be part of the fiscal 2026 budget request expected in the spring, but the incoming Trump administration could upend the planning.

Key companies are showcasing early designs of advanced tankers. Boeing unveiled a long-wing version of its MQ-25 Stingray with increased fuel offload compared with its Navy program, and Lockheed Martin's Skunk Works released a rendering of a large, advanced uncrewed refueler capable of topping up two F-35s.

The Air Force's fondness for the "NG" acronym continues with its upcoming family-of-systems approach to mobility, the Next-Generation Airlift (NGAL). Service officials have outlined a three-aircraft plan to meet this mission. It starts with a Boeing C-17-like strategic airlifter to replace both the Globemaster III and the Lockheed C-5M Galaxy. The effort is in its earliest stages, with funding approved for a capabilities-based assessment (CBA) to determine what the future program could be—from a full clean-sheet design to the far-fetched idea of restarting C-17 production.

The second of the three parts is the Next-Generation Intratheater Airlift (NGIA) concept. The service has completed a CBA for this program and released an early request for information. This could be a Lockheed C-130-like replacement, with features such as runway independence and autonomy. Air Mobility Command is working with Air Force Special Operations Command (AFSOC) on the NGIA, and the latter is collaborating with DARPA

on its Speed and Runway Independent Technologies (Sprint) program. DARPA in May awarded contracts to Aurora Flight Sciences and Bell Textron for preliminary design work on potential prototypes for AFSOC to replace its Bell Boeing CV-22 tiltrotor.

"The ability to have a platform that has high speed, long range, lower profile and the ability to get in and out of places that don't require long runways is something that any combatant commander would find attractive," an AFSOC official tells Aviation Week. While Sprint is its main effort, the command "is one of several stakeholders working to develop a technology road map for intratheater airlift, focusing on runway independence and responsiveness."

Bell in December announced it had completed tunnel tests of its stop-fold tiltrotor design, while Aurora Flight Sciences is using a fan-in-wing design for the program. The companies are expected to complete preliminary design work by around May and first flight within the following two years.

DARPA is also looking at developing a larger, runway-independent aircraft called the Liberty Lifter. In May, the agency selected Aurora to continue development of its ground-effect seaplane with a planned critical design review by the end of 2025 and a demonstrator by 2027. The company's design includes a 213-ft. wingspan and the ability to carry up to 50,000 lb. of cargo using eight engines.

The last part of the family of systems is known as NGAL-Last Tactical Leg (NGAL-LTL). Conveniently pronounced "little," this is planned to be

Boeing is developing a potentially larger variant of its MQ-25 Stingray as the Air Force looks for autonomous, survivable tankers.



BOEING

a much smaller aircraft, likely autonomous, to deliver cargo in highly contested environments. AFSOC and the Air Force Futures office are in early planning; NGAL-LTL first appeared in a list of potential contract opportunities in July.

The other services are also pursuing smaller, autonomous platforms for quick cargo delivery. The U.S. Marine Corps is moving forward on its Aerial Logistics Connector (ALC) program. Four teams have been selected as participants in Phase 1, three of which had announced their presence as of mid-December. This includes Airbus with its uncrewed UH-72B Lakota; Near Earth Autonomy, Leonardo and Honeywell partnering on an AW139; and Sikorsky with its Matrix flight autonomy system on its UH-60 Black Hawk. Flight demonstrations are planned in 2025.

The Marine Corps is conducting a major, long-term review of its future aviation needs. This effort, called Project Eagle, will culminate in a 15-year funding plan for both modernization and new programs. The service is expected to release its biannual aviation plan by year-end to shape its related force structure goals.

The road map includes likely substantial upgrades to the Marine Corps' MV-22 fleet. The service has outlined the Renewed V-22 Aircraft Modernization Program, which leaves the aircraft's fuselage unchanged but would replace the engines, drivetrain, nacelle and tiltrotor wing.

While the Army aviation portfolio is heavily focused on the Bell Future Long-Range Assault Aircraft, the

service has launched other new efforts focused on autonomous supply. Army Futures Command released a solicitation in the spring for the "1 Ton Capable Cargo UAS," seeking information from industry on the payload capacity, cruise speed, range, sea state and wind speed capabilities of potential entrants. Goals include an 80-120-kt. cruise speed and range of up to 500 nm. This is in addition to the service's Joint Tactical Autonomous Aerial Resupply System, which is intended to carry more than 150 lb.

The Navy is continuing to push for additional long-range UAS to operate between its ships and Military Sealift Command suppliers. This endeavor has focused on the Skyways Blue Water Logistics UAS, though Sierra Nevada Co. announced in December that the Navy had selected its Hybrid Voly UAS for the program.

In the long term, the Navy is taking steps to replace its Lockheed Martin MH-60R and MH-60S aircraft that provide lift and fleet protection. In May, the Future Vertical Lift-Maritime Strike (FVL-MS) program completed

its analysis of alternatives and passed a requirements review board, which unanimously decided to proceed with a capabilities development document and concept of operations. The MH-60 fleet will reach its end of service life in the late 2030s after a life extension, and the FVL-MS initial operational capability is expected in the 2040s.

"FVL-MS will be the most widely distributed aviation platform in the Navy, embarking on all surface combatants from future [Constellation-class frigates] to aircraft carriers, and will contribute to more primary mission areas than any other aviation platform in the Navy," says Rear Adm. Michael Donnelly, director of the Navy's air warfare division.

While the FVL-MS will operate primarily from destroyers, frigates and littoral combat ships, the Navy's fleet of CMV-22Bs are taking over the carrier onboard delivery role from Grumman C-2s. The first East Coast-based CMV-22Bs arrived in April, though the fleet has been grounded multiple times throughout the year due to safety concerns. ☼

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What's In

What's Out

A look at which trends are gaining popularity and which are losing steam in defense.

Robert Wall

IN

OUT



Loitering Air-to-Air Missiles



Transatlantic Bonhomie



Suppression of Enemy Air Defenses



Dedicated Close-Air Support Jets



Autonomous Tactical Resupply



Lean Inventories



Air Base Defense



Conventional IRBMs



Soviet-Era Fighters



3% of GDP



2% of GDP

IMAGE CREDITS (FROM TOP): U.S. JUSTICE DEPARTMENT, U.S. NAVY, U.S. MARINE CORPS, U.S. ARMY, LOCKHEED MARTIN, BURAZIN/GETTY IMAGES

IMAGE CREDITS (FROM TOP): NATO, U.S. AIR FORCE, U.S. ARMY, U.S. AIR FORCE, BURAZIN/GETTY IMAGES

ANALYSIS



A New NASA?

Irene Klotz Cape Canaveral

THE U.S. SPACE AGENCY LIKES

to point out that anyone born since Nov. 2, 2000, when the first crew arrived at the International Space Station, has never spent a day without people living in space.

But of late, 66-year-old NASA has been less articulate about why that is important, especially as SpaceX and other commercial entities eclipse government-run programs, such as the Space Launch System (SLS) and Orion spacecraft, in keeping costs in check and cutting time for technology development and testing.

President-elect Donald Trump has nominated a real civilian to run the civilian space agency: Jared Isaacman, a self-made billionaire tech entrepreneur, private fighter jet pilot and two-time private astronaut. Isaacman has no experience running a government agency, but he has honed his business acumen since age 16, when he left high school to become a full-time computer technician.

Now 41, Isaacman has founded two companies: Draken International, which operates the world's largest fleet of privately owned former military tactical jet aircraft for training and air services, and Shift4, a publicly traded payment processing firm that reported nearly \$2.6 billion in revenue in 2023. Isaacman sold Draken in 2019; he is CEO of Shift4.

Isaacman used an undisclosed percentage of his wealth to charter four private astronaut missions with SpaceX. Those began with the three-day Inspiration4 demonstration mission in 2021 and five-day 2024 Polaris Dawn flight, which featured the first civilian astronaut spacewalk demonstration. Polaris Dawn also set a new altitude record for a crewed craft in low Earth orbit.

The status of Isaacman's two remaining Polaris missions, culminating with the first crewed flight aboard SpaceX's new Starship, is uncertain if the Senate confirms him to head NASA. For the second Polaris mission, Isaacman and SpaceX had requested that NASA let a Crew Dragon reboost the Hubble Space Telescope, which the current agency management declined.

"I am honored to receive President Trump's nomination to serve as the next administrator of NASA," Isaacman said in a statement. "Having been fortunate to see our amazing planet from space, I am passionate about America leading the most incredible adventure in human history. . . . This second space age has only just begun."

Isaacman's relationship with SpaceX and its founder,

CEO and Chief Technology Officer Elon Musk, presents opportunity and risk for NASA. During the 2024 presidential campaign, Musk became a Trump ally and ardent supporter. Musk will now oversee, along with biotech billionaire Vivek Ramaswamy, a Trump effort to shave some \$2 trillion from the federal budget.

What that means for NASA has yet to be determined.



BRANDON BELL/GETTY IMAGES

Tech entrepreneur Elon Musk, who founded SpaceX to colonize Mars, has the ear of President-elect Donald Trump.

After the nonprofit California Institute of Technology, which operates the Jet Propulsion Laboratory, SpaceX holds the lion's share of NASA's business, besting heritage contractors Boeing and Lockheed Martin since fiscal 2022. In addition to flight service contracts for crew and cargo to the International Space Station, NASA is buying a version of SpaceX's Starship Super Heavy system to ferry astronauts to and from lunar orbit and the surface of the Moon, a mission now not expected before mid-2027.

If confirmed, Isaacman also will inherit oversight of NASA's SLS heavy-lift rocket and Orion deep-space capsule, programs at the heart of the U.S.-led Artemis lunar exploration initiative that is projected to

cost up to \$93 billion over fiscal 2012-25, NASA's Office of Inspector General determined in an October 2023 audit.

NASA also faces key questions over its flagship planetary science initiative to return samples from Mars. A proposal by SpaceX is among a dozen alternatives the agency has under review for cutting mission costs and speeding up the schedule.

SpaceX competitors, including Jeff Bezos-owned Blue Origin, are cautiously optimistic that Trump's space policy, strongly influenced by Musk, will strike a balance. "I take at face value what has been said, which is that [Musk] is not going to use his political power to advantage his own companies or to disadvantage his competitors," Bezos said during a Dec. 4 interview at *The New York Times* DealBook Summit. "I could be wrong about that, but I think it could be true."

Isaacman is "a thoughtful guy who really cares about exploration, the space program and NASA," former NASA astronaut and U.S. Sen. Mark Kelly (D-Ariz.) told reporters on Dec. 9. "When you consider who the president-elect could have put in there, I actually think he's a good choice."

"He's got some issues that he is going to have to work out with ownership in companies and investments he has made," Kelly added. "But I think, especially right now, NASA needs to make some changes." ☼

—With Brian Everstine in Simi Valley, California

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What is in and what is out [p. 66](#) Satellite-based cellular rivals [p. 67](#)



JAMIE PEER AND MICHAEL DOWNS/NASA

DELAYS FOR ARTEMIS

> U.S.-LED PROGRAM MAY FACE TRUMP-BACKED REBOOT

> HEAT SHIELD WORK DELAYS ARTEMIS II > STARSHIP FLIGHT 7 TARGETED FOR JANUARY

Irene Klotz Cape Canaveral

In his first term, President-elect Donald Trump instituted the Artemis program with the goal of pushing U.S. human space exploration and development from low Earth orbit to the Moon in collaboration with international and commercial partners. His administration set a goal in 2019 of landing astronauts on the lunar surface by September 2024.

The aspirational schedule guided NASA's decision-making. For example, managers decided that Northrop Grumman was the only company capable of manufacturing a Habitation and Logistics Outpost (HALO) module for the Artemis program's Lunar Gateway in time to meet its targeted 2024 launch date. The agency awarded Northrop a sole-source, fixed-price contract worth \$935 million to design and build the HALO.

That, along with Maxar's Power and Propulsion Element (PPE), is to become the foundation of the Gateway, a small station in a gravitationally balanced, near-rectilinear halo orbit around the Moon. The Gateway is intended to serve as a staging ground for lunar surface sorties, communications relay station, technology testbed and short-term lodging for astronauts. The HALO, which is based on the Cygnus cargo ship that Northrop flies to the

The core stage for NASA's second Space Launch System mission reached Kennedy Space Center in July. It is not expected to fly until April 2026 at the earliest.

International Space Station (ISS) for NASA, is designed to support a crew of four astronauts for up to 30 days. The HALO and PPE's launch aboard a SpaceX Falcon Heavy is not expected before 2027.

NASA plans to provide U.S. and partner-country astronauts rides to the Gateway on an Orion deep-space capsule, which would lift off aboard a NASA-owned-and-operated Space Launch System (SLS) rocket. NASA spent about \$50 billion on the SLS, Orion and ground infrastructure be-

tween 2006 and 2022, when the system debuted on the Artemis I uncrewed flight test around the Moon.

The Artemis program also includes a Human Landing System (HLS) to ferry astronauts the last 100 m (330 ft.) to and from an Orion spacecraft or the Gateway in lunar orbit, as well as spacesuits and other hardware. NASA's Office of Inspector General estimated in 2023 that the total cost for the Artemis program would reach \$93 billion in late 2025. At the time, the agency was targeting the Artemis III Moon landing for December 2025. The mission is expected to mark the first landing of astronauts on the lunar surface since Apollo 17 in 1972. The milestone flight is not expected before mid-2027.

The latest delay, announced Dec. 5, stems from a two-year investigation into unexpected heat shield performance during an Orion spacecraft's reentry into the atmosphere on Dec. 11, 2022, which concluded the 25-day Artemis I flight test around the Moon.

Post-flight analysis showed that Orion's 16.5-ft.-dia. heat shield charred in an extensive and unanticipated fashion during the spacecraft's Mach 32 descent. Through more than 100 tests, engineers determined that gases generated within the heat shield's outer ablative Avcoat material were not able to escape the structure as intended. That caused pressure to build up and cracks to form, allowing the material to break away rather than ablating to dissipate the thermal buildup.

Sensors within the Orion, however, revealed the temperatures would have remained safe had a crew been onboard.

"We have to have an absolute technical understanding of the [heat] transporting phenomena that led to that loss char," Amit Kshatriya, deputy associate administrator for NASA's Moon to Mars program office, told reporters Dec. 5.

NASA decided to proceed with the 10-day crewed Artemis II flight test using the current Orion heat shield, which was installed on the spacecraft in June 2023. However, the capsule's reentry into the atmosphere will be tailored to skip in and out with a cadence for better control of the heating that led to the charring. The Avcoat will be reformulated for the heat shield being manufactured for the Artemis III and future crewed lunar landing missions.

"We know how to produce Avcoat

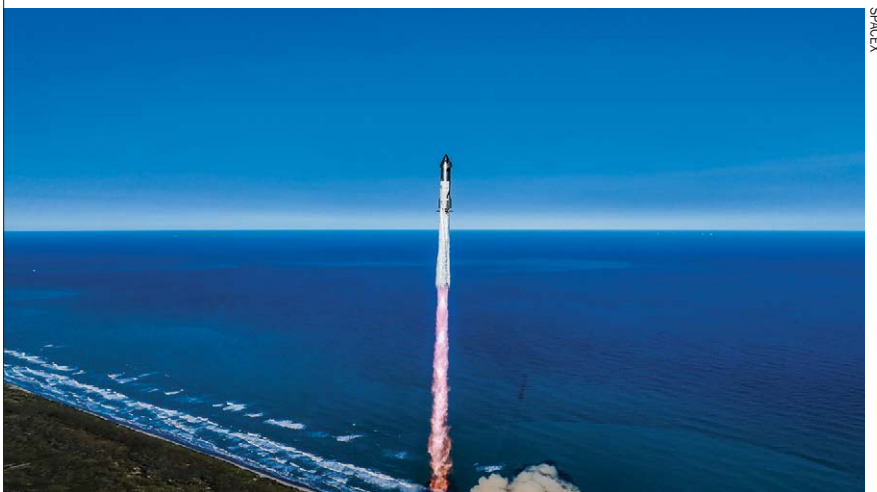
with the desired permeability standard, and we have sized up all of our production capability in order to produce heat shields as fast as we can," Kshatriya said. "We have a 50% improvement in the production rate, but it will still take us time to finish achieving the qualification of that material."

Artemis II, which is to send four astronauts on a looping 10-day mission around the Moon, has been postponed until April 2026, an eight-month delay.

Meanwhile, SpaceX is on track to launch up to 136 orbital missions in 2024 despite three groundings of its Falcon 9 fleet to address technical

program's first lunar landing. An operational Starship also will likely recast thinking about the SLS and Orion, currently the only system capable of deep-space crewed transport.

"We're about to have this light-switch-like moment when Starship comes online," Jared Isaacman, Trump's nominee to head NASA during his second term, said at the Space Force Association's Spacepower 2024 conference in Orlando Dec. 11. "A lot of things are going to change, whether it's point-to-point travel here on Earth, to and from the Moon, or other possibilities."



SpaceX launched a Starship-Super Heavy vehicle for a sixth flight test on Nov. 20. The system is expected to begin lofting SpaceX Starlink satellites in 2025.

issues. The company also conducted four flight tests of its Starship-Super Heavy transport from its privately owned spaceport in Boca Chica, Texas.

During Flight 5 on Oct. 13, SpaceX on its first attempt returned a Super Heavy booster to its launch tower. A communications issue prevented the company from trying to repeat the feat during Flight 6 on Nov. 19, but that mission did include the restart of a Starship upper-stage engine in flight for the first time, a key step toward orbital and deorbit maneuvers.

If Starship performs that well during the upcoming Flight 7, slated for no earlier than Jan. 11, SpaceX could target a launch tower return for Starship as early as Flight 8, SpaceX founder, CEO and Chief Technology Officer Elon Musk said.

No one is cheering harder for SpaceX than NASA. The company is developing a version of the Starship-Super Heavy system for the Artemis

"What happens when industry starts cranking out spaceships out of multiple factories?" he added. "SpaceX has a great vision for this, but so does Blue Origin, and you've got Rocket Lab."

Isaacman, 41, is a self-made billionaire and pilot who has twice chartered SpaceX Dragon capsules for private-astronaut, technology-demonstration missions. "We're going into a new era where some funding can come privately through commercial endeavors but still to the benefit of everyone," he said.

Meanwhile, Musk, who has become part of Trump's inner circle, has been tapped to co-lead a White House effort to cut \$2 trillion in government spending. Whether Musk has his eye on Artemis or other NASA programs is not yet known. ☼

Gallery See more about space sector developments in 2024:

[AviationWeek.com/Space2024](https://www.aviationweek.com/Space2024)



Europe Ramps Up Launches As the Vega C Returns to Flight

➤ SPACE LAUNCHER STARTUPS IN EUROPE FACE A BIG YEAR

➤ UPGRADES ARE PLANNED TO BOOST THE VEGA'S PERFORMANCE

Robert Wall London

After achieving its goal of revitalizing launch services in 2024, Europe is moving to increase the pace of rocket flights.

Arianespace returned the Vega C medium launcher to flight on Dec. 5 after two years on hiatus following a mission failure in 2022. The Avio-made rocket took off from the Guiana Space Center in Kourou, French Guiana, at 6:20 p.m. local time, then deployed its payload about 104 min. later.

The mission, VV25, placed the Sentinel-1C radar satellite in sun-synchronous orbit, restoring the two-satellite Copernicus radar constellation after the Sentinel-1B came to an early end in August 2022 because of a technical fault with the spacecraft. Europe expects to launch the Sentinel-1D in 2025, using another Vega C to replace the first of the radar satellites, which will have been in orbit for more than a decade by then.

The Sentinel-1C is equipped with a C-band radar that provides spatial resolution of up to 5 m (16.4 ft.) and can acquire imagery at swaths of 20-400 km (12.4-248.5 mi.). It also features an automatic identification system to help track shipping. The European Space Agency (ESA) expects the satellite to undergo about three months of on-orbit checks before it becomes operational, Simonetta Cheli, director of Earth observation programs, told reporters during a prelaunch briefing.

The Vega C design has been adapted with a nozzle redesign to address the material issues that caused the previous mission to fail. During VV22, a carbon-carbon insert in the nozzle of the second-stage Avio Zefiro 40 engine degraded prematurely. The partners completed two ground tests in 2024 of the new design, which uses a new material and supplier and has slightly better performance.

The mission marked the second major rocket milestone for ESA in 2024 after the Ariane 6's inaugural launch in July, also from Kourou, restored Europe's heavy-lift rocket capability. Arianespace had hoped to launch a second Ariane 6 in 2024 but has rescheduled that mission to mid-February 2025, in part to address a problem with the auxiliary power unit of the rocket's upper stage, the launch service provider says. Rocket production issues and other factors also contributed to the delay.

Europe's Vega C rocket returned to flight on Dec. 5 after more than two years on hiatus following a mission failure.

"With Vega C back in flight and the inaugural launch of Ariane 6 in July, we are in a great place going forward," ESA Space Transportation Director Toni Tolker-Nielsen said in a statement.

ESA is targeting at least 10 combined Ariane 6 and Vega C launches in 2025 as it moves to step up to a more sustainable pace of operations.



Arianespace will manage the four Vega C flights planned for the coming year before handing over control of the launch operations to Avio.

Avio CEO Giulio Ranzo said in a prelaunch briefing that the company has about 15 launches in its backlog. Avio also is working with suppliers on increasing the launch rate for the Vega C to six missions annually in about 2.5 years. One prerequisite will be constructing a pre-integration building at the Guiana Space Center so the company can work on readying one rocket while another is on the launch pad.

Arianespace also plans to boost the pace of Ariane 6 operations to about 10 flights per year in 2027.

But those launch figures also show how big the gap has become between Europe and its biggest rivals in the space race. SpaceX completed a record 16 Falcon 9 missions in November alone. China launched more than 50 rockets in 2024, including the Nov. 30 initial flight of the Long March 12, the first mission from the Hainan International Commercial Aerospace Launch Center. The 62.6-m-tall rocket, de-

signed by the Shanghai Aerospace System Engineering Institute, lofted two experimental satellites into orbit, the Chinese government said.

Europe is trying to catch up. Next year, ESA plans to kick off the European Launcher Challenge to create more rocket options for the region. Startups are hoping the funding will give them a boost to build more sophisticated systems that can compete with incumbents.

PLD Space, a Spanish startup aspiring to challenge the Ariane 6 in the heavy launch market, plans to commence its first launch campaign from Kourou for its Miura 5 launcher in about a year (*AW&ST* Oct. 14-27, p. 40). The company on Dec. 2 said it had secured an €11 million (\$11.6 million) loan from a Spanish government-owned investment fund to support work on the launch facility.

In Germany, Rocket Factory Augsburg is aiming for the first flight of its RFA One as it looks to recover from a fiery failure of a first stage during a static test in August at the SaxaVord Spaceport in Scotland. Munich-based

startup Isar Aerospace also is working toward the inaugural launch of its Spectrum rocket from the Andoya Spaceport in Norway.

ESA is focused on evolutions of the existing rockets as well. An upgraded version of the Ariane 6 using four boosters rather than two is due for its first flight in the coming year.

The agency and Avio also are pursuing the Vega E, an upgrade to the Vega C. Tolkner-Nielsen said he wants the program to be on contract before the end of 2024. The project would develop a new cryogenic upper stage powered by a 10-metric-ton-class liquid-oxygen/methane expander cycle engine and should have almost three metric tons of payload performance, Ranzo said.

Before the Vega E's launch—projected to occur around 2028—Avio plans to upgrade the Vega C with a larger first stage. Its P160C also is to be used on the Ariane 6, adding around 200 kg (441 lb.) in lift capacity. A multipayload adapter is to be added to the Vega C to address the need to launch more than one satellite on a mission, Ranzo said. 🌐

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SMALL

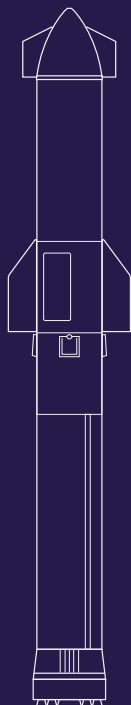
MANUFACTURER (COUNTRY) VEHICLE	PAYLOAD (kg)	STAGES (Propellant)	FAIRING DIAMETER (m)	LAUNCH
AGNILKUL COSMOS (INDIA)				
Agnibaan	100 to LEO	2 (kerosene)	1.5	2025
ASTRA SPACE (U.S.)				
Rocket 4	600 to LEO	2 (kerosene)	1.7	2025
CALT (CHINA)				
Jeilong 3	1,500 to SSO	4 (solid)	3.35	2022*
CAS SPACE (CHINA)				
Kinetica 1	2,000 to LEO	4 (solid)	3.35	2022*
DEEP BLUE AEROSPACE (CHINA)				
Nebula-1	2,000 to LEO	2 (kerosene)	5	2025
FIREFLY AEROSPACE (U.S.)				
Alpha	1,030 to LEO	2 (kerosene)	2.2	2023*
GALACTIC ENERGY (CHINA)				
Ceres 1	400 to LEO	4 (1-3 solid)	1.4	2020*
GILMOUR SPACE TECHNOLOGIES (AUSTRALIA)				
Eris	215 to SSO	3 (1-2 hybrid)	1.5	2024†
INTERSTELLAR TECHNOLOGIES (JAPAN)				
Zero	800 to LEO	2 (methane)	2.3	2025
I-SPACE (CHINA)				
Hyperbola-1	300 to LEO	4 (solid)	1.4	2019*
ISAR AEROSPACE (GERMANY)				
Spectrum	1,000 to LEO	2 (propane)	2	2024†
ISRO (INDIA)				
SSLV	500 to LEO	4 (1-3 solid)	2	2023*
ORBEX SPACE (UK)				
Prime	180 to LEO	2 (propane)	1.45	2025
PLD SPACE (SPAIN)				
Miura 5	540 to SSO	2 (kerosene)	2	2026
PERIGEE AEROSPACE (SOUTH KOREA)				
Blue Whale 1	150 to SSO	2 (methane)	1.6	2025
ROCKET FACTORY AUGSBURG (GERMANY)				
RFA One	500 to LEO	3 (liquid)	2	2025
ROCKET LAB (US)				
Electron	300 to LEO	3 (kerosene)	1.2	2018*
SKYROOT AEROSPACE (INDIA)				
Vikram-1	480 to LEO	2 (solid)		2024†
SKYRORA (UK)				
Skylark XL	315 to LEO	3 (kerosene)	2.2	2025
SPACE ONE (JAPAN)				
Kairos	250 to LEO	4 (1-3 solid)	1.5	2024†
SPACE PIONEER (CHINA)				
Tianlong-2	2,000 to LEO	3 (kerosene)	3.35	2023

MEDIUM

MANUFACTURER (COUNTRY) VEHICLE	PAYLOAD (Metric tons)	STAGES (Propellant)	CONFIGURATION	FAIRING DIAMETER (m)	LAUNCH
AVIO (ITALY)					
Vega C	2.3 to LEO	4 (1-3 solid)		2.18	2022*
CALT (CHINA)					
Long March 8/8A	5/7 to SSO	2.5 (1-2 hydrogen)	2 boosters	4.2/5.2	2020*
Long March 10A	14 to LEO	2 (kerosene)	1st reusable	5	2026
CAS SPACE (CHINA)					
Kinetica-2	12 to LEO, 8 to SSO	2.5 (kerosene)	2 boosters + 1st reusable	4.2	2025
DEEP BLUE AEROSPACE (CHINA)					
Nebula-2	25 to LEO	2 (kerosene)	1st reusable	5	2025
FIREFLY AEROSPACE (US)					
MLV	16.3 to LEO, 3.2 to GTO	2 (kerosene)		5.4	2026
GALACTIC ENERGY (CHINA)					
Pallas-1	8 to LEO	2 (kerosene)	1st reusable	4.2	2024†
I-SPACE (CHINA)					
Hyperbola-3	8.5 to LEO	2 (methane)	1st reusable	4.5	2025
KARI (SOUTH KOREA)					
Nuri	3.3 to LEO, 2.2 to SSO	3 (kerosene)		3.5	2022*
LANDSPACE (CHINA)					
Zhuque-2	6 to LEO	2 (methane)		3.35	2023*
ORIENSPACE (CHINA)					
Gravity-1	6.5 to LEO, 4.2 to SSO	3.5 (solid)	Sea launch	4.2	2024*
SPACE PIONEER (CHINA)					
Tianlong-3	17 to LEO, 14 to SSO	2 (kerosene)	1st reusable	4.2	2024†
SRC PROGRESS (RUSSIA)					
Soyuz-5	18 to LEO, 5 to GTO	3 (kerosene)		4.1	2025
ROCKET LAB (NEW ZEALAND)					
Neutron	13 to LEO	2 (methane)	1st reusable	5	2025
SAST (CHINA)					
Long March 6C	4.5 to LEO, 2.4 to SSO	2 (kerosene)		3.35	2024*
Long March 12	12 to LEO	2 (kerosene)		3.8	2024

*First successful orbital launch.
†Launch expected by year-end.

Sources: Aviation Week Network and manufacturer data



Snapshot

Long March 9

After several redesigns, China's planned Long March 9 super-heavy launch vehicle has evolved into a fully reusable two-stage rocket closely resembling SpaceX's Starship/Super Heavy combination. Unveiled at the Zhuhai airshow in November, the latest design has a first stage powered by 30 YF-215 liquid oxygen-methane engines. Under development by the China Academy of Launch Vehicle Technology, Long March 9 is designed to lift 150 metric tons to low Earth orbit and 50 metric tons to trans-lunar injection. The first stage is designed to return to the launch site to be captured by a gantry while the second stage is designed to return to a vertical landing pad. Launch with a reusable first stage is planned for 2033, with the reusable second stage following around 2035.

Height: **114 m (374 ft.)**

Takeoff Mass: **4,400 metric tons**

Diameter: **10.6 m (34.8 ft.)**

Takeoff Thrust: **6,100 metric tons**



HEAVY

MANUFACTURER (COUNTRY) VEHICLE	MODEL	PAYLOAD (Metric tons)	BOOSTER CONFIGURATION	STAGES (Propellant)	OPERATION	FAIRING DIAMETER (m)	FLIGHT
ARIANESPACE (EU)							
Ariane 6	AR62	7.2 to SSO, 4.5 to GTO	2 solid	2 (LH ₂)		5.4	2024*
	AR64	11.5 to GTO, 5 to GEO	4 solid	2 (LH ₂)		5.4	2025
BLUE ORIGIN (U.S.)							
New Glenn		45 to LEO, 13 to GTO		2 (1st methane, 2nd LH ₂)	1st reusable	7	2024†
CALT (CHINA)							
Long March 9		150 to LEO, 50 to TLI		2 (methane)	Reusable	10	2033
Long March 10		70 to LEO, 27 to TLI	2 liquid	3 (1-2 methane, 3rd LH ₂)		5	2024†
ISRO (INDIA)							
LVM3		8 to LEO, 4 to GTO	2 solid	2 (1 UDMH, 2 LH ₂)		5	2017*
NGLV	NGLV	20 to LEO, 9 to GTO		3 (2 methane, 3rd LH ₂)	1st reusable	5	2031
	NGLV-H	30 to LEO, 12 to GTO	2 solid	3 (2 methane, 3rd LH ₂)	1st reusable	5	
KRUNICHEV (RUSSIA)							
Angara	A5	24.5 to LEO, 7.5 to GTO	4 liquid	3 (1-2 kerosene)		4.35	2014*
MHI (JAPAN)							
H3	H3-22S	4 to GTO	2 solid	2 (LH ₂)		5.2	2024*
	H3-24L	7.9 to GTO	4 solid	2 (LH ₂)		5.2	
NASA (U.S.)							
SLS	Block 1	70 to LEO, 27+ to TLI	2 solid	2 (LH ₂)			2022*
RELATIVITY SPACE (U.S.)							
Terran 6		23.5 to LEO, 5.5 to GTO		2 (methane)	1st reusable	5	2026
SPACEX (U.S.)							
Starship	Block 2	150 to LEO		2 (methane)	Reusable		2025
UNITED LAUNCH ALLIANCE (U.S.)							
Vulcan	VC2S	19 to LEO, 2.6 to GEO	2 solid	2 (1st methane, 2nd LH ₂)		5.4	2024*
	VC6L	27.2 to LEO, 6.5 to GEO	6 solid			5.4	

U.S. SDA Data Transport Satellites Prepare for Prime Time

➤ TRANCHE 1 IS TO LAUNCH MORE THAN 120 SATELLITES

➤ THE NEW CONSTELLATION'S SUCCESS HINGES ON AVAILABILITY OF OPTICAL COMMUNICATIONS TERMINALS

Vivienne Machi Los Angeles

The Space Development Agency is gearing up for the operational debut of its multifunction proliferated satellite architecture in the spring of 2025, and it has much to prove about the functionality, development model and supply chain viability.

16 radio frequency (RF) communications from space to ground and air systems as well as intersatellite laser communications for data transmission and missile tracking.

About 154 operational satellites will soon build out the agency's Prolifer-

ing spacecraft and four missile defense demonstration space vehicles.

The Tranche 0 spacecraft were launched about six months later than planned, which Tournear attributed largely to COVID-19-related supply chain problems. "It became nearly impossible to even buy a resistor, let alone a space-qualified port," he noted.

For Tranche 1, the SDA faced a separate manufacturing challenge. The constellation's success hinges on optical communications, which use infrared frequency to transmit information between spacecraft or between space and airborne or terrestrial assets. That gives the architecture greater speed, security and flexibility than RF communications, such as Link 16, along with reduced size, weight and power needs.

The SDA has developed its own optical communications terminal (OCT) standard for manufacturers' to follow, optimized specifically to connect space-to-air communications, not just space to space.

As the agency prepares to launch more than five times as many satellites in Tranche 1 as in Tranche 0, OCT providers have struggled to produce the critical parts at scale, Tournear noted.

"That's where you see this learning curve," he said. "Tranche 0 was just getting the parts in hand. Tranche 1 is building up your manufacturing capability, which always goes slower than people anticipate."

As OCT production ramped up for Tranche 1 spacecraft, the SDA focused on providing Link 16 connectivity to users as quickly as possible. The radio network is fielded across all U.S. military services, along with allies and partners around the globe.

Since November 2023, the SDA has demonstrated Link 16 connectivity from a York Space Systems-built satellite on orbit to ground-based radios in Australia to a naval carrier in international waters and to an aircraft stationed aboard the vessel. The agency also demonstrated intersatellite optical connectivity between two York spacecraft and between two SpaceX satellites.

The SDA recently completed Link 16 tests between Tranche 0 spacecraft and airborne Norwegian Armed Forces aircraft, with "preliminary good results," Tournear said. The participating aircraft were Lockheed Martin F-35 Joint Strike Fighters and Boeing



The Space Development Agency is preparing to launch its first operational spacecraft for a multifunction, low-Earth-orbit proliferated satellite constellation.

More than five years ago, the newly established office shared its vision to field hundreds of small satellites in two-year cycles to support such missions as 24/7 data communications, missile tracking, battlespace awareness and alternate positioning, navigation and timing.

The Space Development Agency (SDA) currently operates 27 satellites in low Earth orbit under the initial Tranche 0. That tranche serves to demonstrate the transmission of Link

ated Warfighter Space Architecture (PWSA) in Tranche 1, slated to launch as early as March, Director Derek Tournear said in a webinar hosted by the Mitchell Institute for Aerospace Studies in November. The majority—126 satellites—will make up the Transport Layer; providing Link 16 and optical communications to warfighters stationed around the globe from an 80-deg-inclination polar orbit, Tournear said. The Tracking Layer will include 28 missile warning/missile track-

P-8 Poseidon maritime patrol aircraft, the Norwegian Defense Research Establishment revealed in December.

Although the legacy Cold War system will remain operational for decades, optical communications will soon be the mode of choice to enable higher data rate transmissions, Tournear said.

The SDA's Tranche 0 satellites were boosted to orbit between April 2023 and February 2024.

The agency's OCT supply chain is beginning to diversify as demand grows for the critical terminals, not only to support Tranche 2 and later spacecraft in the constellation but eventually to integrate commercial spacecraft into the PWSA architecture.

The SDA contracted with synthetic aperture radar company Umbra in October to develop and demonstrate a low-cost, PWSA-compatible OCT that matches its spacecraft's size, says Jason Mallare, Umbra's vice president of global solutions.

Umbra's satellites weigh about 100kg (220 lbs.) when fully loaded, and a standard OCT would take up about 15% of that weight. "That's way too much," Mallare says. "We really



U.S. SPACE FORCE

need a 1-5-kg optical terminal that is compatible with SDA's network." The initial demonstration phase will focus on testing the terminal's compatibility via a government testbed; an on-orbit testing phase will follow.

The outcome of Tranche 1 will test SDA's advocacy for a spiral technology development model. While the agency's push to field products more quickly and efficiently than traditional Pentagon procurement models has its supporters among leadership and

lawmakers, Tournear has spent much time in the past five years defending the "Android model."

"You'll hear people say, 'You can always get better capability if you're willing to spend more. So why not make the trade to buy a more capable system at the expense of cost?'" he said. "Our motto is: 'Better is the enemy of good enough.' You've got to get that capability that you can afford to show that you can proliferate it and move at scale and push forward." 🗨️

People To Watch



Josef Aschbacher

European Space Agency (ESA) Director General

ESA faces a critical ministerial meeting in November 2025 where Aschbacher must obtain buy-in for projects to keep Europe relevant in lunar and Mars exploration as well as launch. Ahead of that, ESA plans to kick off an initiative to inject energy and competition into the launch market. Aschbacher also might need to maintain transatlantic cooperation amid likely disagreement between leaders in Europe and the incoming U.S. administration.



Peter Beck

Rocket Lab Founder and CEO

After building a successful small-satellite launch services business, Long Beach, California-based Rocket Lab moves into satellite manufacturing and a new launch service with the reusable medium-lift Neutron booster. As evidenced by recently logging two launches within 24 hr., Beck's company has proven itself to be innovative and highly competitive.



Jared Isaacman

NASA Administrator Nominee

The billionaire entrepreneur and commander of two SpaceX commercial space flights is poised to become the next NASA administrator. If confirmed, Isaacman will oversee the agency's first attempt to land on the Moon since the Apollo program and guide the transition from the International Space Station to one or more commercially owned and operated outposts in low Earth orbit.



Elon Musk

SpaceX CEO

The single most influential person in the space industry now has the ear of the president-elect, a keen interest in government policy and a personal ambition to establish a colony on Mars.



Gwynne Shotwell

SpaceX President and Chief Operating Officer

The privately held company faces another set of key milestones for the Starship launch system, including propellant-transfer demonstrations. Starship's first operational missions will be to



Alexandre Tisserant

Kineis CEO

Kineis exemplifies the emergence of French startups in the New Space sector. With 15 satellites launched, the company is on track to have its 25-satellite constellation complete within weeks. It is planning to provide Internet of Things (IoT) full services, in addition to improved ship detection in busy areas, in the middle of 2025. The performance of miniaturized equipment in orbit and cheap IoT devices on the ground will spell success.



Derek Tournear

Space Development Agency (SDA) Director

The agency's first permanent director has spent over five years building out a new proliferated satellite architecture in low Earth orbit and evangelizing about Android-style spiral acquisition models for military space programs. That faith will be put to the test in 2025 when the SDA launches more than 150 satellites about two years after contract award to support 24/7 global communications and missile tracking from space. 🗨️

PHOTO CREDITS TOP TO BOTTOM, FROM TOP LEFT: ESA, ROCKET LAB, SIPA US/ALAMY STOCK PHOTO, U.S. AIR FORCE, NASA, KINEIS, U.S. AIR FORCE

What's In

What's Out

A look at which trends are gaining popularity and which are falling out of favor in the space sector.

Robert Wall

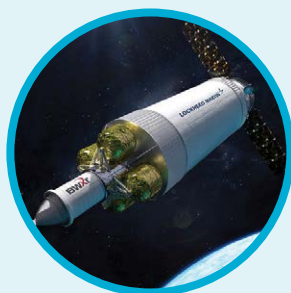
IN



On-Orbit Maneuvering



Small Geostationary-Orbit Satellites



Nuclear Propulsion



Proliferated LEO Constellations



Space Situational Awareness

OUT



Space Incumbency



Space SPACs



Large Geostationary-Orbit Communication Satellites



Cost-Plus Contracts

IMAGE CREDITS FROM TOP: ORBIT FAB, SWISSTO12, LOCKHEED MARTIN, MIREXON/GETTY IMAGES, FRENCH DEFENSE MINISTRY

IMAGE CREDITS FROM TOP: UNITED LAUNCH ALLIANCE, BOPAV/ISTOCK/GETTY IMAGES, AIRBUS, NASA



AST SpaceMobile plans to continue launching and expanding its constellation in 2025.

Space-Based Cellular Service Goes Live in 2025

- > SERVICE PROVIDERS AIM FOR NEWER, UNMODIFIED SMARTPHONES
- > APPLE PLANS TO INVEST \$1.5 BILLION TO EXPAND PARTNER GLOBALSTAR'S CELLULAR SATELLITE CONSTELLATION

Garrett Reim Seattle

Satellite-based cellular services are poised to have a breakout year in 2025 as multiple providers start commercial service and expand their constellations.

SpaceX's Starlink, AST SpaceMobile, Globalstar, Lynk Global and Skylo—to name a few—are jockeying for position in the emerging space-based cellular service market. The companies want to fill mobile phone coverage gaps in areas outside the reach of terrestrial cellular towers as well as provide emergency messaging services and connectivity for Internet of Things devices.

Most providers initially plan to offer texting services; voice and data coverage would come later. Starlink, for example, aims to launch texting with T-Mobile imminently, then roll out voice, data and Internet of Things service in 2025. Apple, through partner satellite operator Globalstar, has offered emergency SOS messaging since 2022, roadside assistance since 2023 and, as of September, texting for iPhone 14 and newer phones in the U.S. and Canada.

Initially, the market for direct-to-cell services is expected to be small, generating \$30 million in annual revenue worldwide in 2025, Juniper Research projects. However, the consultancy anticipates that satellite-based

services will grow quickly and generate nearly \$1.7 billion annually by 2029.

About 5% of the world's population—roughly 400 million people—lives in areas that are not covered by terrestrial cellular service, according to mobile phone trade group GSM Association. This segment of the population often cannot afford satellite-based cellular service; the target market for such service is a more prosperous demographic.

"We think that the largest opportunity is the [current mobile phone service] subscribers who . . . spend some time outside terrestrial coverage, and they want to complement that," explains Lluç Palerm-Serra, research director at telecommunications consultancy Analysys Mason. "It's never going to compete with [terrestrial cellular service] operators; it's going to complement them. For the satellite industry, going from serving 0.1% of the market to serving 1% of the market is a tenfold increase in the market opportunity."

Some satellite-based cellular service providers, such as AST SpaceMobile, Lynk Global and Starlink, partner with terrestrial mobile phone services and then broadcast from space using the borrowed spectrum.

"The advantage of this is that they can be backward-compatible," Palerm-

Serra says. "So an existing 4G phone would connect with the satellite network. . . . But the challenges are that the smartphone today has not been designed to connect with a satellite."

Connecting conventional mobile phones to satellites has performance drawbacks, Palerm-Serra notes. "The other big issue is getting the regulatory approval and managing the interference with terrestrial [signals]," he says.

Because of those issues, another group of satellite cellular service providers, including Apple partner Globalstar, are using a spectrum licensed for broadcasting from space while working with chipset and mobile phone manufacturers to connect to satellites.

Waiting for the mobile phone industry to integrate satellite connectivity slows adoption of the services, but "since the smartphone will be designed to connect with satellites from Day 1, the performances can be higher," Palerm-Serra says. "You have more certainty in terms of the regulatory process because these are [frequency] bands specifically assigned to satellites."

Most direct-to-cellular satellites broadcast from low Earth orbit, since their closer proximity to terra firma lowers latency levels. However, some services use geostationary satellites. Skylo, for instance, says it has partnered with six third-party constellations to provide service. In August, Verizon announced it would start using Skylo's service and expects to offer subscribers emergency messaging and location sharing in the first quarter of 2025 and texting later in the year.

Apple unveiled plans in November to spend \$1.5 billion to finance a new cellular satellite constellation with Globalstar to expand service. SpaceX tested the waters in October, when the U.S. Federal Communications Commission issued it and partner T-Mobile special permission to use Starlink to broadcast emergency alerts and test basic texting capabilities in areas of North Carolina where Hurricane Helene had knocked out terrestrial cellular service.

Still, emergency services are more of a test case than a serious market—Apple is giving them away free of charge, Palerm-Serra notes.

Texting is seen as a slightly better market, but it is not great, he says: "When the market really gets interesting is when voice and data services become available." 📶

Why the Defense Sector Is Globalizing Fast

- > THE U.S. DEFENSE BUDGET IS GROWING MORE SLOWLY THAN THOSE OF ITS ALLIES AND PARTNERS
- > NEW SUPPLY CHAINS ARE FORMING IN EUROPE AND ASIA



LWE DEFENDER/ALAMY STOCK PHOTO

Matthew Fulco Washington

In a world where economic nationalism is ascendant, the defense sector is a defiant outlier. Its globalization accelerated in 2024, from the deepening of the Australia-UK-U.S. alliance and UK-Italy-Japan trilateral fighter jet initiative to South Korea's burgeoning defense production in Europe.

To be sure, the U.S. remains the world's preeminent military power: The country spent \$916 billion in 2023 on defense, accounting for 37% of global expenditure and more than the next nine highest-spending countries combined, according to the Stockholm International Peace Research Institute (SIPRI).

Yet starting from a much lower baseline, the military budgets of U.S. allies and partners are growing faster than Washington's as they warily eye the worst threat environment since the apex of the Cold War. As unprecedented demand strains the U.S. defense industrial base, which is still recovering from pandemic-induced shocks, new supply chains are developing elsewhere.

Supply chain resilience has risen in importance since the COVID-19 pandemic, Melius Research Vice President Scott Mikus says. "When COVID hit, those factories shut down, and countries realized if you don't have some sort of alternative supply in another geographic location, you are at the whim of whatever the government decides."

At the same time, "if you want a

country to order more of your products, having same sort of manufacturing footprint there is a good idea," he adds, using Lockheed Martin as an example. Aviation Week reported in September that Lockheed might assemble and maintain C-130Js at Tata Advanced Systems in India if the defense prime wins an Indian Air Force order for up to 80 medium transport aircraft. An expanded partnership with Lockheed would move Tata into the defense maintenance, repair and overhaul market for the first time.

In the first nine months of 2024, non-U.S. NATO military spending rose 18%, while Asia's defense expenditure increased 10%, compared with 7% in the U.S., investment bank TD Cowen said in an Oct. 7 report. The spending mix is shifting toward weapons, which surged 35% for non-U.S. NATO members. In contrast, such spending by the U.S. has risen only an estimated 9%.

Among the top beneficiaries of this trend are the largest defense contractors. By TD Cowen's estimate, foreign military sales represent about 21-26% of revenue for Lockheed Martin, Boeing Defense, Space & Security and RTX's Raytheon Missiles & Defense.

In Europe, the Baltic states, alarmed by Russia's invasion of Ukraine, are increasing defense spending and cooperation. Estonia, Latvia and Lithuania pledged in December 2022 to raise defense spending to 3% from 2% of GDP. In January 2024, they agreed to set up a common Baltic defense zone on

Lockheed Martin might assemble and maintain Hercules C-130Js at Tata Advanced Systems in India, if the defense prime wins an Indian Air Force order for a new fleet of up to 80 medium transport aircraft.

their borders with Russia and Belarus.

There is "some uncertainty about U.S. support, plus the fact that our adversaries are now cooperating," says Cynthia Cook, senior fellow and director of the Defense-Industrial Initiatives Group at the Center for Strategic and International Studies. North Korean troops are now fighting alongside Russia against Ukraine, illustrating the "willingness of North Korea to engage in expeditionary warfare," she notes. "They may take lessons away from this conflict about modern warfare" that improves their capabilities.

During the Zero Gravity Summit in October in Salt Lake City, Palantir Senior Counselor Greg Little painted a bleak picture of rising geopolitical tensions. "It's not hard to make the argument, in my mind, that in a lot of ways, World War III has already started," he said. Unlike during World War II, the U.S. now lacks a world-leading defense industrial base, putting it at a competitive disadvantage vis-a-vis China, Little added.

Concerns about China's military buildup, widely judged to be the largest of any country since World War II, are driving greater defense spending

across the Asia-Pacific region. In July, the U.S.-Japan Security Consultative Committee released a statement that highlighted Beijing's "intensifying attempts to unilaterally change the status quo by force or coercion in the East China Sea," where Japan administers the Senkaku Islands, which are also claimed by China. The statement further expressed concern about China's "threatening and provocative activities in the South China Sea" and nontransparent, "rapid expansion of its nuclear weapons arsenal."

Newly published data by SIPRI shows that revenue among Japan's five largest defense manufacturers rose 35% to \$10 billion in 2023. "A policy of military buildup in Japan since 2022 drove a flurry of domestic orders," SIPRI said in a Dec. 2 news release, adding that the value of some companies' new orders jumped more than 300%.

Italy's Leonardo, the UK's BAE Systems and Japan's Mitsubishi Heavy Industries are collaborating on the Global Combat Air Program.

Japan announced a \$59 billion defense budget for 2025, its largest yet, in September. In its budget request, Tokyo emphasized that the international community "has entered a new era of crisis."

Italy, Japan and the UK said in October that they are expediting their joint development of an advanced fighter jet under the Global Combat Air Program, with the goal of deploying it by 2035. Leading the program are Italy's Leonardo, Japan's Mitsubishi Heavy Industries and the UK's BAE Systems.

Leonardo DRS CEO William Lynn said on a third-quarter earnings call that the company's international sales have doubled in the past 3-4 years to 10% of overall revenue from 5%. "Putin crossing borders in Europe, Iran in the Middle East and then the threats that China is posing by its increasingly aggressive behavior—all that's driving our allies to higher defense budgets," he said.

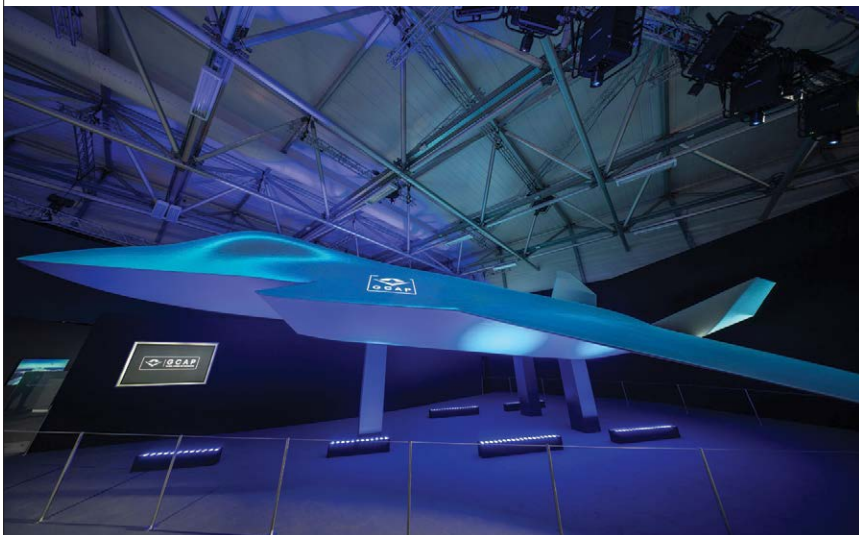
Among U.S. allies, South Korea has emerged as the most significant player in new defense supply chain. It aims to become the world's No. 4 defense exporter by 2027. Wooyeal Paik of Yonsei University notes that Seoul's defense exports have surged in value to a projected \$20 billion in 2024 from \$2-3 bil-

lion in the late 2010s. With major sales to Australia, Poland, Romania and Saudi Arabia in 2024, "the South Korean defense industry is indeed truly going global," Paik states in an April report published by the Italian Institute for International Political Studies.

Looking ahead, some industry executives see a bigger role for autonomous systems in new supply chains and a revival in the U.S. defense industrial base. "Mass matters again—we're learning that from [Russia's full-scale invasion of] Ukraine and wargames focused on China," says Paul Benfield, head of strategy at autonomous vehicle-

Taiwan established a counterpart to the Pentagon's Defense Innovation Unit in February. This move "opened up the possibility of coproduction," Tzuli Wu, an associate research fellow at Taiwan's Institute for National Defense and Security Research, said during an Atlantic Council event in October.

Phoenix-based autonomous systems developer ZenaDrone intends to manufacture up to 90% of its drone components, including batteries, sensors and circuit boards, in Taiwan, Taiwanese industry newspaper DigiTimes reported in November.



MALCOLM PARK/ALAMY STOCK PHOTO

maker Forterra. "We've been oriented toward expensive platforms. We can't afford that moving forward, and neither can our allies and partners with smaller budgets."

Cost-efficient advanced manufacturing and robotic processes can help alleviate the strain on the U.S. defense industrial base while boosting domestic manufacturing, he says. At the same time, given the challenges of transporting defense systems across theaters, production capacity in the Indo-Pacific region makes sense.

Taiwan's bid to become an Asia-Pacific drone production hub is a key example of this trend. It hopes to leverage its advanced manufacturing capabilities and capitalize on growing antipathy toward China, the world's top producer of uncrewed aerial vehicles (UAV). Taipei aims to reach NT\$30 billion (\$920 million) in drone production value by 2028 with a monthly manufacturing output of 10,000 UAVs.

U.S.-Taiwan Business Council President Rupert Hammond-Chambers says that "Taiwan is certainly focused on drone development, and they are making some headway" with such companies as Thunder Tiger in developing platforms for domestic and foreign markets.

The possible entry of Taiwan's system integrators into the research, development and production of defense articles is important, Hammond-Chambers says. "They can bring real expertise and entrepreneurialism to the sector while also producing end-items at the most efficient time and cost," he notes.

As for the prospects of joint production with the U.S. in Taiwan, Hammond-Chambers notes that "domestic voices" might argue that U.S. technology should be made in America as part of the incoming Trump administration's industrial policy. "We'll have to wait and see which voices win out," he says. 🇺🇸

Labor and Management Both Will Keep Adjusting Their Yokes in 2025

- > MORE AEROSPACE UNION STRIKES ARE POSSIBLE AS OTHER NEGOTIATIONS LIE AHEAD
- > TECHNOLOGY COULD CHANGE DEMAND FOR LABOR

Michael Bruno Washington

If 2024 was the year of big walkouts and wake-up calls in the aerospace and defense workforce, then 2025 could be the year when industry finally faces the new realities affecting labor pools.

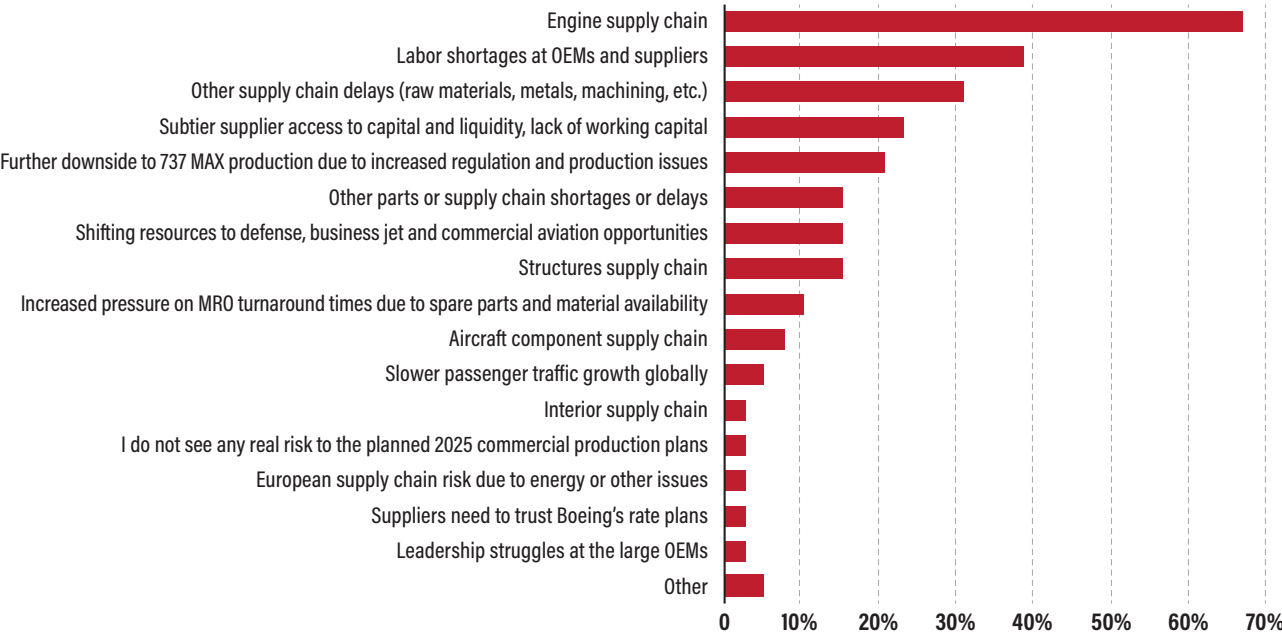
face renegotiation in the coming months and years. One reason the strikes occurred was that management remained out of touch with its line workers. Despite open warnings, the strikes at Boeing and Textron in

baby boomers retire, and rising protectionism worldwide has led to more demand for workers at home. This dynamic differs from that in the previous era when workers were comparatively at a surplus.

“Even if free trade were to continue unhindered, labor has more power,” Aboulafia wrote in his November newsletter. “Also, as countless sociologists have commented, there’s been a generational shift, and employees have much less loyalty than in the past. They’re now as transactional as management has become.”

At the same time, the Boeing, Spirit and Textron strikes stand as examples

Key Risks to Commercial OEM Recovery and 2025 Production Rates



Note: Respondents were allowed to choose up to three responses. Source: RBC Capital Markets

The 53-day strike by nearly 33,000 International Association of Machinists and Aerospace Workers (IAM) union members in the fall at Boeing’s Pacific Northwest commercial manufacturing hub punctured any remaining delusions that labor-management relations were good enough to focus on finally ramping up aircraft production rates. Indeed, the surprising state of disconnect was underscored by Textron Aviation workers’ own strike in Wichita in the middle of the Boeing spat.

Industry could face more work stoppages as other union contracts

2024 and Spirit AeroSystems in 2023 surprised executives and insiders time after time.

But other factors have bolstered workers to go ahead and strike, starting with a long-term shift in power dynamics between labor and management. Richard Aboulafia, *AW&ST* contributing columnist and Aero-Dynamic Advisory managing director, has stressed at industry conferences and in his own writings that aerospace manufacturing has turned from a question of demand to one of supply. Unemployment now generally is low, demographics are changing as

for others of what can be achieved by group action.

“Peripheral impact also is critical since suppliers will see the Boeing agreement as a benchmark for their upcoming contract negotiations,” TD Cowen analysts Cai von Rumohr and Gautam Khanna stated in a November note to investor clients. “For example, Spirit AeroSystems, which Boeing has agreed to acquire, also is represented by the IAM. Their contract is up in 2026, and the differential between wages in Wichita, where Spirit is located, and Seattle was an issue before Spirit was spun out of Boeing in 2005.”

IAM represented 57% of Spirit workers at the start of 2024 under two major agreements—one expiring in June 2027 and another in November 2027, according to the company's latest annual regulatory filing. Besides the roughly 1,000 Society of Professional Engineering Employees in Aerospace (SPEEA) workers who settled with Spirit in late November for at least a 23% raise over four years, other union members face another contract expiration in January 2026.

"These are the largest wage pools we've ever received from Spirit, going back to its formation in 2005," said SPEEA Strategic Development Director Rich Plunkett, who led the recent bargaining negotiations. "This contract can only help Spirit attract and retain top-level engineering talent."

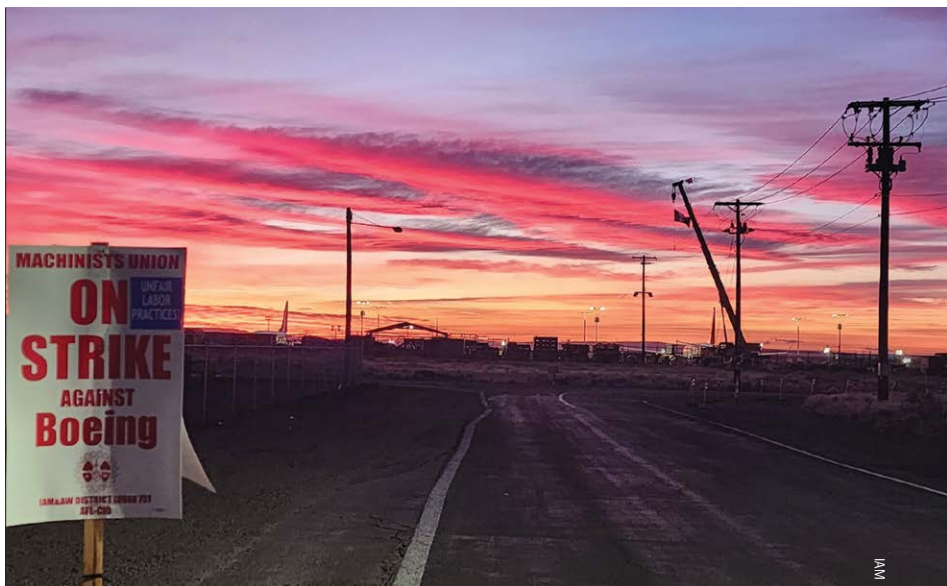
SPEEA represents 16% of the Spirit workforce. Another 6% are represented by the United Auto Workers (UAW) and have an agreement expiring in December 2025. The International Brotherhood of Electrical Workers represents 1% and has a contract that expires in September 2027.

At Triumph Group, 55% of the collectively bargained workforce is under contracts set to expire within a year of the company's last annual filing in May.

Boeing also has more negotiations coming. SPEEA represented 10% of Boeing's workforce at the start of 2024 under two agreements—one with SPEEA Professional and one with SPEEA Technical—and both expire in October 2026. UAW represented 1% in Pennsylvania, and that agreement expires in April 2027.

Regardless of union representation or whether an employer is publicly traded, workers everywhere will remember that Boeing's Puget Sound factory workers won the roughly 40% wage increase they sought. The result could be general pressure across industry to continue raising pay and benefits, industry advisers tell Aviation Week.

These inflationary pressures come as the supplier base continues to struggle in the aftermath of the COVID-19 pandemic. At Aviation Week Network's Engine Leasing, Trading & Finance Europe conference in London in June, Alistair Forbes, senior market analyst at MTU Maintenance, stressed that smaller repair providers are still contending with labor shortages.



The 53-day strike by Boeing union workers in the Seattle area ended in November, but the reverberations could be felt for years to come as other contracts must be renegotiated.

"Most of the big people have been able to recruit and train, but some of the smaller outfits are finding it harder to get people in, and that's where we're probably seeing the pinch point," he said.

Employers know this. Accenture's latest Commercial Aerospace Market Insight Report and survey of the commercial aerospace industry, issued in October, noted that executives expect their production labor costs to keep rising over the next two years. According to the latest semiannual Voice of the Supplier survey from RBC Capital Markets, released in November, labor shortages remain at the top of the list of industry's concerns (see chart).

Still, some of the strain might be ameliorated in 2025. For starters, larger companies are starting to let go some of their staff, potentially opening up labor for suppliers. Boeing announced cuts to 10% of its workforce, or roughly 17,000 workers, in October as it tries to turn itself around. Industry insiders expect more back-office white-collar workers could be let go after Boeing closes its acquisition of Spirit, slated for mid-2025. Rival Airbus also announced in October that it will cut staff and reorganize its defense and space unit to respond to business challenges that have dented the company's earnings since 2023.

Second, industry is increasingly adopting and implementing new technologies to address labor concerns.

This trend is not new, and it remains a piecemeal and uneven phenomenon across the sector; consultants tell Aviation Week. But artificial intelligence (AI) and newer generative AI-based services are adding to executives' proverbial toolbox for facing labor concerns.

"Although the industry has faced this issue before, 2025 may prove to be a pivotal year for aerospace and defense companies considering the role digital technologies like AI/GenAI could play in enhancing traditional talent strategies," Deloitte said in its 2025 Aerospace and Defense Industry Outlook.

Deloitte believes that the benefits will accrue to both labor and management. While executives can keep operations going or ramp up, workers could see gains sooner. "With help from emerging technologies, such as extended reality, the industry will likely begin to enhance the training environment and shorten the time it takes to bring employees up to speed," the consultancy said.

Such advances might ultimately help the two sides better connect. "As aerospace and defense companies account for the current talent challenges, they are likely to begin to plan for deploying people and fostering career development opportunities with the same rigor that they plan for parts and products," the outlook suggested. 🛩️

ANALYSIS



Confusing, Complex, Contradictory

Jens Flottau Frankfurt

SEEMINGLY NOW MORE THAN EVER, TRENDS in commercial aviation are confusing, complex and contradictory. Conventional wisdom suggests that wars in several regions, the threat of new trade tensions and tariffs, protectionism, onshoring, and complaints of overtourism are bad for aviation. Yet the industry is set to grow 8% next year. Airlines and lessors are accepting almost any aircraft they can get their hands on, yet manufacturers cannot deliver nearly the numbers necessary. The need to become more sustainable is blatantly obvious, yet the industry's emissions continue to rise, as do costs for labor and infrastructure.

IndiGo has more than 900 aircraft on firm order as it seeks to take advantage of strong growth in India's aviation market.



How will this industry continue to thrive in the new year? Part of the answer is that it has stopped thriving already. Very different commercial aviation industries are taking rather different paths in various regions, sometimes even from one country to another. Take Europe, for example: Greece is expected to reach 127% of 2019 seat capacity in the first half of 2025, Poland is at 120% and Spain at 119%. Finland and Germany are at 85%. Europe's overall expected growth, which is still substantial, is largely slated for markets dominated by leisure traffic. The more mature economies—and some of the biggest—are showing severe signs of crisis.

These crises stem in large part from political decisions. A huge increase in air traffic control charges, security fees and aviation taxes has made flying very expensive. Domestic flights in Germany are disappearing. The Netherlands is expected to reach 99% of 2019 capacity in early 2025, but the Amsterdam hub is under serious threat by a proposed flight cap. Flying is a political target in the Netherlands and elsewhere, economic and social consequences notwithstanding. Even the UK, an island nation, appears to be discouraging air travel politically.

Two interesting watch items: likely deregulation under a new U.S. administration and the Draghi Report, which recommends that Europe increase its competitiveness vis-a-vis other regions.

It cannot be ignored that in some regions, flying is on the rise. The center of gravity in the airline industry is shifting farther east: Air India has just added an order for 100 more aircraft and is awaiting 570 new aircraft. Those numbers are of course exceeded by IndiGo's order for 909 aircraft. In Saudi Arabia, several airlines are expanding, and Riyadh Air is expected to start commercial service by the middle of the year. Discussions of flight caps are as far away as an ultra-long-haul flight.

Some common themes prevail on the manufacturing side of the industry: trade risks, the dysfunctional supply chain that will continue to be problematic for several

years and the pressure to meet delivery dates and volumes. There are also distinct differences between the big players. Boeing has to show marked progress in 2025 in production quality, schedule adherence and output volumes. Certification of the 737-7, -10 and 777X are huge concerns for its customers. Airbus is in better shape but also has caused its customer base big frustration with late deliveries. On the other hand, the A321XLR will begin to reshape long-haul networks as more airlines introduce the type.

Embraer appears to be walking away from an earlier timeline in which it would have made a decision in 2025 to look more deeply into the potential launch of a new commercial aircraft, even though airlines generally welcomed the idea and told Embraer they would consider large orders if it went ahead. The Airbus-Boeing duopoly among Western manufacturers of large commercial aircraft looks as if it will remain the status quo for the time being.

Sustainability progress is stalling in some ways as many sustainable aviation fuel production projects have been put on the back burner, and the prospect of cheaper jet fuel for the foreseeable future is slowing the impetus to replace aviation's energy source. But it appears that 2025 will see considerable advances in contrails research, which could lead to relatively quick advances in curtailing aviation's impact on the climate. 🌱



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TRACKING CONTRAILS

- > INDUSTRY STEPS UP EFFORTS TO BETTER UNDERSTAND NON-CO₂ EFFECTS
- > EUROPEAN AIRLINES MUST MONITOR AND REPORT NON-CO₂ EFFECTS STARTING JAN. 1
- > IMPROVED MODELING AND FORECASTING CAN HELP CARRIERS AVOID FORMING CONTRAILS



Research is underway to assess the radiative-forcing impact of contrails.

NASA PHOTOS

Helen Massy-Beresford Paris, **Guy Norris** Norfolk, Virginia, and **Graham Warwick** Washington

Beginning on New Year's Day, European airlines will face a new requirement: As part of the European Emissions Trading System legislation, carriers will have to conduct monitoring, reporting and verification of aviation non-CO₂ effects.

The European regulatory policy is just one indication that the effects of contrails and aviation's other non-CO₂ effects are increasingly in the spotlight. As awareness grows about the climate impact of contrails, a doubling down is expected in the new year of research into potential mitigation methods and into the fundamental atmospheric physics of the phenomenon.

The pace of contrail research is accelerating as aviation recognizes that improving sustainability depends as much on addressing climate-influencing non-CO₂ emissions as it does on reducing CO₂ emissions by expanding the use of low-carbon fuel and improving aircraft efficiency.

But environmentalists argue that although progress is being made, it is not happening rapidly enough. While

the COP29 climate conference was underway in November in Baku, a group of aviation and climate scientists wrote an open letter urging faster action on contrails, calling it an opportunity to make a big difference at a relatively low cost to industry.

The problematic effects of contrails have been known for decades, but the issue has simply been swept under the rug, says environmental nongovernmental organization Transport & Environment (T&E), which published the letter.

"Crucially, if decisive action is taken, these effects may be partly mitigated in a faster and more cost-effective way than other climate issues, thanks to slightly rerouting a small number of targeted flights," the letter said. "This would entail minimum impact on the aviation industry and pas-

sengers and a negligible risk of doing more climate harm than good."

T&E Aviation Technical Manager Contrails are "aviation's climate opportunity of the decade," T&E Aviation Technical Manager Carlos Lopez de la Osa said. "There are very few climate solutions that can be implemented so quickly at so little cost."

Recent research efforts aimed at better understanding contrails support T&E's position. Contrails form when hot engine exhaust mixes with the surrounding colder air to form ice crystals. In ice-supersaturated regions of the atmosphere, these crystals grow, and the contrail can persist and expand into an aircraft-induced cirrus cloud.

During the day, this thin layer of cirrus reflects sunlight and cools the Earth; at night, however, the cloud traps the heat and warms the planet. This imbalance, or "radiative forcing," stemming from contrails is considered to have an overall warming effect on climate.

A major focus for investigators is

perfecting techniques to measure and assess contrails produced by the current generation of aircraft and engines, thereby setting a baseline against which improvements can be measured and mitigation achieved.

In the U.S., NASA and GE Aerospace began evaluating aircraft-wake scanning technology in November during flight tests under the Contrail Optical Depth Experiment (CODEX). Conducted from Norfolk, Virginia, the tests involved NASA Langley Research Center's Gulfstream G-III aircraft and GE's Boeing 747-400 flying testbed.

Operating at altitudes over 30,000 ft. in restricted airspace off the East Coast, the Gulfstream trailed at various distances behind and above the 747, scanning the GE testbed's wake with light detection and ranging (lidar) sensors to generate 3D imaging of the contrails. For CODEX, the 747 was configured with four standard GE CF6-80CB1F engines powered by regular Jet A fuel.

Besides improving knowledge of contrail formation and behavior over time, CODEX's data is also expected to help GE pave the way for future flight-testing of lower-emission combustors and other advanced propulsion technologies planned with CFM International partner Safran under the Revolutionary Innovation for Sustainable Engines (RISE) program.

"We know from recent modeling assessments and consensus reports that contrails have a significant climate impact, and we think from current model estimates the magnitude of that impact from contrail cirrus clouds today is of similar magnitude to that from the accumulated emissions of aviation CO₂ over the past century," says Richard Moore, physical research scientist at NASA Langley Research Center.

"So while it's highly uncertain, we know that it's a potentially important effect how the contrail interacts and evolves in the atmosphere and interacts with the radiation and the sunlight coming down and the radiation coming up from the earth," Moore explains. "This directly depends on the optical properties of that cloud. With the lidar, we're bringing our own light source. Instead of having to rely on the Sun and specific solar angles, we can shoot a laser down at a green wavelength, 532 nanometers, and we

can measure the amount of light that is backscattered up by the ice crystals in the contrail."

The G-III was configured with Langley's High-Altitude Lidar Observatory (HALO), an instrument developed to characterize distributions of greenhouse gases, clouds and small particles in the atmosphere. HALO provides nadir-viewing profiles of water vapor, methane columns and profiles of aerosol and cloud-optical properties. Until NASA conducted a test with Boeing under the ecoDemonstrator program in late 2023, HALO had never been applied to contrail analysis.

"We get a profile of that light being scattered back to the aircraft, and then we are able to relate that to the amount of light being not only scattered back but also absorbed and extinguished," Moore says. "If we take that profile of light extinction through the contrail, we can add it up, and that's something we call the optical thickness of the cloud, or the contrail.

tions and forecast the optical thickness properties that feed into radiative-forcing calculations. The work is targeted not only at comprehending contrail formation but also, in the longer run, providing hard data to an industry, which is wary of encouraging contrail-mitigation policies if it turns out that the warming cirrus would have formed naturally anyway.

"There may be 70% uncertainty in the effective radiative forcing of contrails, but that should not prevent us [from] starting to reduce them," Christiane Voigt, head of the cloud physics department at German aerospace center DLR, said at the ICAO Symposium on Non-CO₂ Aviation Emissions in Montreal in September. "At the lowest point on the error bar, they are still important."

While many industry insiders believe immediate action is necessary to tackle contrails, some argue that a deeper comprehension of the phenomenon should take first priority.



That's an important parameter for understanding the radiative impacts."

Together with information from the high-spectral-resolution lidar channels, the sensor suite included a laser tuned to specific absorption bands for water vapor. "So in addition to dragging the laser beam across the aircraft's track to give us the profile of the contrails, we're continuously measuring along the track the curtain of the water vapor field below the aircraft," Moore says. To complete the dataset, the NASA aircraft also dropped radiosondes to measure temperatures.

The atmospheric data from the contrail surveys will help validate models that predict contrail formation condi-

A recent research study by scientists at Imperial College London highlighted the complexity of understanding how reducing contrails fits in with broader efforts to limit aviation's climate impact.

The study, based on machine-learning analysis of satellite data on contrails over the North Atlantic, showed that modern commercial aircraft create longer-lived contrails at high altitudes than older aircraft do. Although modern aircraft emit less carbon than older aircraft, they may be contributing more to climate change through contrails, the researchers said in August.

"This study throws a spanner in the

works for the aviation industry,” the study’s lead author, Edward Gryspeerd, a Royal Society University Research Fellow at Imperial College London’s Grantham Institute-Climate Change and the Environment, said at the time. “Newer aircraft are flying higher and higher in the atmosphere to increase fuel efficiency and reduce carbon emissions. The unintended consequence of this is that these aircraft flying over the North Atlantic are now creating more longer-lived contrails, trapping additional heat in the atmosphere and increasing the climate impact of aviation.

“This doesn’t mean that more efficient aircraft are a bad thing,” he added. “Far from it, as they have lower carbon emissions per passenger mile. However, our finding reflects the challenges the aviation industry faces when reducing its climate impact.”

The study found that one simple step—reducing the amount of soot emitted from aircraft engines—could shorten the lives of contrails.

“Our study provides the first evidence that emitting fewer soot particles results in contrails that fall out of the sky faster compared to contrails formed on more numerous soot particles from older, dirtier engines,” said study co-author Marc Stettler, a professor of transport and the environment in Imperial College London’s department of civil and environmental engineering.

Mitigating strategies for contrail formation are focused primarily on avoiding ice-supersaturated conditions in the atmosphere and reducing the particles in the engine exhaust on which ice crystals can nucleate. Avoiding areas prone to contrail formation would require rerouting only a small fraction of flights, Voigt said.

Aircraft can avoid contrail-forming regions by flying higher or lower, but that will require improvements in modeling and forecasting to enable airline operations centers to predict atmospheric hot spots where contrails could form and to reroute flights with minimum impact on fuel consumption and emissions.

It also will also require collaboration with air traffic control, which must approve the changes. Operational trials are underway to determine the practicality and effectiveness of altitude adjustments. “Operationally, it is very challenging, and weather and contrail models must be improved and tested,” Voigt said.

A T&E study released in November found that slightly altering the routing of just a few flights could halve contrail warming by 2040 at a cost of less than €4 (\$4.20) per flight.

and contrails. But the results include some surprises.

The latest generation of commercial turbofans with lean-burn combustion, such as GE’s GENx 1 and CFM’s Leap 1, generate significantly less soot, also known as nonvolatile particulate matter (nvPM). Reducing soot should reduce ice crystals and therefore contrail formation, but recent flight tests show there is a limit.

As nvPM emissions fall, some models predict that ice crystal formation will diminish until reaching a lower

limit set by naturally occurring aerosols in the atmosphere. Other models predict that ice formation will reduce at first but then increase as volatile particles in the plume take over from soot as nucleation sites.

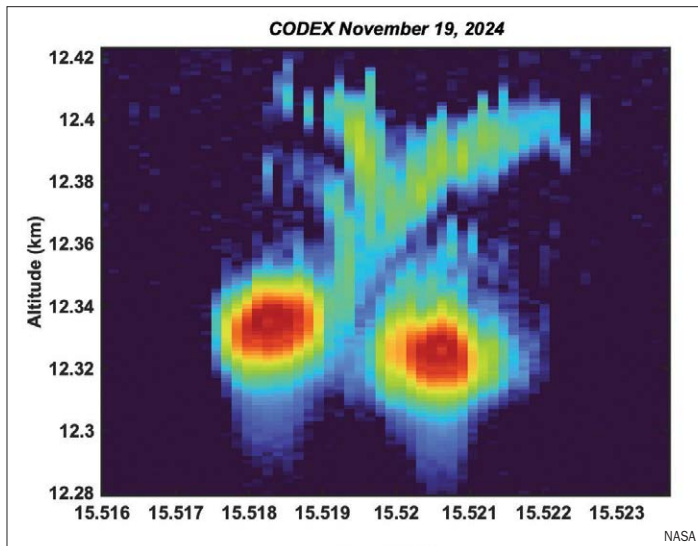
The latter effect was confirmed by flight tests of a Leap 1A-powered Airbus A320neo in France under the Volcan project and a Leap 1B-powered 737-10 in the U.S. under the NASA-Boeing ecoDemonstrator program. The Volcan flights indicated that volatile particles become

nucleation sites as soot reduces. The ecoDemonstrator flights showed 100% SAF reduces ice crystal formation, but contrails still form due to volatile particles.

In contrast to nvPM emissions, volatile particulate matter (vPM) consists of condensable gases in the exhaust plume that can form new particles or coat existing soot particles, making them more able to form ice crystals. They depend on both the combustion process and fuel composition, Richard Miake-Lye, principal scientist and vice president at Aerodyne Research, told the ICAO symposium.

Examples of vPM include unburned and partially combusted fuel, sulfuric acid from the fuel and lubrication oil vented from the engine. Oil is currently not considered an emission and is vented differently among engine manufacturers. There are certification standards for nvPM emissions, which are measured on the ground at the exhaust exit, but not for vPM, which evolves after emission.

Fuel composition is also an import-



Backscatter from ice crystal vortices in a contrail cross-section over time are captured in this CODEX experiment lidar image.

The report said that 80% of contrail warming is generated by only 3% of flights; geography, flight latitude, time of day and seasonality all play a role in their climate warming effects. The study noted that the extra fuel expended to avoid contrails would be less than 0.5% across the whole fleet over a year.

Overall, the T&E study showed that the climate benefits from contrail avoidance would be 15-40 times greater than the CO₂ penalty. Changing the flightpaths of only the worst culprits would have a disproportionately big impact.

The second key to contrail formation, soot in exhaust plumes, is already being tackled through engine technology improvements and fuel changes. Cleaner-burning engines and sustainable aviation fuel (SAF) have been shown to generate less soot

ant factor. SAF has lower sulfur and higher hydrogen content than fossil jet fuel, reducing soot and ice formation. When fewer ice crystals are in the plume, those crystals grow larger and sediment out more quickly, reducing the lifetime and radiative forcing of the contrail, Stettler told the symposium.

All these tests, including those undertaken for the EU's Emission and Climate Impact of Alternative Fuel (ECLIF) experiments, indicated the need for future campaigns to map a

wide range of fuel compositions, engine types and combustor technologies. In particular, the surprise discovery of contrail formation even from lean-burn engines using SAF has led to calls for studies of other species of vPM, including engine oil. Such programs as CODEX have added to the database for evaluating contrails from older engines and have broadened the knowledge about their properties over time.

Plans to gather more data to improve climate and contrail models

include launching satellite atmospheric infrared sounders and deploying water vapor sensors on in-service aircraft. "We have limited data in cruise with different aircraft, engines and fuels," Moore says. "There are going to be some surprises, just as oil has risen to the surface with lean-burn engines." 📷

Gallery See more about commercial aviation developments in 2024: [AviationWeek.com/Commercial2024](https://www.aviationweek.com/Commercial2024)

People To Watch



Michael Augello
Airbus UpNext CEO

Airbus' long-term push for autonomous flight is facing headwinds, with major players in aviation expressing opposition or withdrawing support. The airframer's innovation arm, Airbus UpNext, has been at the forefront of the quest for autonomy, potentially enabling single-pilot operations as a first step. UpNext has conducted three autonomy demonstration programs, the latest dubbed Optimate. With the European Union Aviation Safety Agency having replaced "autonomous flight" with "advanced automation," Augello and his team face a reality check.



Rick Deurloo
Pratt & Whitney Commercial Engines president

Facing another tough year of balancing increased geared turbofan production for Airbus and returning compliant engines to operators, Deurloo aims to deliver on Pratt & Whitney's goal of steadying the ship in 2025. Since being appointed to his role in 2022, Deurloo has led efforts to rectify the powdered-metal issues that continue to plague the GTF-powered A320neo family, while adding to the global MRO network to accelerate the return to service program. Although supply chain issues continue to slow production rate recovery, material constraints appear to be easing. Deurloo also is overseeing the planned transition to the upgraded PW1100G Advantage version, certification of which is expected early in 2025.



Nathalie Tarnaud Laude
ATR CEO

Regional turboprops seemed to have a bright future, with their environmental credentials and the global insatiable appetite for air travel. But since the mid-2010s, reality has been contradicting expectations. The new year may indicate whether Tarnaud Laude will be able to stop the flow of bad news for ATR, from slow



Ben Minicucci
Alaska Air Group CEO

As Alaska's integration with Hawaiian Airlines comes into full force, 2025 will be a pivotal year for Minicucci. The companies are working to secure a single operating certificate from the FAA, which would enable Alaska and Hawaiian to operate as a single carrier with an integrated passenger service system. Minicucci is no stranger to mergers. He handled the integration of Alaska and Virgin America from 2016 to 2018, which was arguably one of the smoother combinations in U.S. airline consolidation history. Will he be able to replicate his previous success?



Francisco Gomes Neto
Embraer CEO

Embraer has been weighing options for investment into its next aircraft development program. With Gomes Neto leading the effort, the company is considering new aircraft in defense and business aviation and a larger commercial jet that would compete with Boeing's 737 MAX and Airbus' A320neo family. A first decision could be made by the middle of the year.



Adrian Neuhauser
Abra Group CEO

Since Neuhauser stepped into his role at Abra Group—parent company of Avianca and GOL—the company has acquired Spanish wet-lease operator and charter specialist Wamos Air and tried to form a joint venture with Volotea to seize slots if they became available through International Airlines Group's (IAG) acquisition of Air Europa. Although IAG ultimately abandoned its pursuit of the Spanish carrier, Abra's moves show its growth ambitions. The next big milestone for Abra is GOL's planned emergence from Chapter 11 bankruptcy protection in early 2025, which should unlock opportunities for increased cooperation between Avianca and GOL and could usher in more consolidation in Latin America.



Kelly Ortberg
Boeing president and CEO

Having survived a few torrid months since taking the helm at Boeing in August—including a crippling 53-day machinists strike that ended in November—Ortberg has his hands full as he implements an aggressive multipart plan to turn around the struggling company. The first target is ramping up production of 737s and 787s to generate much-needed cash flow, which he hopes to achieve by mid-year. Much will depend on progress in hitting quality improvement targets established with the FAA for the 737 line. In parallel, Ortberg is focused on obtaining long-delayed certification of the 737-7 and -10 and 777-9 through improvements in risk management as well as holding to schedule, cost and performance. Underpinning it all are broad-ranging organizational streamlining and cost-reduction efforts, including divestment of noncore aircraft production businesses.



Pat Shanahan
Spirit AeroSystems CEO

Shanahan was a board member of the company in October 2023 when he was appointed to executive leadership in a surprise transition with a mandate to fix the ailing aerostructures giant. Soon, his job became signing and executing on the planned sale of Spirit to its key OEM customers, Airbus and Boeing, to be completed in 2025. His career included decades rising at Boeing before he became deputy U.S. defense secretary in the first Trump administration, and Shanahan was widely discussed as a candidate to replace Dave Calhoun as Boeing CEO as that OEM started a turnaround of its own.

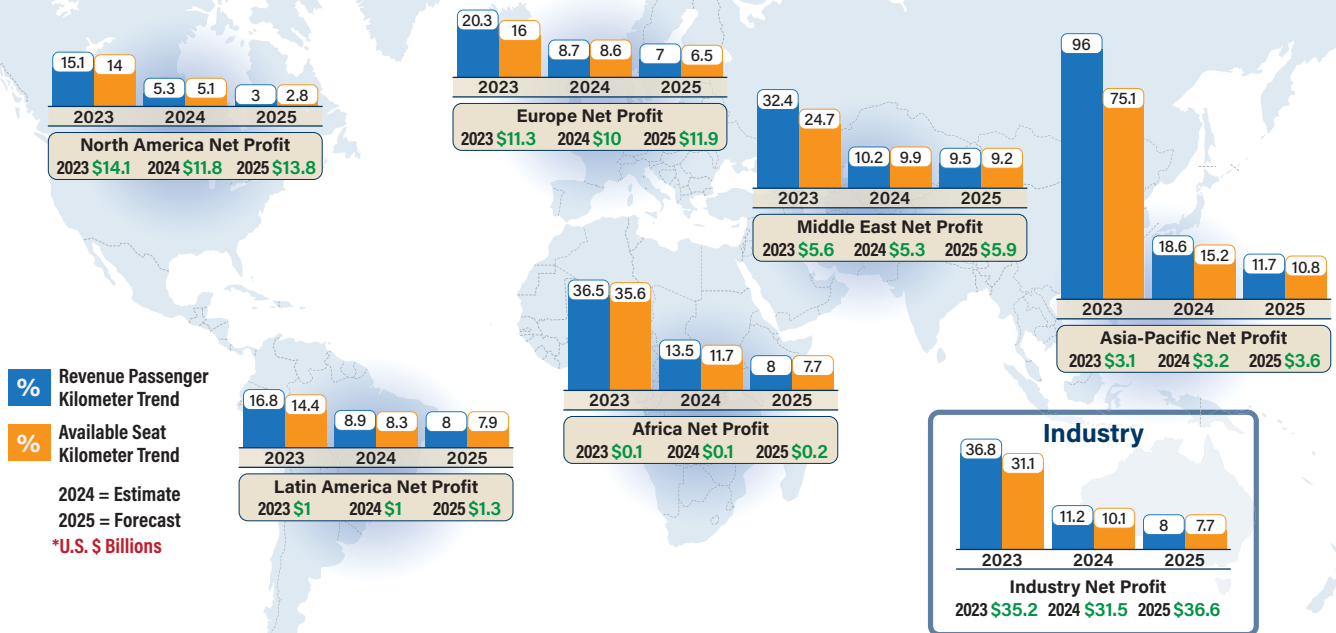


Lars Wagner
MTU Aero Engines CEO

A key figure behind the company's continuing success amid the turmoil of Pratt & Whitney geared turbofan durability shortfalls and in the post-COVID-19 recovery, Wagner is about to change course. In early 2026, he will take over as CEO of Airbus Commercial Aircraft, succeeding Christian Scherer, who plans to retire that year. Before Wagner moves to Airbus, he needs to deliver on the PW1100 production ramp-up to deliver strong results in his final year at MTU. 📷

PHOTO CREDITS TOP TO BOTTOM FROM TOP LEFT: ICAO, PRATT & WHITNEY, ATR, ALASKA AIR GROUP, EMBRAER, ABRA GROUP, BOEING, SPIRIT AEROSYSTEMS, MTU AERO ENGINES

Airline Capacity, Demand and Net Profit by Region*



Source: International Air Transport Association

Growing in Crisis Mode

- > AIRLINES CRITICIZE INDUSTRY FOR DELIVERY DELAYS
- > STRONG DEMAND INCREASE EXPECTED FOR 2025
- > THE SECTOR FALLS BEHIND ITS SUSTAINABILITY TARGETS

Jens Flottau Geneva

Overregulation and inadequate, expensive infrastructure traditionally top the list of carriers' complaints. But as the airline industry heads into 2025, governments, airports and air traffic control have been replaced as the greatest sources of frustration. Instead, airframers and their suppliers are turning what would otherwise be a wonderful air transport boom into an operational nightmare with deep effects on airline bottom lines.

Some 700 aircraft are currently grounded because of engine durability issues and a lack of spare parts, according to estimates by the International Air Transport Association (IATA). Boeing deliveries have fallen far below original projections be-

cause of production quality issues and the recent International Association of Machinists and Aerospace Workers strike. Airbus, too, has struggled to meet its overall delivery targets, and many of the deliveries taking place had been delayed at least several months. Engines, cabin interiors and structural components are the main pacing items slowing aircraft production.

Now it seems that the airlines have had enough. IATA plans to look for evidence of anti-competitive behavior among aircraft manufacturers and within the aerospace supply chain.

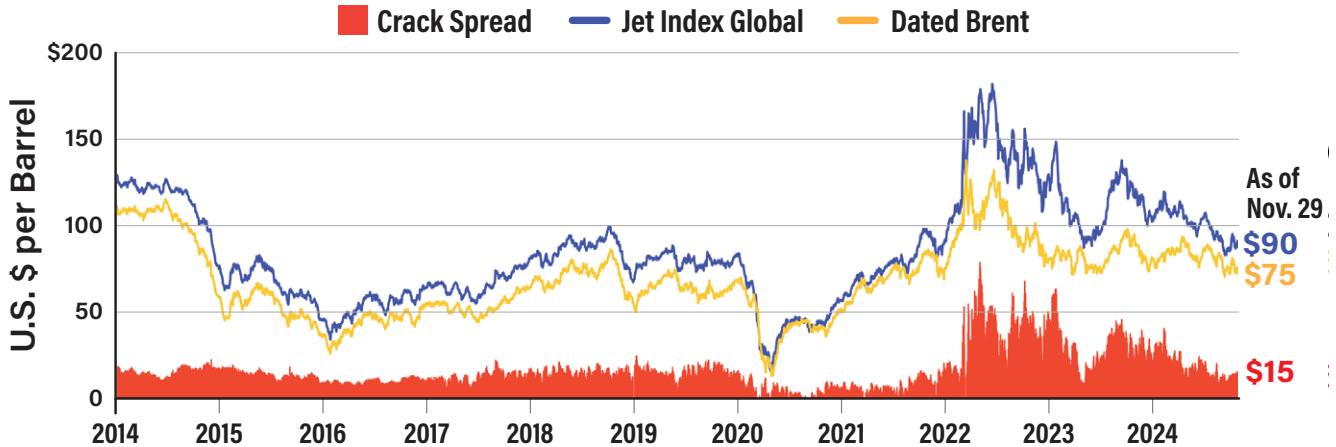
"I prefer if we didn't have to go down that road, but we have been patient for too long," IATA Director General Willie Walsh said at the association's

global media day here Dec. 10. "IATA can play a significant role in this.

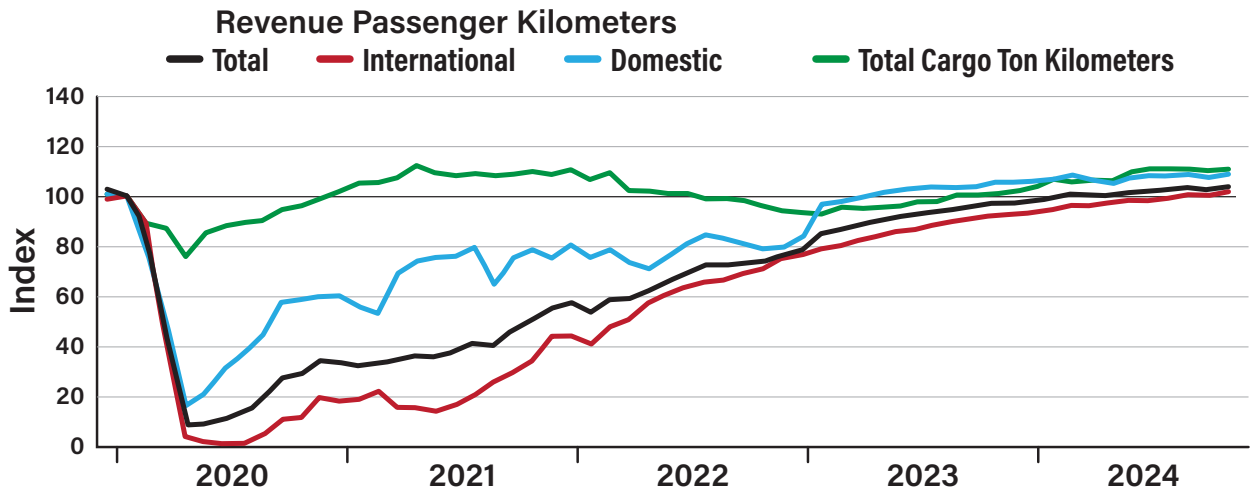
"Key suppliers appear to be immune from normal competitive dynamics," Walsh added. "We are dealing with quasi-monopoly suppliers. There could well be evidence that this is a case of these suppliers being able to abuse their dominant position... They are benefiting from the supply chain issues. There is no evidence that they are resolving this." What aircraft and engine manufacturers are doing so far to address the situation is "just not good enough," he noted.

IATA has investigated potential anti-competitive behavior by a supplier before. In 2016, the group and some of its members joined a case before the European Commission.

Jet Fuel Price Trends



Air Transport Demand Recovery



Source for charts: IATA

That complaint, against CFM International, involved information-sharing with third-party maintenance, repair and overhaul providers. The issue was eventually settled in 2018.

“Our biggest frustration is the supply chain, aircraft and engines; it is a bigger impediment right now than infrastructure,” Walsh said. “There is no evidence of it getting better.” At this point, he said he doubts industry will be able to get back on track before the end of the decade.

The supplier shortfalls are hitting

the airline industry in otherwise good times. While the strong growth rates in the immediate aftermath of the COVID-19 pandemic are moderating, carriers are still growing substantially, and far more quickly than global GDP. IATA estimates that demand will be up 11.2% for 2024 and still 8% in 2025. This trend continues to be supported mainly by the Middle East and Asia-Pacific regions, where revenue passenger kilometers are expected to grow 9.5% and 11.7%, respectively.

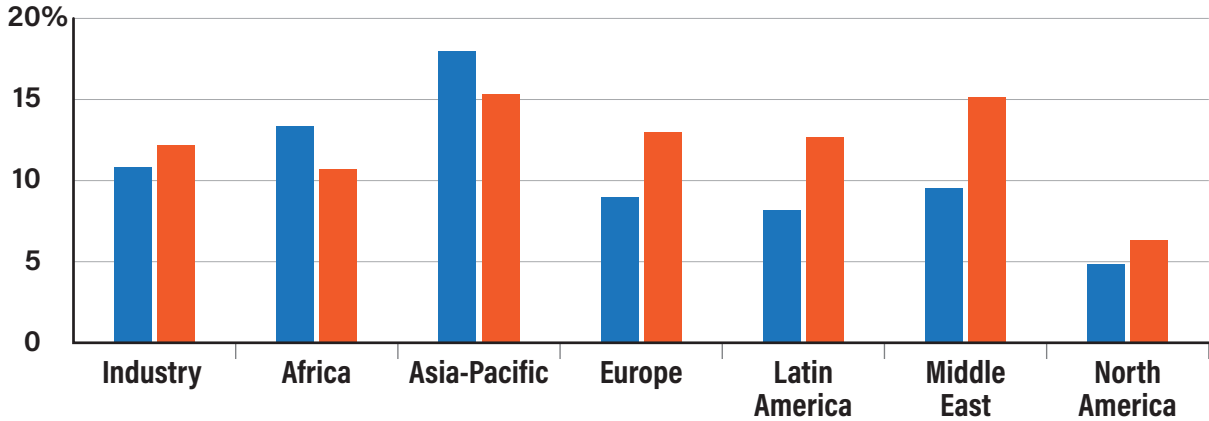
Air travel in other regions, such as

Europe (7%) and Latin America (8%), also will likely rise substantially next year, despite recessions in markets like Germany and slow economic growth in many others. With capacity expanding slightly more slowly than demand, load factors are expected to edge up even further.

IATA forecasts global airline industry net profits will reach \$36.6 billion in 2025, somewhat higher than in 2023 and 2024 but still in line with the relatively weak net margins that have been typical for the industry for de-

Airline Growth by Region*

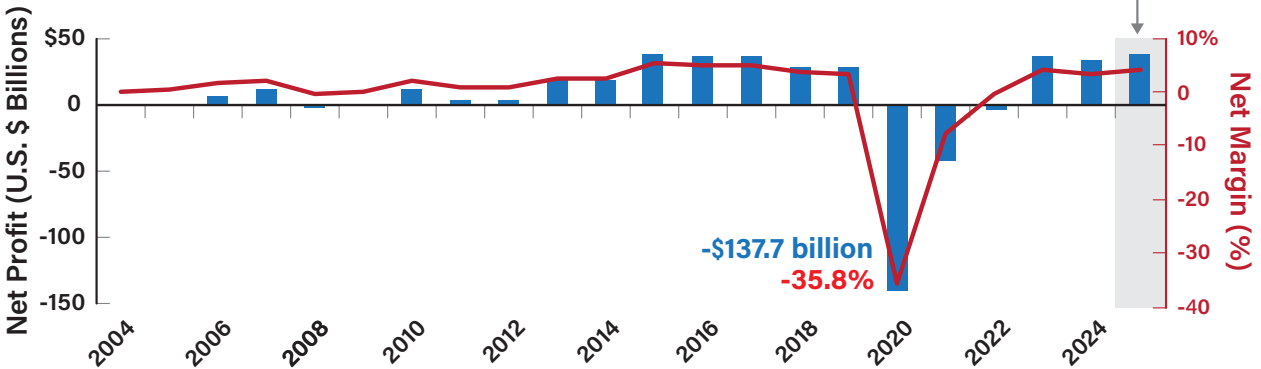
■ Revenue Passenger Kilometers ■ Cargo Ton Kilometers



*October 2024 compared with October 2023.

Airline Industry Net Profit

■ Net Profit — Net Margin



Source for charts: IATA

acades. All regions are expected to show combined industry profits. Revenues are projected to rise to \$1 trillion, an increase of 4.4% over 2024. Total costs are forecast to grow 4%.

Some outside factors support profitability—oil prices are the most important. In September, jet fuel fell below \$70 per barrel for the first time since the start of Russia’s full-scale invasion of Ukraine. IATA predicts an average price of \$87 per barrel for next year, down \$12 from 2024 levels, which should provide airlines considerable cost relief. Overall, industry jet fuel demand is set to rise 6% in 2025, but airlines are forecast to spend 4.8%

less (or \$248 billion) as a result of cheaper oil. Fuel is projected to account for 26.4% of total costs, compared with 28.9% in 2024.

IATA Chief Economist Marie Owens Thomsen says a price around \$80 per barrel is a cutoff point for the global economy. Prices below that are supportive of general economic growth. “The ‘drill, baby, drill’ mantra will make sure that the oil market is oversupplied,” she predicts. “It will benefit our industry.” Moreover, the crack spread—the difference in price between oil and jet fuel—is coming down to normal levels (see chart on page 79).

Carbon credits to be purchased as

part of the Carbon Offsetting and Reduction Scheme for International Aviation (Corsia) will add \$700 million to airline industry costs in 2024 and about \$1 billion in 2025. Airlines are expected to spend \$3.8 billion more on fuel as they take on higher quantities of the more expensive sustainable aviation fuel (SAF). The figure was just \$1.7 billion in 2024.

Geopolitics add an element of uncertainty. The situation in the Middle East is evolving quickly with the collapse of the Assad regime in Syria. Many airlines in the region are still substantially affected by airspace limitations and security concerns, but an end to

the war in Gaza as well as stabilization in Lebanon and Syria could create new opportunities for the industry.

Likewise, cessation of the war in Ukraine would benefit airlines not only in the immediate region but more broadly, as that could ultimately reopen Russian airspace, although that is still highly unlikely to occur in 2025.

craft and outstanding deliveries they expected to arrive a long time ago. Across the board, carriers have kept their current aircraft flying for much longer than anticipated.

"We are seeing aircraft being operated that really should be retired," Walsh said. He was referring to Airbus A340s and A380s, among others,

then. In 2024, the average age rose to 14.8 years, and it is not expected to come down in the coming year.

IATA estimates deliveries of 1,254 aircraft in 2024, down from 1,813 in 2018. Production expansion at Airbus and Boeing in 2025 is highly unlikely to lead to deliveries anywhere near 2018 levels.

The delays also are impeding industry efforts to become sustainable. Average fuel consumption has been unchanged in 2024 at 0.23 liters (0.06 gal.) per 100 available ton kilometers. Between 1990 and 2019, airlines improved fuel efficiency 1.5-2% annually.

Meeting sustainability targets is a broader concern. "We are not making as much progress as we need and as we were hoping," Walsh conceded. He criticized governments for not addressing the issue "in a coordinated fashion." In his view, mandating quotas for SAF use and other compulsory measures have not worked.

Fuel producers "have made big announcements but have pulled back from their commitments," he said. 🌐

"IATA estimates deliveries of 1,254 aircraft in 2024, down from 1,813 in 2018."

Tariffs threatened by the incoming Trump administration in the U.S. are a major concern for airlines, as they could unleash trade wars. The tariffs remain a watch item for the time being. On the other hand, the industry sees proposed deregulation led by the future U.S. government as a positive and hopes that Europe might be forced to follow.

The more immediate challenge for airlines is to achieve planned capacity growth, given the many grounded air-

craft that are being brought back into service, but many A320neos and Boeing 737NGs that would otherwise have been retired are still flying.

Therefore, the planned industry growth in 2025 will be "coming at significant additional cost" as airlines are forced to continue operating uneconomical aircraft.

According to IATA, the average aircraft age in 1990 was just over 12 years; it has averaged 13.6 years since

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NETWORK

A Year of Steady Progress for Airline Consolidation

> SOME CARRIERS ARE MAKING PROGRESS IN LONG-SOUGHT MERGERS

> CERTAIN DEALS REQUIRE CONCESSIONS

Helen Massy-Beresford Paris, **Christine Boynton** Boston, **Lori Ranson** Washington and **Adrian Schofield** Auckland

In the evolution of many industries around the globe, consolidation has a role to play, and there is no shortage of movement among airlines looking to grow amid significant headwinds in the post-pandemic marketplace.

But 2024 began on a tough note for some proposed mergers. In January, a federal district judge in Boston sided with the U.S. Justice Department and handed down a ruling to block the combination of JetBlue Airways and Spirit Airlines. The carriers had argued in court that a merger would be key to achieving planned growth. Both had seen profits dwindle in the wake of the COVID-19 pandemic and sought

Asia-Pacific region: Korean Air's takeover of Asiana and Air India's merger with Vistara.

Korean Air first proposed acquiring Asiana in November 2020 and over the past four years steadily worked its way through the necessary approvals. The acquisition was finally completed on Dec. 11. Gaining sign-offs from several overseas competition authorities took longer than expected, as many of them raised concerns about the merger's effect on competition in both the cargo and passenger arenas.

To assuage these concerns, Korean Air agreed to a range of concessions, including slot transfers and the leasing of wide-bodies to smaller carriers to help them get established on certain routes. On the cargo side, Korean proposed divesting Asiana's freighter unit; Air Incheon was the successful bidder.

While regulators have extracted considerable concessions, the merger remains a very positive move for Korean Air. Together, Korean Air and Asiana accounted for 35.8% of weekly seats in South Korea's international market for the week of Nov. 25, according to data from CAPA – Centre for Aviation and OAG. Korean Air currently ranks 22nd among global carriers in international seat capacity, and combining with Asiana would kick it up to 11th place.

Air India formally completed its takeover of Vistara on Nov. 12 after receiving the remaining approvals from Indian and Singaporean authorities. The process, which began in November 2022, stemmed from the Tata Group's desire to streamline and consolidate its various airline holdings. Tata



a way to compete better with larger legacy carriers. Initially the airlines launched an appeal to contest the decision, but the two officially terminated their agreement in March.

At the same time, a decision on another U.S. airline merger was pending as Alaska Air Group sought to acquire Hawaiian Airlines for \$1.9 billion, a deal it had announced in December 2023. For months, industry waited to see whether the antitrust decision blocking JetBlue and Spirit's deal would set the tone for Alaska's case. Despite a U.S. administration wary of consolidation, the fifth- and 10th-largest airlines in the country closed their deal in September, becoming the first merger of major U.S. carriers since 2016.

Alaska CEO Ben Minicucci told investors on an earnings call on Dec. 3, 2023, that the combination was an opportunity the airline had "looked at for a while" and would create a stronger competitor to network carriers. "While we do not view this combination as an imperative for the continued success of Alaska, we do see this as a unique opportunity at this moment in time to accelerate and enhance the strategy that we've been deliberately cultivating over the past several years," he said.

More broadly, industry consolidation efforts have progressed over the past year, in part because some transactions were still pending at the end of 2023 (*AW&ST* Dec. 25, 2023-Jan. 14, 2024, p. 95). Two of the industry's most significant consolidation efforts have been playing out in the

Several potential bidders are interested in the planned privatization of TAP Air Portugal.

acquired Air India in January 2022 and jointly owned Vistara with Singapore Airlines. Under the merger deal, Singapore Airlines gained a 25.1% share in the enlarged Air India.

Tata Group has also consolidated its low-cost carrier (LCC) brands. In October, it completed a merger between Air India Express and AIX Express, which was formerly AirAsia India.

Despite the merger, the Vistara brand will not be disappearing yet. Air India will allocate Vistara's narrowbodies with the same crews and service product to the busiest domestic trunk routes. This will ease the transition, as Vistara has established a popular brand since its launch in 2015.

According to data from CAPA and OAG, the post-merger Air India Group—including Air India Express—holds 28% of weekly seats in the Indian domestic market, giving it the second-highest share behind IndiGo. The group accounts for 23% of seats in the international market, the highest share among Indian and overseas-based airlines.

IMPORTANT STEPS FOR EUROPE

The long-planned privatization of TAP Air Portugal is almost certain to progress in 2025, as Portuguese Prime Minister Luis Montenegro said in October that the process should

commence in the first half of the year. The government has been speaking to many potential bidders and wants clarity on their plans for the carrier before privatization goes ahead, Montenegro said during a TV interview.

Air France-KLM, Lufthansa Group and International Airlines Group (IAG) have expressed interest in TAP, coveted for its Lisbon hub and South American network—not to mention its fleet of new-generation Airbus aircraft. For IAG, taking over TAP would enable it to expand further into Southern Europe after its plans to buy Spanish leisure carrier Air Europa fell through due to regulatory hurdles.

Potential bidders for TAP—there are more than a dozen, according to Montenegro—will want to know exactly what the Portuguese government would require of them before they launch formal bids. Keeping the airline's hub in Lisbon and retaining strategic routes are likely priorities.

Elsewhere, other important consolidation steps are already taking place. Lufthansa overcame a last-minute hurdle in November in its deal to take over ITA Airways, successor to Alitalia, when the Italian Ministry of Economy and Finance signed an agreement confirming European Commission (EC) concessions, including slot remedies, that cleared the way.

After final validation by the EC and the closing of the transaction, Lufthansa plans to start integrating Airbus operator ITA beginning in early 2025, seeking synergies and turning Rome-Fiumicino Airport into a hub dedicated to African and Latin American destinations.

Smaller carriers may also have further consolidation roles to play. Aegean Airlines in September agreed to invest an initial €25 million (\$26 million) and potentially as much as €50 million in Volotea as part of an overall capital increase alongside the Spanish LCC's shareholders. The two carriers are looking to deepen an existing partnership through more commercial cooperation and to grow their networks.

While Lufthansa will be focusing on ITA, its signing in September of an expanded wet-lease partnership with Air Baltic has given new momentum to rumors that the German group could be seeking a stake before the Latvia-based operator launches its long-planned initial public offering.

Air France-KLM is also interested in TAP and had a “very positive meeting” with the Portuguese state, CEO Ben Smith said in November. For now, the Franco-Dutch group is focusing on SAS Scandinavian Airlines, having bought an initial minority stake in 2024 and signed a codeshare agreement, while SAS has switched to SkyTeam.

MORE TO COME?

Roughly a decade after Avianca and LATAM Airlines Group emerged as regional powerhouses from the combinations of Avianca with TACA International Airlines and LAN Airlines with TAM Linhas Aereas, respectively, momentum is growing in Latin America.

In the aftermath of the pandemic, Latin American operators have turned to consolidation to ensure they can compete effectively. GOL gained approval from Brazilian regulators in early 2022 to acquire MAP Linhas Aereas, paving the way for expanding its presence at Sao Paulo Congonhas Airport, one of Brazil's most strategic hubs.

Avianca attempted to purchase Colombian ultra-low-cost rival Viva, but government foot-dragging ultimately



Korean Air's takeover of Asiana will expand its fleet and international network.

ANGEL DI BILIO/ALAMY STOCK PHOTO

derailed the purchase, and Viva ceased operations in early 2023. In the meantime, Avianca was forging consolidation elsewhere. Shareholders of Avianca and GOL formed the Abra Group in 2022, and the holding company completed its acquisition of Spanish wet lease and charter operator Wamos Air in October 2024.

More cooperation could occur between Avianca and GOL once the latter exits bankruptcy protection in 2025. GOL announced in November that Abra had agreed to convert \$950 million of its secured debt in the Brazilian carrier to equity.

The question going forward is whether more consolidation is on the horizon in Latin America. GOL and Azul launched a domestic codeshare in May after reports emerged that Azul was interested in acquiring GOL. Azul and Abra, meanwhile, have discussed business opportunities.

A potential wild card is Aerolineas Argentinas. Argentinian President Javier Milei has been aggressively working to privatize the loss-making flag carrier. But it is not clear if he will succeed. Aerolineas Argentinas has not fared well financially under government ownership, while newer ultra-low-cost carriers Flybondi and JetSMART Argentina continue to grow, representing 17% and 14% of the country's system departing seats, respectively, according to CAPA and OAG. Aerolineas Argentinas' share is 47%.

Aerolineas Argentinas and Abra agreed in October 2023 to strengthen collaboration and explore commercial, operations and technology cooperation opportunities. The holding company is “interested in Aerolineas [Argentinas],” Abra Group Chief Commercial Officer Joe Mohan said at the Skift Aviation Forum in November. “But what exactly Aerolineas represents at this point, we're in the due diligence to figure out.”

Activist Investors See Opportunity in U.S. and European Airlines

> CRITIQUES OF AIRLINE OPERATIONS TAKE VARIED APPROACHES

> THE ADDED SCRUTINY HAS ENCOURAGED CHANGE

Christine Boynton Boston and **Lori Ranson** Washington

In the years since the height of the COVID-19 pandemic, tried-and-true airline models have faced new challenges in the form of industry-wide constraints as well as shifting consumer preferences.

For Southwest Airlines, 2024 became a year of turmoil and change. Activist investor Elliott Investment Management spotted what it described as “the most compelling airline turnaround opportunity in the last two decades,” taking a large

The nature of the involvement from each investor has varied. Southwest and Elliott waged a public back-and-forth battle for months, trading barbed statements. In contrast, Icahn’s involvement has appeared more placid. In fact CEO Joanna Geraghty has expressed alignment with him on key priorities while commiserating with JetBlue’s peer in Texas.

“I’ve been seeing what’s happening at Southwest, [and] I don’t wish it on anybody because it’s hard,” Geraghty

“That’s why [activist investors] get involved here, because they think . . . fundamentally that the opportunity looks great, and these are just companies that are lagging at present, but strong franchises,” Bloomberg Intelligence analyst George Ferguson says.

Ferguson describes Southwest as one of those robust franchises, noting that the company is “sort of struggling because right now it looks like we just have too many economy-class seats in the marketplace.”

AVIATION PREMIUM

Southwest and Elliott came to an accord in late October. The carrier added five of the 10 directors nominated by the fund and replaced longtime leader Gary Kelly as executive chairman. Rakesh Gangwal, co-founder of IndiGo and former CEO of US Airways Group, is now leading the board into the airline’s next chapter. Those changes stopped short of replacing CEO Bob Jordan, on whom Elliott had continually called to step down.

The Dallas-based carrier is working through a three-year plan to “usher in a new era of change, profitability and industry leadership,” Jordan said during Southwest’s investor day in September. One sweeping change Southwest has planned is the introduction of assigned seating in the first half of 2026.

Ferguson says Southwest would have eventually adopted the change in seating and other product enhancements, but “Elliott just helped them understand that change had to occur quicker.”

Elliott also has announced a \$5 billion stake in Honeywell International and demanded its split into two companies, one focused on aerospace (AW&ST Nov. 25-Dec. 8, p. 16).

“I think when some of these activist investors look at the space, they think there are good fundamentals in aerospace and aviation,” Ferguson says. Some of those investors likely conclude that “if we could just get in and unlock more of that aviation premium, we can get a nice return out of our work at the companies,” he explains. “I think that’s kind of how Honeywell fits in . . . [being] one of these remaining conglomerates where this is a whole bunch of different divisions wrapped up inside.”

Meanwhile, JetBlue’s discussions with Icahn have taken place outside



Southwest and JetBlue each had activist investors announce large stakes in 2024 as the carriers were developing plans for improved profitability.

stake in the carrier and launching a public campaign to spur a shake-up at the top (AW&ST June 17-30, p. 47). JetBlue Airways also found itself with a change-maker among its shareholders as Carl Icahn made his return to the airline industry (AW&ST Feb. 26-March 10, p. 35).

The two U.S. carriers face a pivotal year in 2027, when they are due to deliver on earnings before interest and taxes (EBIT) goals promised within the turnaround plans they presented to investors. Both are pursuing network and fleet adjustments while introducing new premium product offerings and cutting costs.

said at the Skift Global Forum in September. “But at the end of the day, we are all focused on trying to drive a better business. . . . We’re focused on returning to profitability, and we are all aligned in that regard.”

The two activist investors each announced their stakes within four months of each other, at a time when high labor and fuel costs, in addition to overcapacity in domestic U.S. markets, have pressured the margins of lower-cost operators. This marked a turnaround from the segment’s pre-pandemic advantage, which had allowed for growth and winning market share at the expense of the larger mainlines.

the public eye. Geraghty's recent remarks provide insight, describing some "really constructive discussions."

Icahn today is the founder and chairman of Icahn Enterprises, with investments spanning diverse industries including energy, automotive and pharmaceuticals. In mid-2023, he announced a reset on a core activism strategy. In his first encounter with the airline industry, he wrested control of Trans World Airlines in 1985 with the purchase of more than 20% of its stock. In 1991, he purchased Pan Am Express in a court-ordered bankruptcy auction.

"With many exceptions, most CEOs are incapable of creating great businesses (or even improving them), and the desire to empire-build is rampant," Icahn wrote in a letter to unit holders in 2023. "When an activist is successful in changing the board or the CEO, great value can be unlocked for all shareholders, and this is why our record over the last 23 years has been so impressive."

Icahn announced his stake in Jet-

Blue in February; two of his executives from Icahn Enterprises have since joined the airline's board of directors.

JetBlue's improvement plan aims to deliver an incremental "EBIT uplift" of \$800-900 million in 2025-27. For 2024, the carrier expects revenue to be down 4-5% compared with 2023, an improvement from prior expectations of a 4-6% decrease for the year.

"The progress we made this quarter is evidence that we are taking the necessary steps to get the business back to operating profitability," Chief Financial Officer Ursula Hurley said during JetBlue's third-quarter earnings call.

Southwest, too, is encouraged by the early results of its go-forward strategy and aims to add roughly \$4 billion to EBIT by 2027.

As both JetBlue and Southwest work to execute on their financial goals, Ferguson agrees that activist investors "want to make their money and get out."

Those investors seek above-average returns by becoming involved "in something that's depressed," Fergu-

son explains, then motivate the board and management to make changes. When the company returns to a more typical valuation or "even a little bit better, then [activist investors] take their money off the table and go look for the next opportunity," he says.

Activist investors are playing a role in countries other than the U.S. In Europe, Germany's wealthiest citizen appears to be pushing for change at Lufthansa, in which he already owns a 20% stake. The carrier's strategy is "vulnerable," and it is getting bogged down with too many side products and affiliate airlines, Klaus-Michael Kuehne said in an interview with a German newspaper. "I don't find that good," he said. "I am a friend of simple and clear structures."

Kuehne asserted that Lufthansa is neglecting its core brand and said further talks with the chairman and CEO lie ahead. "They are valuing the dialog with us but so far have not changed the strategy," he added. "Depending on how that continues, we have to articulate ourselves in a stronger way." ☛

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Commercial Aircraft Manufacturers Struggle To Resume Past Output

➤ BOEING FACES A PIVOTAL YEAR OF RECOVERY FROM SETBACKS

➤ SUPPLY CHAIN ISSUES CONTINUE TO IMPEDE AIRBUS OUTPUT

Jens Flottau Frankfurt, **Guy Norris** Colorado Springs
and **Sean Broderick** Washington

Both Airbus and Boeing had reason to believe the worst was behind them at the end of 2023. Boeing was depleting its backlog of undelivered 737 MAXs and slowly improving rates of new-build aircraft. It had a plan in place for correcting assembly quality issues on the 787 program. Airbus faced the dramatic impact of the Pratt & Whitney geared turbofan durability shortfalls in the in-service A320neo-family fleet, but other parts of the supply chain

seemed to send encouraging signals.

One year later, both large aircraft manufacturers are dealing with many of the same issues as well as new ones that have destroyed hopes of a quick and sustained recovery to levels of output similar to 2018 and earlier.

The Jan. 5 Alaska Airlines Flight 1282 accident uncovered the extent of production quality problems at Boeing and fuselage supplier Spirit AeroSystems while making Spirit's already troubling financial situation even

worse. The sharpened crisis led to the resignation of then-Boeing CEO David Calhoun as well as tightened oversight, an FAA-mandated production cap and a review of the production system. After a painful strike by the International Association of Machinists and Aerospace Workers (IAM), Boeing is struggling to restart production and is burdened with billions in excess costs caused in 2024—another annus horribilis.

Airbus, too, is struggling with the fallout as operational performance has nosedived at Spirit, a key aerostructures supplier on the A220 and A350 programs. Other parts of the supply chain, including engine manufacturers and cabin specialists, have been holding back planned growth at Airbus, which is struggling to reach its guided targets for the year until the last minute.

Embraer, meanwhile, faces many of



JENNIFER BUCHANAN/THE SEATTLE TIMES POOL PHOTO

the same issues as its larger competitors and has been forced to dial back its delivery ambitions.

For 2025, the emphasis in commercial aircraft manufacturing is still on recovery. At the same time, all three aircraft-makers are continuing to research what could be their next generation of aircraft.

BOEING

The American airframer faces one of its most pivotal years—perhaps the most important one since its late-1990s merger with McDonnell Douglas—as it seeks to recover from a series of devastating setbacks stretching back to the first crash of a 737-8 in October 2018.

The first six months of the year will be particularly critical under CEO Kelly Ortberg's multipoint recovery plan to stabilize the company and stem the ongoing hemorrhaging of cash. The first step—ending the debilitating

53-day IAM strike—was accomplished with an agreement on Nov. 4.

Moving into the new year, the priority will shift to the second main goal: a focused ramp-up in production of Boeing's key cash generators, the 737 and 787, as well as the valuable 777F freighter. Production of the 737, which was at a rate of around 25 per month prior to the strike, remains well below the 38-per-month cap the FAA imposed following the January Alaska Airlines 737 door-plug blowout accident. Increasing the rate will be a longer and more torturous process in the wake of the strike.

Despite shoring up its balance sheet with an unprecedented \$24 billion stock offering in October, Boeing acknowledges that ramping up production remains a vital priority in its quest to reverse negative cash flow by the second half of 2025. The success of this ramp-up plan depends heavily on the 737 program.

S&P Global Ratings analysts said in October that they expect Boeing to meet its target of producing 38 737s per month by mid-2025. Others are more circumspect.

Jefferies analysts project the ramp-up will be drawn out by the combined impact of the strike on the supply chain and the Safety Management System quality improvement plan metrics the FAA is monitoring. Jefferies expects production to increase to just 35 per month in the fourth quarter of 2025 after 24 in the first quarter, 27 in the second and 31 in the third.

RBC Capital Markets predicts an even slower ramp-up path, with rate 38 occurring sometime in the first half of 2026.

Ortberg "has repeatedly indicated that he expects a slow and careful ramp back on the 737 program," RBC wrote in a late-November research note. "Indeed, another quality lapse or escape on the program could have a material impact on Boeing's future as a stand-alone company."

Production of the 787 in North Charleston, South Carolina, currently moving to five from four per month, also is set to form an important element of Boeing's 2025 rebalancing act. The company has targeted a rate of 10 787s per month, but it remains to be seen if the stretched supply chain can support such a rapid expansion.

Boeing's final acquisition of Wichita-based Spirit AeroSystems, which is a

major part of the airframer's supply chain, is expected to close around mid-2025. In the meantime, Boeing has seen improvements in deliveries and fuselage quality and no longer considers these core components a restricting factor in its 737 or 787 production ramp-up plans. Further streamlining of the Spirit operation is expected throughout 2025 to prepare for more rate increases.

The 767-300F will continue to be produced in the coming year, although it is slated to be shut down in 2027. Boeing announced the sunsetting plan, which came with a \$400 million charge, in October along with the news that the all-new 777-8F freighter variant of the 777X also will be delayed at least a year, to 2028. The manufacturer plans to deliver the remaining 28 767-300Fs in the firm backlog for FedEx and UPS before terminating the line, and it is still taking orders to fill out the remaining slots in the production skyline for the "metal-wing" version of the 777F through 2027.

Beyond current production models, Ortberg is focused on seeing the 737-7, -10 and 777-9 cross the long-delayed certification finishing line. Despite plans for improved risk management as well as holding to schedule, cost and performance goals, it remains unclear how confident Boeing is about achieving these targets over the coming year.

Deliveries of 737-7 and -10 derivatives have been delayed by the need to redesign and flight-test the engine nacelle inlet structure and associated anti-ice system. Certification of those is expected in the second half of the year. The 737-10 also must incorporate other agreed-upon improvements, notably a third source of angle-of-attack data, part of the agreement for the 737 MAX's return to service in 2020 that was earmarked for all future and in-service variants.

The timetable for deliveries of the first 777-9 also remains in doubt amid ongoing debates with the European Union Aviation Safety Agency (EASA) over compliance with dissimilarity requirements in elements of the flight control system as well as test delays following an engine thrust link failure in August. Although replacement thrust link components have been fitted to the test fleet, initial deliveries now seem set to slip into 2026, even if certification can be clinched by the end of 2024.



Ramping up cash-earning 737 deliveries is a key target for Boeing in early 2025.

Boeing also is proceeding with a workforce reduction plan that will cut 17,000, or roughly 10%, of employees by February. The scale of the layoffs reflects Boeing's shrinking business and forms part of the company's broad-ranging organizational streamlining and cost reduction efforts. Divestments of noncore aircraft production businesses, potentially including parts of the company's space sector, are expected, too.

This plan also will include some reductions in research and development spending, although Boeing is not ex-

potentially to thrive. If not, headline-generating topics such as its dwindling share of the narrowbody market will be the least of the once-iconic aircraft-maker's problems.

AIRBUS

For major European airframer, 2025 will be a transition year that could become very complicated. Production rates, supplier performance and integration, and changes in top management are on the watchlist.

The biggest challenge: delivering on the firm order backlog. Airbus

as CEO Guillaume Faury recently put it, the bigger suppliers are causing the current issues.

One main internal task is to integrate into the group the Spirit sites dedicated to Airbus work. That process is to be concluded in 2025 and will continue to require management's attention.

Engine supply is another bottleneck. Airbus is pushing continuously for Pratt & Whitney and CFM International to deliver more powerplants to the final assembly lines. Of course, pressure from aircraft manufacturers means fewer engines may be available for the in-service A320neo-family fleet, a substantial part of which continues to be grounded as durability shortfalls force airlines to remove engines from service prematurely while the supply of replacement parts remains insufficient.

While Pratt said the groundings peaked in 2024, the problem will continue to limit Airbus and its operators throughout 2025.

Cabin suppliers are also behind the curve, particularly when it comes to galleys and lavatories. Inflight entertainment systems are part of the problem, too. And seat manufacturers have been struggling with an avalanche of orders both for new-build aircraft and refurbishment of in-service jets that are flying longer than planned. Late certification of new seats, particularly in business and first class, has been holding back some deliveries.

Airbus is struggling with internal shortfalls and will have to focus on eliminating them in 2025. Costs per aircraft built have crept up considerably, partly because of higher-than-usual inflation but also because of deteriorating productivity. In mid-2024, Airbus launched a cost-cutting program that is not planned to include layoffs but adds a hiring cap as well as measures to improve operational performance.

Looking at the bigger picture, Airbus has decided to focus on fine-tuning its production system in 2025 and beyond rather than trying to make drastic changes in the middle of a fast and long production ramp-up. It is slowly introducing more automation in some facilities, such as the logistics operation in the new A321neo final assembly line in Toulouse. An A321XLR-dedicated component manufacturing hangar in Hamburg has been added.

Airbus plans to nearly triple A350 output in the next few years.



AIRBUS

pected to reduce its commitment to development of the X-66 transonic truss-braced wing demonstrator for NASA. The high-wing design, which is set to fly in 2028, is to demonstrate advanced low-drag aerodynamics that could feature in a next-generation 737 successor for the 2030s.

Finally, Ortberg's plan has a strong focus on improving the company's safety culture. Calhoun's ouster was sealed by the Alaska accident and Boeing's seemingly tepid response.

Ortberg's pledge to return front-line workers to the forefront of key day-to-day production-related decisions must go beyond words spoken at all-hands meetings and typed in internal messages.

The company says it is taking action on long-requested changes, such as simplifying work instructions and ensuring that new hires are adequately trained, as well as setting up a two-way dialog to flag and address similar issues. And the airframer says it has ended its overreliance on workers to fix incorrect or incomplete work from further down the supply chain—both inside and outside Boeing's walls.

If the initiatives are successful, Boeing has a chance to recover and

must deliver 7,832 aircraft in the coming years. The vast majority of orders are for the popular A321neo. Airlines and lessors have bought 5,276 of the aircraft so far. Airbus has stated that it intends to raise output of the A320neo-family to 75 aircraft per month by 2027, of the A220 to 14 monthly by 2026 and of the A350 to 12 by 2028. The relative growth is fastest on the A220 and A350, with output planned to almost triple in the coming years and A320neo-family rates growing from just over 44 for the first 10 months of 2024.

Airbus had targeted delivery of about 760 aircraft in 2024, some 100 fewer than it delivered in 2019, its biggest single year so far.

The company has strengthened its supplier supervision organization. Around 100 engineers are seconded to Spirit AeroSystems sites to put production back under control. In the initial recovery phase after the COVID-19 pandemic, smaller suppliers were the main culprits for delays: Sometimes only a few missing parts prevented Airbus from delivering an aircraft to a customer. Company sources now say that key performance indicators across the board are improving. But

Deeper changes will have to wait until Airbus introduces a new aircraft, presumably a successor for the A320neo family, toward the end of the next decade. As for design work on a new aircraft concept, 2025 also will be a crucial year. Airbus needs to make fast progress on defining the ZEROe hydrogen aircraft if it does not want to risk missing the planned 2035 service entry date.

Faury has complained about the slow progress in ground infrastructure development that might lead to the ZEROe hydrogen aircraft being ready far ahead of the logistics necessary for commercial operations. He did not say that Airbus is looking at slowing down ZEROe development work.

In parallel, Airbus continues its work on defining the next narrowbody, including a new production system that will be capable of transitioning quickly and be more efficient, avoiding some of the legacy structures of the current industrial system. As Faury has indicated, a launch of the conventional aircraft is now planned for the turn of the decade rather than 2028 or 2029, and the work on this project does not have any crucial 2025 milestones that cannot be changed.

In the nearer term, Airbus is assisting airlines in the introduction of the A321XLR, the first version of which received EASA approval in July. Iberia took first delivery of the aircraft in November and has started scheduled flights between Madrid and Boston.

Airbus has to deliver three more A321XLRs in 2024—one each to Aer Lingus, Iberia and Flynas, according to the Aviation Week Network's Fleet Discovery database. The rollout in 2025 has 48 aircraft scheduled to be handed over. Among the largest customers are American Airlines, JetBlue and Flynas.

JetBlue will use the aircraft on transatlantic services and flights to Latin America, a growth segment for the airline. In what could herald structural change for the India-Europe long-haul market, low-cost carrier IndiGo also will receive its first three XLRs. IndiGo plans to use the aircraft from the largest Indian catchment areas on new routes to build a bigger presence in the international market.

Airbus needs to make fast progress on the XLR in 2025 in order to meet its target for 2026—handing over 103 of the type. XLRs will enable American to continue to build its new sub-

fleet and United to take the first portion of its order that is intended to replace Boeing 757s among other aircraft on transatlantic routes.

Christian Scherer, current CEO of the commercial aircraft business, is to leave Airbus at the end of 2025. MTU Aero Engines CEO Lars Wagner will replace the former head of sales in early 2026. Wagner, an aerospace engineer and production specialist, likely will have a strong focus on production efficiency and upgrades as well as preparing the industrial system for next-generation aircraft.

EMBRAER

The Brazilian airframer has been struggling to gain production and sales momentum of its E2 jets for the past several years. Supplier constraints, in particular a lack of en-

mercial aircraft have been ongoing for some time. Embraer has for some time indicated that it would make a decision about the business on which it will focus its investment by the middle of 2025, but that date appears to be no longer referenced. "We have a very robust plan until 2030, but from 2030 onward we are thinking about Embraer's new product, or Embraer's new products," Gomes Neto recently told the *Folha de Sao Paulo* newspaper. "We don't have that definition at the moment."

For Embraer, the example of Bombardier is a stark warning. C Series development costs forced Bombardier to exit the commercial aircraft business, after it sold the C Series to Airbus, which now markets it as the A220.

Embraer has looked at building larger aircraft before, and Boeing's

Embraer's decision on how—or whether—to expand its current product line is not likely to be made in 2025.



EMBRAER

gines, forced it to revise its output guidance downward for 2024, meaning the company must start 2025 at a lower base. CEO Francisco Gomes Neto told investors that campaigns for orders of around 200 additional aircraft are pending, and the company is positive about winning many of them, but Embraer's production level is still far from its bigger rivals as well as its own ambition to see E-Jet production exceed 100 aircraft per year.

Production is expected to shift more toward the E2 versus the E175, which still sells well in the U.S. market, where scope clauses are likely to hold back larger regional aircraft for the foreseeable future.

Strategically, the company is facing a crossroads. Studies of a larger com-

current weakness might provide an opening in the market not to be missed. Embraer has been exploring international partnerships to fund the project in India and Saudi Arabia, among other countries.

COMAC

Chinese aircraft manufacturer Comac has so far delivered 13 C919s to Chinese customers Air China, China Eastern and China Southern airlines. According to Fleet Discovery, production is to be ramped up substantially in 2025, with 49 aircraft scheduled to be handed over.

Comac also is slated to deliver the recently rebranded C909 (formerly the ARJ21) to customers. Only one aircraft has been handed over in 2024. 🌐

New Airframe Concepts Inch Forward

➤ AIRBUS GEARS UP FOR MORPHING-WING DEMONSTRATION

➤ JETZERO PLANS FURTHER FLIGHT TESTS OF SCALED BLENDED WING BODY AIRCRAFT

Thierry Dubois Lyon and **Guy Norris** Colorado Springs

Aviation has been well served by the tried and trusted tube-and-wing configuration over the decades, with improved airliner designs showing an 80% decrease in fuel burn per seat. Impressive as the achievement is, the rate of improvement remains too slow for aviation to meet its net-zero emissions target by 2050.

In parallel, drawing boards have long displayed novel aerodynamic configurations for drastically better fuel efficiency at the airframe level, such as the blended wing body (BWB) and morphing-wing concepts. Research centers have studied them as ways to optimize aircraft for lower fuel consumption. However, because those novel concepts would add complexity, raise manufacturing cost and increase operational hurdles, airframers have expressed only polite interest.

Often deemed futuristic, those designs face multiple challenges before they can become reality. Their feasibility is nevertheless progressing, and their technology readiness levels will soon as well. Beyond research centers, they can now be found in the design offices of established and startup airframers.

NASA has shown the latest evidence that these new, more efficient shapes are being considered realistic options. The agency outlined updated subsonic transport metrics in November to guide design targets for future sustainable airliners, following the template it established in 2008 for the N+3 subsonic fixed-wing project. However, NASA has radically revised and expanded those metrics to provide a fresh set of performance targets for technology that could support full-scale development for new aircraft in the medium term by 2030 and in the long term by 2040-45 (*AW&ST* Nov. 25-Dec. 8, p. 50).

California-based JetZero and Natilus each have begun development of a commercial BWB, which NASA originally studied under the subscale X-48 project. By combining wing and fuse-

lage, BWBs have more efficient volume wrapping, which reduces wetted area. The cross-sectional area distribution decreases wave drag and enables thicker root airfoil sections without a high-speed drag penalty.

BWBs also have a lifting center body that provides more elliptical span loading distribution with lower

senger aircraft. It aims to develop a 200-seat BWB to replace the Airbus A321 and Boeing 737-10 beginning in the early 2030s. The project leverages design work underway for Natilus' ongoing autonomous cargo blended wing Kona project (*AW&ST* Nov. 11-24, p. 24).

Dubbed the Horizon, the design promises to build on the baseline aerodynamic efficiency of the BWB configuration to deliver considerably lower CO₂ emissions, Natilus says, while being 25% lighter and providing 40% greater capacity than today's comparable conventional tube-and-wing aircraft.

Airbus' eXtra Performance Wing (or X-Wing) program intends to cut



Startups like JetZero plan to develop new-generation airliner families based on the blended wing body concept.

induced drag. The baseline design incurs less induced drag as well through its greater tip-to-tip span for the same aspect ratio of an outboard wing. BWBs also typically operate close to trim in cruise flight, reducing trim drag. The combined aerodynamic effect could improve efficiency by at least 20%.

In Long Beach, California, JetZero is working on the Z4 midmarket model, partially supported by a U.S. Air Force demonstrator contract. The Z4, sized to seat 170-290 passengers, is targeted to enter service around 2030. The startup plans to prioritize further flight testing of scaled demonstrators in 2025, building up ground test facilities—including an iron bird systems rig—and assembling initial structural components.

Farther south, San Diego-based Natilus is the latest company to announce plans to develop a BWB pas-

seenger aircraft. It aims to develop a 200-seat BWB to replace the Airbus A321 and Boeing 737-10 beginning in the early 2030s. The project leverages design work underway for Natilus' ongoing autonomous cargo blended wing Kona project (*AW&ST* Nov. 11-24, p. 24).

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Airbus' eXtra Performance Wing (or X-Wing) program intends to cut

feature a hinged wingtip extension, an adaptive trailing edge and pop-up spoilers. The goal is to improve aerodynamic performance without weighing down the wing's structure.

"If you increase the aspect ratio by lengthening the wing, the bending moment at the wing root increases," X-Wing Demonstrator Leader Franck Delaplace explains. "Instead of adding heavy reinforcements, you can alleviate aerodynamic loads. That approach calls for a fast response to turbulence, hence the need for a lidar that sees air movement hundreds of meters ahead." The system then actuates surfaces, such as ailerons on the trailing edge and the folding wingtips, alleviating the gust load.

During the first phase of the program, Airbus UpNext validated the communications system that will support remote control during Phase 2. In the second phase, Phase 1's crew of four—two test pilots and two flight-test engineers—will test the new technologies to their limits while flying the aircraft remotely.

Airbus UpNext has started conversion work on the Citation VII at the French Air and Space Force base near Cazaux in southwest France. Its main task will be replacing the Citation VII's wings. At Airbus' development facility in Filton, England, the new wings are pretty much complete, says Mark Bental, head of research and technology.

Because a higher-aspect-ratio wing is more flexible, the design must suppress aeroelastic effects—specifically flutter. Side-view cameras in the fuselage will measure wing deformation.

A fly-by-wire control system, including electric actuators, will replace conventional flight controls. Water ballast of up to 1.5 metric tons, or 15% of the modified aircraft's maximum takeoff weight, will simulate various levels of payload.

The remote-controlled demonstrator is planned to undergo 6-9 months of ground tests before flying for nine months in 2026. The tested wing will represent that of a commercial narrowbody at a reduced scale factor of 30%.

Working closely with NASA, Boeing is set to begin fabrication of key structural elements of the X-66 transonic truss-braced wing (TTBW) demonstrator. Due to start flights in 2028 under the agency's Sustainable Flight Demonstrator program, the modified



Airbus is preparing to replace the wings of a Cessna Citation VII business jet to use it as a flying testbed for the morphing-wing concept.

McDonnell Douglas MD-90 will be configured with a low-drag 145-ft.-span wing design that is expected to reduce fuel burn up to 10% compared with the conventional cantilevered wings on today's narrowbodies.

The TTBW's efficiency gains stem largely from the lower induced drag of the much higher-aspect-ratio and thinner wing, which is enabled by the truss. The thinner profile minimizes wave drag at transonic speeds compared with conventional wings.

The X-66 is scheduled for flight testing starting in late 2028, mainly at Edwards AFB, California. If successful, the program could form the basis for a follow-on new product family targeting a Boeing 737 replacement for the 2030s. For the moment, Boeing is focused through 2025 on finalizing the complex design of the new overwing section as well as the wing and supporting strut. Once this design work is underway, a two-year modification program is expected to begin in early 2026.

Meanwhile, the Japan Aerospace Exploration Agency (JAXA) is due to enter the demonstration phase of its recently revealed Wake Adaptive Thruster (WAT) concept to reduce aviation carbon emissions via hybrid propulsion (AW&ST Nov. 11-24, p. 12). The study is part of a technology demonstration project known as Megawatt, funded by Japan's Ministry of Education, Culture, Sports, Science and Technology.

The WAT consists of a pair of tail-mounted electric fans designed to ingest the fuselage boundary layer airflow and reenergize the wake to reduce drag. Similar studies by NASA and German design house Bauhaus

Luftfahrt have shown boundary layer ingestion (BLI) could cut fuel burn more than 3% compared with an equivalent-technology conventional aircraft.

NASA's Single-Aisle Turbo-electric Aircraft with Aft Boundary Layer Propulsion (STAR-ABL) study concluded the block fuel-burn reduction was 2.6% for a 900-nm mission, increasing to 3.4% for a 3,500-nm segment.

The BLI drag-reducing concept works by lowering skin friction drag. In a widebody, that can account for 60-70% of total drag, most of it from the fuselage. Skin friction induces kinetic energy, and in a conventional aircraft, that is lost in the wake. BLI diminishes the portion of energy loss associated with the ingested share of the boundary layer. In addition, ingesting moving air over the fuselage reduces the excess momentum in the jet from the tail fan and thus also the required thrust.

Unlike the German and U.S. studies, that incorporated annular fans encircling the fuselage just aft of the vertical tail, the WAT configuration consists of two closely coupled, horizontally mounted ducted fans. JAXA believes positioning the fans laterally will reduce ingestion of turbulent flow from the upper fuselage while maximizing the overall benefits of BLI.

In addition, JAXA says the twin ducted fan configuration enables larger-diameter fans without substantially reducing ground clearance. In previous studies with a single aft-mounted propulsor, the fan's diameter was limited due to low clearance between the tail and ground during takeoff and rotation. WAT wind tunnel tests are scheduled to begin by 2027, and full-scale tests are slated to occur by the mid-2030s. 

Air Cargo Looks Forward to Another Strong Year

> IATA SEES 6% AIR CARGO GROWTH IN 2025

> SHIPPING SET FOR ANOTHER TURBULENT YEAR, BENEFITING AIR CARGO

Helen Massy-Beresford Geneva

With the year-end peak season in full swing, cargo operators are confident that 2024 will finish on a strong note and 2025 will bring more of the same, with sustained demand from e-commerce and constraints on the shipping sector.

Geopolitical and economic headwinds are always of concern to the cargo sector—and 2025 begins amid uncertainty on many fronts—but for now, the signs are positive. The International Air Transport Association (IATA) in December projected cargo demand growth for 2024 would reach an all-time high, with 11.8% growth, continuing at about 6% for 2025.

COLIN FISHER/ALAMY STOCK PHOTO



Pharmaceuticals and e-commerce are supporting ongoing cargo growth.

Alton Aviation Consultancy Managing Director Adam Guthorn sees GDP forecasts and shipping disruption underscoring projections of strong growth for air cargo in 2025.

“[In 2024,] there’s been a collapse in maritime availability, so some of that demand has shifted toward air cargo, which has been a beneficiary in terms of yields and overall market growth,” Guthorn tells Aviation Week. “With the caveat that any economic slowdown would present headwinds, we see those trends continuing into 2025.”

Guthorn notes that several other factors also are driving growth. “The rise of e-commerce, the increased focus on cold chain logistics and relocation of supply chains are all trends that are driving increased demand above and beyond the baseline for bulk air cargo,” he says.

IATA also pointed to maritime disruption on Red Sea shipping routes from escalating conflict in the region as increased risks to key shipping lanes and higher prices encourage shippers to send goods by air instead of by sea.

“In 2024, it was on average roughly six times more expensive to ship something by air than by sea, but before the pandemic, it was roughly 10-15 times more expensive to do the same,” IATA Economist Ghislaine Lang said at the association’s global media day here Dec. 10.

“This is quite a comprehensive shift,” Lang said. “The global sea freight market does appear to be set for another turbulent year in 2025.” Noting strike-related and geopolitical uncertainties, she explained: “The cargo market remains markedly above pre-pandemic levels. It appears the industry has undergone structural change after the pandemic, and for the better.”

IATA warned, however, of possible headwinds from U.S. tariffs that might be imposed by the incoming Trump administration—the exact scope of which is unknown.

After a year of moderation in fuel prices, any new rise could hurt the cargo sector. “Cargo in particular is impacted because freighters tend to be older and less fuel-efficient,” Guthorn says. “Any kind of spike in fuel prices can make it uneconomical to use some of the fleet. That could have a significant impact on demand.”

The aircraft delivery issues affecting the industry as a whole will have an impact on air cargo, too, said Brendan Sullivan, IATA’s head of cargo, even if the continuing higher use of freighters compared with pre-pandemic times is holding off much of the potential effect.

“We’re going to see, or are seeing, the supply chain constraints on new freighters entering, which is obviously very important for modernizing the fleet,” Sullivan said. “But we’re also going to see this coming down the line as we talk about what potential feedstock is available for conversion. We’re probably operating some aircraft which are longer in their operating life span than they maybe would have been.”

That is bad news for the sector’s sustainability efforts and cargo operators’ own drives for greater efficiency—and it affects some areas of the cargo business more than others.

“Belly capacity has come back fairly significantly in the last year, which has helped to satisfy some demand,” Guthorn explains. “But for e-commerce and some of the cold chain logistics, there is still a challenge in getting dedicated freighters for conversion. Pharma had been growing at a pretty significant clip even in the years before COVID. In the next few years, it’ll be challenging to find suitable conversion candidates.”

One important sector commentators are confident is going to continue to drive air cargo growth is e-commerce.

“E-commerce has just exploded since COVID and doesn’t really show any signs of abating,” Guthorn says. “That’s starting to mature in some markets, but there are a lot of other markets with plenty of headroom.”

E-commerce revenue is set for an annual growth rate of 9.49% in 2024-29, resulting in a market volume of \$6.5 trillion by 2029, according to Statista. That strength will drive demand for narrowbody use in the cargo sector and support development of emerging trade lanes needed to connect suppliers, manufacturers and consumers.

“Supply chains are very much realigning, relocating—the U.S. looking to Mexico, Europe looking to Morocco, Eastern Europe—that’s a long-term trend that was accelerated with COVID,” Guthorn says. “Those intermediary steps in the supply chain very much lend themselves to air shipping because of the just-in-time logistics nature of it.”

Five years after the pandemic thrust cold chain logistics into the spotlight and demonstrated the world’s reliance on air cargo to transport temperature-sensitive goods safely around the world, the pharmaceutical sector is also set to remain a driver of growth. 🌐

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What's In

What's Out

A look at which trends are gaining popularity and which are falling out of favor in commercial aviation.

Jens Flottau

IN



In-House Manufacturing



Airbus A321XLR



Starlink



Airbus A380



**Aircraft, Crew,
Maintenance and
Insurance**



Premium Cabins

OUT



**Outsourcing
Aerostructures**



Turboprops



Airbus A380



MD-11s



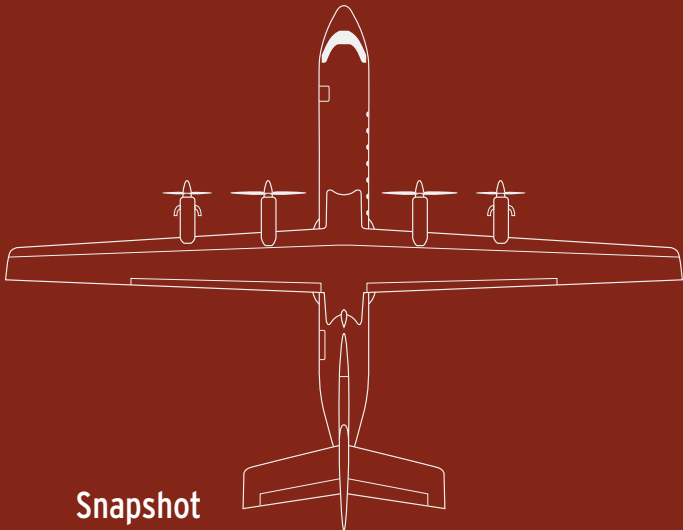
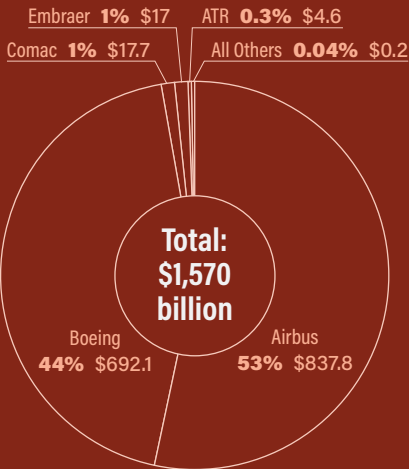
Lessor Orders



U.S. ULCCs

Commercial Aviation Forecast, 2025-29

Value of Five-Year Production
Billions of U.S. 2024 Dollars



Snapshot

Heart Aerospace ES-30

Swedish startup Heart Aerospace unveiled a full-scale demonstrator in September for its planned 30-seat hybrid-electric regional airliner, the ES-30. Dubbed the Heart X1, the demonstrator will be used for testing of ground-based operations at Heart's headquarters at Save Airport in Gothenburg, but it is scheduled to make an all-electric first flight in early 2025 in the U.S. from Plattsburgh International Airport in New York. A second prototype, the X2, is planned to follow by the end of 2026 and will have independent parallel hybrid propulsion, enabling the full flight envelope and range. Heart is aiming for service entry of the ES-30 in 2029.

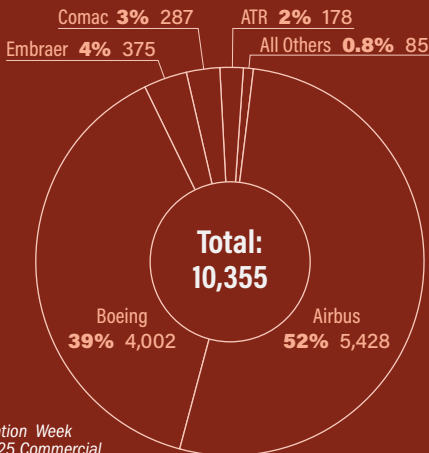
Wingspan: **105 ft.**

Range: **108 nm all-electric, 432 nm hybrid (25 pax)**

Runway Length: **3,600 ft.**

Charge Time: **30 min.**

Five-Year Unit Production

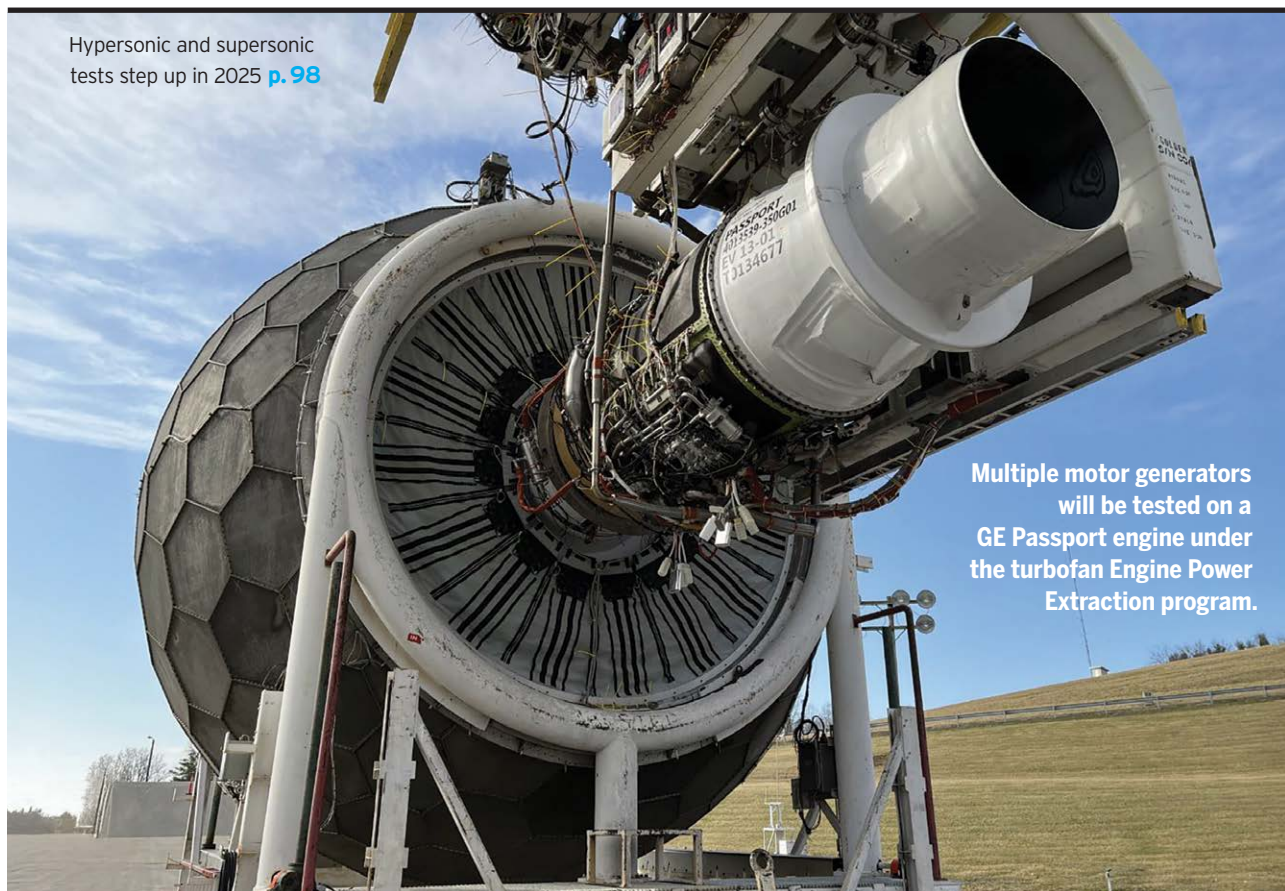


Source: Aviation Week
Network 2025 Commercial
Aviation Fleet & MRO Forecast.
All numbers and percentages rounded.

COMMERCIAL AIRCRAFT TO WATCH

MODEL/ DESIGNATION	PAX/ PAYLOAD	WING- SPAN (ft.)	WING AREA (ft. ²)	MAX. LENGTH (ft.)	MAX. HEIGHT (ft.)	EMPTY WEIGHT (lb.)	GROSS WEIGHT (lb.)	POWERPLANT (No./Type)	MAX. SPEED	CRUISE SPEED	RANGE (nm)
AIRBUS											
A321XLR	244	117.4	1,324	146	38.6	—	222,250	2 X CFM Leap 1A or P&W PW1100G	M 0.82	M 0.78	4,700
A350F	244,700 lb.	212.4	4,770	232.3	56	—	703,400	2 X RR Trent XWB	M 0.89	M 0.89	4,700
BOEING											
737 MAX 10	188-230	117.8	1,370	143.7	40.3	99,360	194,700	2 X CFM Leap 1B	—	—	3,100
777-9	400-425	235.4/ 212.7	5,025	251.8	64.5	362,000	775,000	2 X GE GE9X-105B	—	—	7,285
COMAC											
C919	158-192	117.5	1,390	127.6	39.2	92,815	159,835/ 170,400	2 X CFM Leap 1C	—	M 0.785	2,200/ 3,000 (ER)
EMBRAER											
E175-E2	80-90	101.7	—	106.3	32.7	—	98,120	2 X P&W PW1715G	M 0.82	—	2,000
YAKOVLEV											
MC-21-310	163-211	117.8	—	138.6	37.6	—	187,400	2 X Aviadvigatel PD-14	M 0.82	—	2,820

Hypersonic and supersonic tests step up in 2025 [p. 98](#)



Multiple motor generators will be tested on a GE Passport engine under the turbofan Engine Power Extraction program.

GE AEROSPACE

PROPULSIVE GOALS

- NEXT-GEN SINGLE-AISLE ENGINE TESTING ACCELERATES
- HYBRID CORE TESTS SET FOR RISE PROGRAM
- PRATT & WHITNEY AND ROLLS-ROYCE PLAN GEARED CONTENTENDERS

Guy Norris Colorado Springs

While Airbus and Boeing converge on critical propulsion choices for their next-generation single-aisle designs, 2025 promises to be a pivotal year for engine-makers as they vie for pole position in the early stages of the coming power contest.

For CFM International joint venture partners GE Aerospace and Safran, a new wave of component and increasingly large-scale systems testing is expected early in the new year under the continuing Revolutionary Innovation for Sustainable Engines (RISE) engine technology program. Arrayed across thermodynamic and propulsive efficiency initiatives, the outcome of these tests will pave the way for crucial configuration decisions later this decade.

A major innovation of RISE is the use of a 13-ft.-dia. open fan that touts potential major efficiency gains—although it faces several airframe integration challenges. To help understand these better, GE Aerospace is leading a project in collaboration with Boeing, NASA and the U.S. Energy Department's Oak Ridge National Laboratory to use supercomputers to evaluate complex engine-airframe airflow interactions.

The project, which will use up to

840,000 supercomputing hours, forms part of the Energy Department's Innovative and Novel Computational Impact on Theory and Experiment program—an initiative launched in 2024 to award research time to large-scale scientific and technological innovations.

GE previously used the Oak Ridge Leadership Computing Facility Frontier supercomputer at Oak Ridge National Laboratory to model the performance and noise levels of the open fan's blades and associated stator vanes.

The work, completed in 2023, helped GE identify interaction areas and make design changes where appropriate ahead of testing using full-scale hardware. The new tests will focus on the aerodynamics of an open fan mounted on an aircraft wing in

simulated flight conditions. This allows the engine design to be optimized for additional efficiency, noise and other performance benefits, GE says.

The researchers will be able to replicate a full-size integrated engine and aircraft in the design phase, GE says, a task that would be impossible without the computational power of the newest supercomputing machines. The studies could go some way toward answering critical questions about the installation effects of the open fan on the airframe and could help alleviate concerns expressed by Boeing in 2024 over the use of RISE on a future single-aisle. In August, the manufacturer questioned if the additional structural weight and potential aerodynamic impact associated with mounting the open fan might offset much of the concept's expected 20% efficiency gain.

While the open fan and propulsive efficiency focus for RISE is an obvious attention-grabber, the program includes an equal emphasis on boosting thermodynamic performance through small core innovations and hybrid power technology.

Hybrid and compact core elements are set for key tests in 2025 under NASA's Hybrid Thermally Efficient Core (HyTEC) program. In the nearer term, under the Turbofan Engine Power Extraction (PEX) effort, a modified Passport business jet engine reconfigured with multiple motor generators is nearing completion at GE's Evendale, Ohio, complex and will be tested over the next few months at the company's facility in Peebles, Ohio. PEX goals include demonstrating up to 20% power extraction, or roughly four times the current state of the art.

The overarching aim of HyTEC and the related PEX programs is to develop technology for small, high-power density cores for integration with larger lower-pressure fans—ducted or open—thereby enabling higher bypass ratios and a 5-10% fuel-burn reduction versus a 2020 best-in-class engine. For the program to be counted as a success, metrics for a single-aisle 25,000-35,000-lb.-thrust engine in the 2035 time frame include a bypass ratio of 15:1 or higher and an engine overall pressure ratio of at least 50:1.

Targets also include a high-pressure compressor (HPC) exit corrected flow rate of under 3 lb. of mass per second (lbm./sec.), compared with the current Leap 1B's HPC exit flow rate of around

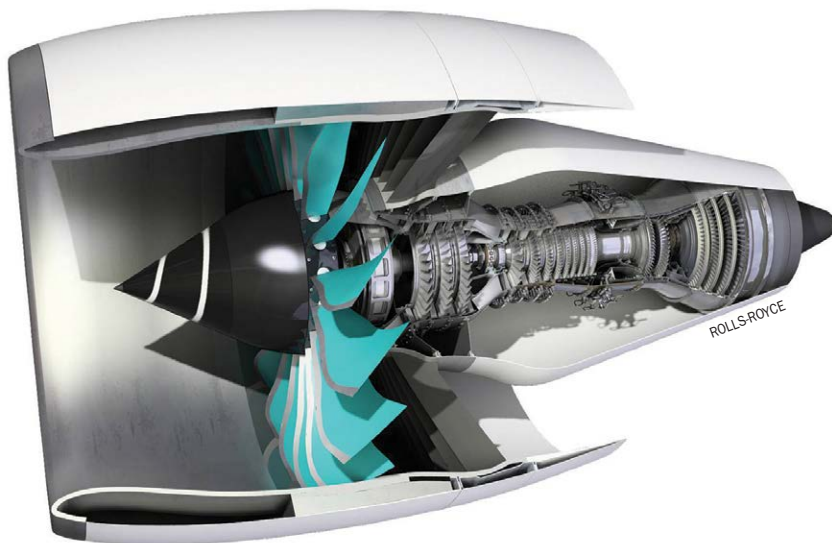
4.23 lbm./sec. and the Pratt & Whitney PW1127G geared fan's 4.41 lbm./sec.

"We will do a core demonstration to [technology readiness level (TRL) 6] in late 2028 and wrap up in 2029," NASA HyTEC Project Manager Tony Nerone says. "By 2029, we will be very close to achieving those goals, if we are successful."

The current Phase 2 effort, which officially began in early 2024, will build on small core technology work undertaken in the initial part of the HyTEC program. This has focused to date on the development and testing of ad-

space cost share, covers the integration of Phase 1 technologies into an engine for the compact, high-power density core ground demonstration within the next four years.

Pratt's focus remains on development of an enhanced second-generation geared turbofan (GTF) with 25% lower fuel burn than today's engines on an installed basis. The company plans to move to a bigger-diameter composite fan contained in a composite case and shrouded within a compact, shorter duct nacelle. The engine also will incorporate a revised, smaller



Rolls-Royce is evaluating a single-aisle version of the UltraFan geared engine architecture as part of Clean Aviation's Heaven research initiative.

vanced high-pressure (HP) compressors, HP turbine blade aerodynamics and cooling, environmental barrier coatings (EBC) for vanes and blades and advanced ceramic matrix composites (CMC) for combustor liners. Some of the Phase 1 work on CMC/EBC and sustainable aviation fuel compatibility involves Pratt & Whitney.

Of the eight projects underway in Phase 1, "three are done, and the rest should be completed [in 2025]," Nerone says. Three new high-temperature EBC achieved TRL 5 in mid-2024 and, key for GE's RISE goals, the company's small core turbine concept also reached TRL 4 by the middle of 2024.

The Phase 2 cost-share contract with NASA, which has a maximum government value of about \$68.1 million and a 50% minimum GE Aero-

core with a higher overall pressure ratio, ultralow emissions combustor and, more than likely, hybrid-electric motor-generators.

Although the configuration will retain the same baseline geared architecture, the next-generation version will maximize the potential benefits of the gear system, Pratt Senior Vice President Geoff Hunt says. "If you want propulsive efficiency, you're driving up bypass ratio, and that's going to keep pushing on gears," he notes. "We're currently running a little over 3.5:1 gear ratio, but in a ducted configuration you must push up to four or so."

Pratt says it was conservative with the first-generation GTF gear design, which now gives it margin to increase the gear ratio. "We protected the capability to have a viable engine by removal of the fan drive gear system and

making it a direct drive,” Pratt Chief Sustainability Officer Graham Webb says. “So we didn’t go for the full optimized gear in the architecture—we held some back. We’ll have hundreds of millions of flight hours experience in the fan drive gear system by 2035 and have that technical confidence, so now let’s go for it.”

At the same time, the newer configuration also will “take more work off the low-pressure spool and reduce the work off the high-pressure spool,” Webb says. “That enables us to increase overall pressure ratio while improving durability.” To increase bypass ratio, fan diameter also will increase to 85-90 in. from the 81 in. of the PW1100G. Rig tests also are underway of GTF Gen 2 combustors, compressors, high-pressure turbines and composite fan blades, he adds.

Tests of the hybrid electric elements are being developed as part of Europe’s Clean Aviation Sustainable Water-Injecting Turbofan Comprising Hybrid-Electrics (Switch) engine research program. RTX subsidiary

Collins Aerospace is supplying two motor generators for Switch, the hybrid-electric element of which will be tested in a modified PW1100G. Both are identical 1-megawatt machines, but the unit connected to the high-pressure spool is derated to 500 kW, while the motor generator attached to the aft of the low-pressure shaft is rated to 1 megawatt. In an operational version, the electric system will be used for taxiing and to boost power for takeoff and other transient phases, RTX says.

Rolls-Royce is evaluating a single-aisle version of the UltraFan geared engine architecture as part of European Clean Aviation’s Hydrogen Engine Architecture Virtually Engineered Novelty (Heaven) research initiative. Actively supported at the corporate level under a strategic plan launched by Rolls-Royce CEO Tufan Erginbilgic in late 2023, the project is focused on scaling effects on components such as combustion, gearbox and the composite fan.

“We will bring all those together in a ground test of a narrowbody-size

engine,” Alan Newby, director of research and technology at Rolls-Royce, said at the International Society for Air Breathing Engines conference in September. “We will also continue to develop other technologies, including hybridization, for example, and there will be others. We won’t necessarily be using UltraFan itself as a validation vehicle, these could be tested either on a business jet engine or one of the Trent family engines. And, ultimately, we will bring that altogether in a flight test—and that’s one of our targets.”

Newby said the requirements for a new single-aisle engine are clear. “We all know you’re going to need a gear,” he noted. “You’re going to need to split the speed of the low-pressure turbine and the fan—that’s a given. You’re going to need a high-efficiency, small, hot core—we all agree on that. You’re probably going to have some more electric systems in there.”

Gallery See more about propulsion developments in 2024:

[AviationWeek.com/Propulsion2024](https://www.aviationweek.com/Propulsion2024)



Hypersonic and Supersonic Tests Step Up in 2025

➤ FOCUS GROWS ON ROTATING DETONATION

➤ SCRAMJET FLIGHT TEST SET FOR 2025

Guy Norris Colorado Springs



Tests of the Hermeus Quarterhorse Mk. 1 at Edwards AFB, California, will pave the way for a follow-on full-scale turbine-based, combined-cycle-powered version.

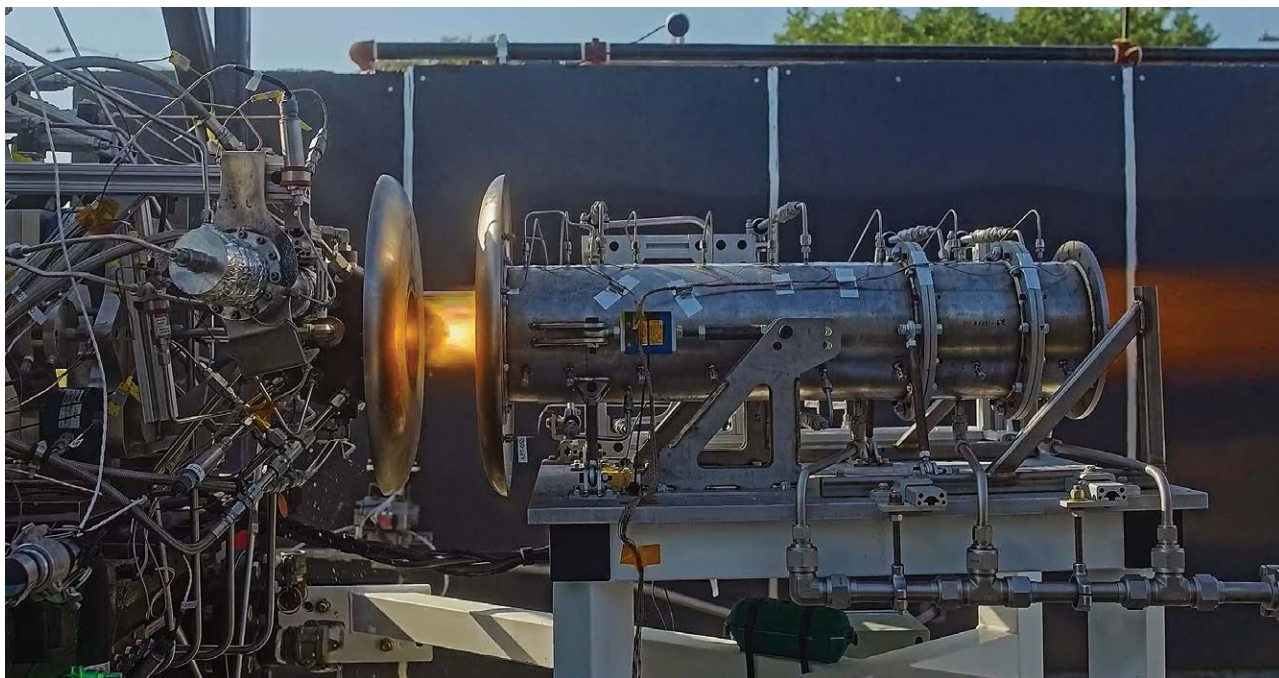
High-speed air-breathing propulsion has been the exclusive purview of traditional engine-makers since the birth of the jet age. But as 2025 dawns, it is the emerging generation of startup vehicle and engine developers that is making news.

Showing marked progress is Atlanta-based hypersonic aircraft developer Hermeus, which continues to defy the odds by ground-testing a turbine-based, combined-cycle (TBCC) propulsion system and a prototype flight vehicle to go with it.

Following the completion of low-speed taxi tests of its Quarterhorse Mk. 1 aircraft in mid-2024, Hermeus delivered the vehicle to Edwards AFB, California, on Nov. 16 as part of the buildup to flight tests, which are due to begin around the turn of the year. The Quarterhorse is intended to demonstrate the company’s ability to fly a high-wing loaded vehicle with high takeoff-and-landing speeds, paving the way for a series of larger, more capable Mk. 2 and Mk. 3 test vehicles designed for high-Mach supersonic speeds.

The Mk. 1 vehicle is powered by a GE Aerospace J85-21, a

HERMEUS



Tests of the Venus Detonation Ramjet engine will combine a rotating detonation rocket engine with a ramburner.

3,500-lb.-dry-thrust engine. The follow-on Mk. 2 will be powered by a 29,000-lb.-thrust afterburning Pratt & Whitney F100-229 with an integrated precooler—the first element of the Hermeus-designed Chimera TBCC propulsion system. Further elements of the TBCC, including a ramjet, will feature in the follow-on Mk. 3 version.

The Mk. 2 version is expected to achieve speeds greater than Mach 2.5, while the Mk. 3 with the full TBCC system is designed for speeds close to Mach 4. The Mk. 3 version will also pave the way for a future Hermeus aircraft capable of hypersonic speeds, the company says. This is scheduled to be the Darkhorse, a twin-engine design that will target cruise capability above Mach 5.

In parallel, Hermeus is ramping up activity at a newly inaugurated engine test facility and a flight-test base at Cecil Airport in Jacksonville, Florida. Designed to support testing of the Quarterhorse and Darkhorse series, along with the Chimera engine, the High Enthalpy Air-Breathing Test Facility has been developed for propulsion system runs at continuous high-Mach airflow at high temperatures and low pressure conditions.

Another startup, Houston-based Venus Aerospace, is meanwhile making headway in efforts to develop a rocket-based, combined-cycle (RBCC) propulsion system for a high-speed transport dubbed the Stargazer M4. The hypersonic spaceplane is slated to be powered by a pair of Venus Detonation Ramjet (VDR) engines that will combine a rotating detonation rocket engine (RDRE) with a ramjet.

Designed to travel at Mach 9 from California to Japan, variants of the Stargazer will be offered to the U.S. military and allies, which could perform transport or intelligence, surveillance and reconnaissance missions. The concept aims to leverage the potential thermodynamic efficiency gains offered by rotating detonation engines (RDE), in which combustion takes place at constant volume rather than constant pressure.

An RDE combusts the fuel-air mixture at supersonic speed as a detonation rather than the subsonic deflagration that occurs in conventional combustors. The process results

in a pressure gain—rather than loss—during combustion and takes place over a shorter distance, which reduces the size of the combustor and therefore its weight.

Although the first VDR variant (the 2,000-lb.-thrust-rated VDR2) was not unveiled until October, baseline work to underpin the VDR has been underway since the company was founded in 2020. While the detonation ramjet is targeted at hypersonic missions in the atmosphere, its development has been supported in part by foundational work undertaken with NASA on RDREs that could pave the way for space applications. Through extended ground tests of scaled RDREs Venus has progressively tackled key technical issues of the constant volume combustion system including stability, parasitic deflagration, stiffness and thermal management.

This work was augmented by flight tests in early 2024 of an RDRE-powered, 8-ft.-long, 300-lb. drone. Along with ground rig work, the flight trials clear the way for tests of the RDE integrated in an air-breathing RBCC. The VDR will combine the Venus RDRE, mounted in the aft of the axisymmetric supersonic shock cone inlet, with a ram burner, called the Bronco, provided by Cincinnati-based hypersonic propulsion specialists Velontra.

Venus aims to flight-test the propulsion system at sub-scale in a hypersonic drone in 2025. In the nearer term, the company aims to evaluate the integrated RDRE with a ram burner in ground tests following integration of the two units on the test stand in late November. “We aim to have full ground tests of the VDR2 done in the second quarter of 2025 and hit the preliminary design review of the VDR2-powered Mach 5 drone,” Venus co-founder and Chief Technology Officer Andrew Duggleby says.

“We are looking to fly a detonation engine this January-February, if we can navigate a few remaining constraints,” he added. “Otherwise, our full Mach 5 drone [RDRE powered, not VDR2 powered] should be ready to fly in the summer-fall of 2025.”

From the moment of ignition on the runway the RDRE exhaust adds pressure and temperature to the core flow entering the rest of the engine, including the ram burner.

Once supersonic Venus says the pressure will be sufficiently high to ignite the ram burner, further accelerating the vehicle. With added speed and more compression from the shockwave, the VDR becomes less dependent on the RDRE, which can be throttled back until, beyond about Mach 3.5 onward, the detonation engine can be shut off with all thrust coming from the ramjet.

Venus hopes to keep the combined propulsion system simple by avoiding the use of turbine engines for initial takeoff and climb, as well as landing. Whether it achieves this goal “will depend ultimately on the noise level of the VDR50—the planned 50,000-lb.-thrust version planned to power the Stargazer. Our initial experiments are hopeful, but it’s way too early to tell,” he says.

first phase of the AFRL-led Advanced Turbine Technologies for Affordable Mission capabilities initiative. In early 2020, Raytheon also began studies of an RDE-powered long-range strike-missile concept under a DARPA contract.

Another air-breathing high-speed test slated for the coming year is Rocket Lab’s HASTE (Hypersonic Accelerator Suborbital Test Electron) mission in 2025 for the U.S. Defense Department’s Defense Innovation Unit. Scheduled to deploy a suborbital payload built by Australian company Hypersonix called DART AE—a scramjet-powered vehicle capable of nonballistic flight at speeds of up to Mach 7—the mission will launch in early 2025 from the Virginia Spaceport Authority’s Mid-Atlantic Regional Spaceport on Wallops Island.

Key milestones also are expected in the coming year for Denver-based Boom Supersonic, another startup with high-speed ambitions, which aims to develop the Mach 1.7 Overture airliner by the end of the decade. Having found no existing engine core suitable for its intended mission cycle requirements, Boom is developing its own 35,000-lb.-thrust propulsion system—dubbed the Symphony—with a partnership including StandardAero, Kratos unit Florida Turbine Technologies (FTT) and GE Aerospace.

Ahead of more than 30 hardware rig tests and multiple iterations of full-scale cores planned prior to finalizing the design for FAA/EASA certification, parts for initial tests are coming together. Metal forging began at Dallas-based ATI in mid-November for the first superalloys intended for the compressor and turbine.

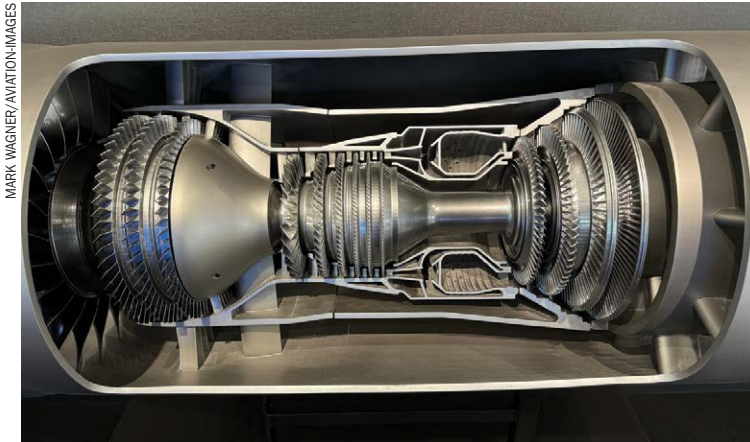
Forging work comes as rig tests of the combustor section continue in collaboration with FTT at

Kratos’ design and test facility in Jupiter, Florida. Colibrium Additive, a supplier owned by GE Aerospace, has meanwhile produced the first 3D-printed parts for the Symphony, including fuel nozzles and turbine center frames.

More details of the Symphony design have emerged in advance of the initial core tests, the first of which is also expected to take place by the end of 2025. The two-spool, 3:1 medium-bypass turbofan engine will be equipped with a single-stage 72-in.-dia. fan and optimized for prolonged supersonic operation with an air-cooled, single-stage, high-pressure turbine and three-stage, low-pressure turbine. The Symphony’s compressor will be made up of a six-stage high-pressure unit and a three-stage low-pressure section, while the engine’s mixed compression supersonic inlet, diffuser and exhaust design is devised to meet Chapter 14 noise levels.

Based on expectations of a favorable thrust-to-drag ratio, Boom says the Symphony is designed with sufficient thrust to accelerate the Overture through the sound barrier and maintain a cruise speed of Mach 1.7 without afterburners. The engine’s design optimizes the core for top-of-climb performance in supercruise, while the fan is optimized for noise reduction during takeoff.

The Symphony’s turbine inlet temperature will be approximately 2,800F at the top of the climb, with an overall pressure ratio of around 21:1. While this ratio is less than half that of most state-of-the-art subsonic engines, Boom says it is appropriate for a supersonic engine, in which a significant portion of the compression is handled by the aircraft’s inlet and high-speed aerodynamics. 



Initial component rig tests for Boom’s Symphony supersonic engine are underway, and core tests are expected to begin in late 2025.

Research and development of high-speed propulsion systems incorporating rotating detonation engines is also underway at GE Aerospace, where follow-on tests of a dual-mode ramjet (DMRJ) continue after initial runs began at the company’s Evendale, Ohio, facility in March 2024.

Testing ran through August and, according to GE, exceeded performance expectations by demonstrating robust DMRJ operation. After designing, building and running the engine in less than a year, the company is confident it can build up to full-scale evaluation of an integrated system capable of delivering thrust performance of at least Mach 5.

Work to integrate the DMRJ with a full-scale rotation detonation combustor is meanwhile underway and is targeted at firing up on the ground rig test in the first quarter of the new year. GE also plans to combine the RD-DMRJ with a high-Mach turbine engine for a ground rig test of a hypersonic TBCC system by the end of 2025.

Pratt also expects to provide updates in early 2025 of the results of RDE demonstrator tests conducted under a U.S. Air Force Research Laboratory (AFRL) contract awarded in 2022. The ground-test demonstration program was run jointly by Pratt, Raytheon (now RTX) Missiles & Defense and the RTX Technology Research Center and followed on the heels of earlier initial concept-development work by Pratt’s Gatorworks rapid prototyping unit.

The demonstrator award builds on long-running pressure-gain propulsion-gain research by Pratt and Raytheon prior to their merger in 2020. This includes an RDE technology development contract that Pratt won in 2018 under the



ANALYSIS

Time of Transition

Lee Ann Shay Washington

IT FEELS LIKE 2025 WILL BE

a year of many changes—a lot of transitions.

Leadership Influential and well-regarded leaders are stepping down. Pete Bunce, who has been president and CEO of the General Aviation Manufacturers Association (GAMA) for 20 years, will retire by April. Vertical Aviation International CEO James Viola will move into the role. Bunce has been a formidable presence in the industry and at the FAA and European Union Aviation Safety Agency. He expanded GAMA's presence into Europe and into helicopters and the advanced air mobility (AAM) sector. He also inspired workforce development, the use of unleaded avgas for piston aircraft and many other important matters. Viola, who spearheaded Vertical's name change from Helicopter Association International to widen the organization's focus, previously was the FAA's director of general aviation safety assurance, as well as a U.S. Army colonel and aviator. Viola has big shoes to fill but the background to succeed.

In addition, FAA Administrator Michael Whitaker announced on Dec. 12 he plans to step down on Jan. 20, four years early (page 16). During his tenure, the FAA released the Special Federal Aviation Regulation that set the operating and pilot training basis for AAM. President-elect Donald Trump will nominate the next administrator.

AAM The coming year will be a pivotal one for AAM on many fronts. It could be the year the first AAM manufacturer outside China—Archer Aviation, Beta Technologies or Joby—certifies a vehicle (page 115). Germany-based Lilium and Volocopter are both cash-strapped and seeking investors. Volocopter still hopes to certify its two-seat Velocity, having originally planned to fly it at the 2024 Paris Olympics.

Speaking of transitions, Australia and Germany recently released their strategic road maps for AAM, laying out the foundations for routes, infrastructure and operations.

In the Middle East, the United Arab Emirates and Saudi Arabia both aspire to be early adapters of the technology and have advanced ecosystem plans underway.

New Aircraft Four new aircraft should be certified in 2025: Bombardier's ultra-long-range Global 8000, Gulfstream's 8,000-nm-range G800, Textron Aviation's midsize Cessna Citation Ascend and the single-engine turboprop Beechcraft Denali.

All of these new aircraft include advanced avionics, engines and cabin features designed to deliver more efficient operations and greater performance. Even the smallest of the four, the Denali, is equipped with Garmin Emergency Autoland and synthetic vision technology. Textron's 3D technical manuals also are expected to become available, making technicians' job easier as the maintenance world moves into digital documentation.



VOLOCOPTER

Volocopter plans to certify its Velocity air taxi in 2025.

Innovation General and business aviation have long incubated new technologies. One exciting area is propulsion. EcoPulse, the Daher TBM aircraft outfitted with six Safran ePropellers, just concluded its flight-test campaign, partners Airbus, Daher and Safran announced Dec. 10 (page 18). The jointly developed hybrid-electric propulsion aircraft demonstrator helped the partners validate low-carbon-emission technologies and “tackle critical technological hurdles,” Daher Chief Technology Officer Pascal Laguerre says. Expect more electric, hybrid and hydrogen propulsion tests in general aviation in 2025.

Workforce The number of certified pilots and mechanics has been increasing, which reflects the industry's grassroots efforts to promote these careers. However, demand still exceeds supply. The business aviation industry often likes to be stealthy, but how do you recruit, attract and retain the best candidates that way?

And now that several generations are in the workplace—each with different views of job satisfaction and loyalty—how is the industry tapping into the best of each and transitioning talent? ☯

Aircraft data **p.104** Sustainable aviation fuel **p.105** Airports and FBOs with SAF supply **p.106**
Top 10 trends **p.108** What is in and what is out **p.109**

'A LITTLE FROTHY'



- > THE BIZAV MARKET IS STABILIZING, BUT SOME TRENDS ARE CONCERNING
- > FIRST-TIME BUYERS ARE STAYING
- > THE CUSTOMER PROFILE IS CHANGING

Going into 2025, business jet manufacturers have strong backlogs, with about two years of deliveries for some models.

Molly McMillin Wichita

The business aviation market is stabilizing following a major expansion, but it continues to grow as new entrants during the COVID-19 pandemic are staying. That factor is key to the industry going forward, experts say.

During the pandemic, first-time business aircraft buyers rose to nearly 40% of all buyers, up from the normal range of 9-12%, said Embraer Executive Jets President and CEO Michael Amalfitano.

Although the market is normalizing, only 8% of first-time buyers across the industry sold their aircraft during the first year, Amalfitano told attendees in September at the JetNet iQ Global Business Aviation Summit in New York. "The stickiness is there," he noted. Of those who decided to sell their aircraft, the majority are upgrading to a new one.

"We're coming off a huge high," Amalfitano said. "It's still a growth that the industry hasn't seen in a decade."

At the same time, he said, the sectors remain strong: "You're getting corporate flight departments, high-worth individuals, billionaires, owner-pilots, fractional, fleet—all buying. And that's not always the case. There are usually variabilities in those places, but you're seeing growth in all those sectors. That's important."

The pandemic changed the way business aviation is used as well as the typical customer profile.

"Surprisingly, it's gotten younger; I would say almost 10 years younger, which is a great thing because they'll be with us longer," Kenn Ricci, principal of Directional Aviation Capital and chair of Flexjet, said at the November Corporate Jet Investor conference in Miami. "We sell four times as many mid- and super-mid aircraft than we do light jets. [The aircraft have] gotten bigger, they've gotten younger, and they're going international."

At the same time, "there's a lot of wealth showing up," Ricci said. "There's a huge wealth transfer going down, and they're buying the planes their parents didn't."

The industry has made some adjustments for the new entrants.

"Everybody thinks the first-time buyer is someone who can't afford the airplane, and they don't really know what they're doing," Amalfitano said. "But that's not where the buyers are. The buyers are people who know they

need the airplane; they've always known they needed the airplane and could afford the airplane. And guess what COVID did? Gave them a reason [to buy] that nobody questioned: safety, privacy, security, time management. 'My business is more important; my family is more important.' It gave them camouflage."

Timing was a factor, Guardian Jet Co-managing Partner Don Dwyer added. "It was COVID on the end of a 12-year bull run," he said. "It might be the greatest creation of wealth in the creation of the planet."

That demand drained pre-owned inventory levels and "reset the market," Dassault Falcon Jet CEO Thierry Betbeze said at the JetNet Summit.

Pre-owned inventory has grown over the past year, giving buyers increased negotiating leverage when considering older models. Newer pre-owned models remain in demand, however.

"There is movement, and it is becoming more of a buyer's market than a seller's market, but it's a very normal progression," International Aircraft Dealers Association (IADA) Executive Director Wayne Starling said at Corporate Jet Investor.

During the third quarter of 2024, IADA reports, dealers closed 373 transactions for pre-owned aircraft, a

JETLINER IMAGES/GETTY IMAGES

15% year-over-year increase and the highest level of third-quarter closings the group has recorded since it began surveying members in 2020. For the first three quarters of 2024, dealers closed 993 transactions, up 14% compared with the same period in 2023.

For 2025-34, the Aviation Week Network's newly released Business Aviation Fleet & MRO forecast projects deliveries of more than 9,000 new business jets and nearly 2,800 turboprops valued at \$298 billion.

Light jets are projected to lead deliveries with a 27% share, followed by ultra-long-range business jets, super-midsize jets, very light jets, large jets and midsize jets.

The forecast projects nearly 6,600 legacy business jets and turboprops will be retired over the 10-year period, with yearly retirements peaking at 744 aircraft in 2031. It also projects growth on the maintenance, repair and overhaul side, forecasting more than a 3.2% compound annual growth rate overall and \$146 billion in demand, 27% of it for aircraft engine requirements.

The new year will be marked by service entry of several new products.

For one, Bombardier's Global 8000 ultra-long-range jet, based on the Global 7500, is on track to enter service in the second half of 2025. Gulfstream's G800, the manufacturer's longest-range aircraft to date, is expected to earn certification soon. Meanwhile, Textron Aviation is looking forward to two new products entering service in 2025: the Cessna Citation Ascend, a midsize business jet seating up to 12 passengers, and the Beechcraft Denali single-engine turboprop.

Business jet manufacturers have strong backlogs going into 2025, with about two years of demand, depending on the product, in part due to lingering supply chain constraints. The dynamic, however, gives manufacturers stability and opportunities for improved pricing and profitability, they note.

"We've seen a very good environment for several years now," Bart Demosky, executive vice president and chief financial officer for Bombardier, told analysts during a third-quarter earnings call. Given the backlog, Demosky noted, "the gains you see us enjoying now were locked in 18-24 months ago." He expects favorable pricing to continue in the coming quarters, with "very stable demand," although he conceded that increased costs due to

supply chain challenges and inflation have outstripped some of that gain.

Bombardier is not alone. Parts shortages continue to plague all manufacturers. While the number of problem parts at Textron Aviation has declined, "there's still a problem, and that was continuing to drive a lot of out-of-station work and just significant inefficiencies in the factory," Chairman and CEO Scott Donnelly told analysts on a third-quarter earnings call for Textron Aviation's parent company.

At Gulfstream Aerospace, supply chain issues slowed third-quarter deliveries, although the number of prospects for the purchase of business jets continues to increase.

"The overall number of prospects in our pipeline is at an all-time high, with the most active models being the G500, G600 and G700," Phoebe Novakovic, chair and CEO of General Dynamics, Gulfstream's parent company, told analysts on a third-quarter financial call. She predicted "reasonably strong order intake" during the fourth quarter.

In the big picture, the economy is sound, the banking industry is strong, pre-owned aircraft inventory levels remain below historical averages, access to capital is plentiful for the right profiles, and the in-service fleet is aging and spurring replacements, Embraer's Amalfitano said.

Still, there are concerning trends. Low interest rates are a thing of the past, fuel prices have been vulnerable, labor pressures continue, and aggressive GDP recovery predictions around the world seem unachievable.

While business is good, Ricci said, "you're wondering when the next shoe will drop." On the plus side, the fractional business is stable and enjoys a backlog, one that Flexjet has not experienced in the past.

"Friends used to call me for a discount," he said. "Now they call to see if they can move up in the queue."

So where is the market going in 2025? Ricci sounded cautious.

"I think we're going to have a downside surprise," he said. "That's the thing about downside surprises. We don't know what they are. . . . Business is good, but I'm paranoid. . . . It's been too strong for too long. So I think things are a little frothy." 📷

Gallery See more about business aviation developments in 2024: [AviationWeek.com/bizav2024](https://www.AviationWeek.com/bizav2024)



People To Watch



Joe Ben Bevirt
Joby Aviation
Founder and CEO

A pioneer in the advanced air mobility industry, Bevirt plans to launch initial service with the Joby S4 air taxi in late 2025 in Dubai. He also has led the company through recent acquisitions of hydrogen propulsion and autonomy startups, technologies he plans to integrate into Joby's aircraft.



Kyle Clark
Beta Technologies
Founder and CEO

Under Clark's leadership, Beta appears to be the most likely candidate to certify an electric aircraft in the U.S. in 2025, beginning with its conventional-takeoff-and-landing Alia. The company also plans to continue expanding its network of dozens of electric aircraft chargers at airports and fixed-base operators across the U.S. while increasing output at its factory in South Burlington, Vermont.



Chris D'Acosta
Swift Fuels CEO

D'Acosta has long promised to release a 100-octane unleaded avgas and has urged pilots to "be patient" for its arrival. The company expects its new 100R unleaded fuel to become commercially available in 2025 with both FAA approval and a key industry-consensus ASTM product specification.



Zipporah Marmor
Opus Aero North America
Managing Partner

Marmor was appointed managing partner of Opus Aero North America in 2024, marking a milestone in the Monaco-based company's expansion strategy. She leads development of Opus' footprint in the U.S. and Canada. She also is chair emerita and a certified broker for the International Aircraft Dealers Association.



George Mattson
Wheels Up CEO

Since averting bankruptcy for Wheels Up in September 2023, Mattson has worked to stabilize and position the business for growth as it moves to become profitable in 2025 for the first time.



Jim Segrave
FlyExclusive CEO

In 2024, FlyExclusive went public, made fleet changes and took on aircraft management for Volato. The challenging year was the first time the company was not profitable, but Segrave is predicting growth in 2025. 📈

Business Aviation Forecast, 2025-29



Snapshot

Airbus ACJ TwoTwenty

The ACJ TwoTwenty is an extra-large-cabin business jet produced by Airbus and based on the A220-100 airliner. With three times more cabin space than purpose-designed large business jets, the Pratt & Whitney PW1500G-powered TwoTwenty was announced by Airbus Corporate Jets in October 2020 and made its first flight in December 2021. Switzerland-headquartered Comlux is outfitting the first 15 aircraft at its completion center in Indianapolis and delivered the first ACJ TwoTwenty to FIVE Hotels and Resorts in April 2023.

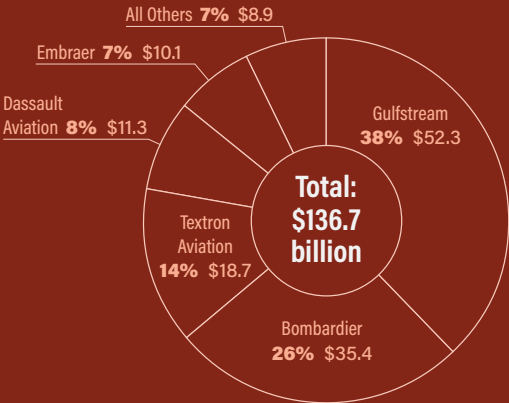
Cabin Height: **81.6 in.**

Cabin Width: **130 in.**

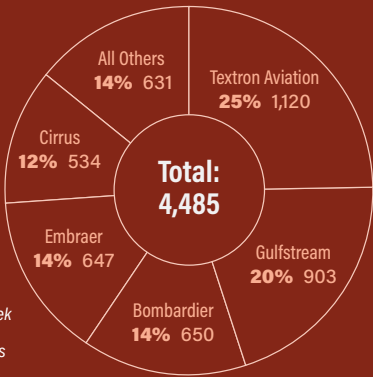
Cabin Length: **78 ft.**

Cabin Volume: **5,120 ft.³**

Value of Five-Year Production
Billions of U.S. 2024 Dollars



Five-Year Unit Production



Source: 2025 Aviation Week Network Business Fleet & MRO Forecast. All numbers and percentages rounded.

BUSINESS AIRCRAFT TO WATCH

MODEL/ DESIGNATION	WING- SPAN (ft.)	MAX. LENGTH (ft.)	MAX. HEIGHT (ft.)	MAX. CABIN WIDTH (in.)	MAX. T/O WEIGHT (lb.)	MAX. LANDING WEIGHT (lb.)	POWERPLANT (No./Type)	THRUST (lb.)	MAX. SPEED	MAX. RANGE (nm @ speed)	OPERATING ALTITUDE (ft.)
AIRBUS											
ACJ TwoTwenty	115.2	114.8	37.7	129.6	139,000	112,500	2 X P&W PW1500G	24,000 ea.	M 0.82	5,650 (8 pax @ M 0.78)	41,000
BOMBARDIER											
Challenger 3500	69	68.75	20	86	40,600	34,150	2 X Honeywell HTF7350	7,323 ea.	M 0.83	3,400 (4 pax @ M 0.77)	45,000
Global 8000	104	111	27	96	—	—	2 X GE Passport	18,920 ea.	M 0.94	8,000 (8 pax @ M 0.85)	51,000
DASSAULT AVIATION											
Falcon 6X	85.1	84.3	24.5	102	77,460	66,190	2 X P&WC PW812D	13,500 ea.	M 0.9	5,500 @ M 0.8	51,000
Falcon 10X	110.25	109.6	27.6	109	115,000	—	2 X RR Pearl 10X	18,000 ea.	M 0.925	7,500 @ M 0.85	51,000
GULFSTREAM											
G400	86.3	86.25	25.3	91	69,850	60,000	2 X P&WC PW812GA	13,496 ea.	M 0.90	4,200 @ M 0.85	51,000
G800	103	99.75	25.5	98	105,600	83,500	2 X RR Pearl 700	18,250 ea.	M 0.925	8,000 @ M 0.85	51,000
HONDA AIRCRAFT											
HondaJet Echelon	56.7	57.8	15.9	61	17,550	—	2 X Williams FJ44-4C	3,450 ea.	450 kt.	2,625 (4 pax)	47,000
TEXTRON AVIATION											
Beechcraft Denali	54.25	48.75	15.2	63	—	—	1 X GE Catalyst	1,300 shp	285 kt.	1,600	31,000
Cessna Ascend	55.75	52.75	17.25	66	20,500	18,700	2 X P&WC PW545D	4,213 ea.	441 kt.	1,900	45,000



Increasing production of SAF in the U.S. will fall to the Republican-controlled Congress and the second Trump administration.

BILL CAREY/ANAST

SAF's Fast Start Meets Speed Bump

- BIZAV EMBRACES SUSTAINABLE AVIATION FUEL
- MORE FIXED-BASE OPERATORS ARE SUPPLYING BLENDED SAF

Bill Carey Washington

Business aviation has leapt ahead of airlines in adopting sustainable aviation fuel, but a change in U.S. presidents and renewed Republican control of Congress has injected uncertainty into the wider industry's progress toward the goal of net-zero carbon emissions.

As of late November, sustainability consulting company 4AIR listed 42 airports serving business aviation in the U.S. and 39 in European countries as well as Dubai, and Singapore that have a physical supply of sustainable aviation fuel (SAF) or have announced they will soon offer the sustainably sourced jet fuel.

Signature Aviation, the world's largest network of fixed-base operators (FBO), said it would offer blended SAF—35% “neat” SAF and 65% conventional jet fuel—at six new locations in the U.S., including some of business aviation's busiest airports, in 2025.

The expansion extends Signature's SAF availability to 23 locations.

SAF acceptance by operators is on the rise, as is production of the fuel, the National Business Aviation Association says. In the three years since the Biden administration announced its ambitious SAF Grand Challenge, annual domestic production and imports of SAF have increased tenfold to 52 million gal. from 5 million gal. through the first half of 2024, the association notes, citing data from the U.S. Energy Department.

But ongoing progress toward the Grand Challenge goal, which calls for the U.S. to ramp up domestic SAF production to 3 billion gal. a year by 2030, now falls to President-elect Donald Trump and a Republican-dominated Congress. Republicans last controlled the House and Senate from January 2017 to January 2019, during Trump's first administration.

Trump, who has expressed doubts

about the science of climate change, has vowed to roll back President Joe Biden's climate policies and repeal the landmark 2022 Inflation Reduction Act (IRA), which allotted \$369 billion in tax incentives, grants and subsidies for clean-energy projects.

Derided by Trump as the “Green New Scam,” the IRA contained a Blenders Tax Credit that business aviation had long advocated to incentivize SAF production, but it expires in January. After that, a new Clean Fuel Production Credit, known as the 45Z credit, allows an income tax credit for the domestic production of lower-emission SAF and non-SAF transportation fuel through 2027.

“Any reduction in Clean Fuel Production Credit under a Trump administration could hurt SAF's trajectory just as the market is beginning to gain traction,” commented online publication SAF Investor. “Trump's previous stance on biofuel blending requirements—and his willingness to reduce Renewable Fuel Standard compliance costs for refineries—could signal further cuts to biofuel blending incentives, impacting feedstock demand and creating volatility in the SAF market.”

The Energy Department's GREET

Airports and FBOs With Physical SAF Supply

Below are airports and fixed-base operators (FBO) in the U.S., Europe, Dubai and Singapore that offered or plan to offer sustainable aviation fuel (SAF) as of November, according to 4AIR, which tracks business aviation destinations that have a physical supply for purchase. Supply may be limited at some locations, and 4AIR advises calling ahead to ensure a destination has SAF available.

U.S.

KASE Aspen/Pitkin County Airport, Colorado. Atlantic Aviation.

KBFI King County International Airport-Boeing Field, Washington. Skyservice and Signature Aviation.

KBUR Hollywood Burbank Airport, California. Million Air.

KBZN Bozeman Yellowstone International Airport, Montana. Jet Aviation.

KCMA Camarillo Airport, California. Sun Air Jets and Avex.

KCRQ McClellan-Palomar Airport, California. Atlantic Aviation.

KDAL Dallas Love Field. Signature Aviation.

KEGE Eagle County Regional Airport, Colorado. Signature Aviation.

KFAT Fresno Yosemite International Airport, California. Signature Aviation.

KFFZ Falcon Field Airport, Arizona. Avflight.

KFTY Fulton County Executive Airport, Georgia. Hill Aircraft.

KHDN Yampa Valley Regional Airport, Colorado. Atlantic Aviation.

KHIO Portland-Hillsboro Airport, Oregon. Hillsboro Aviation.

KHOU William P. Hobby Airport, Texas. Signature Aviation.

KIAD Dulles International Airport, Virginia. Signature Aviation.

KLAX Los Angeles International Airport. Signature Aviation and Atlantic Aviation.

KLGB Long Beach Airport, California. Atlantic Aviation and Signature Aviation.

KMHR Sacramento Mather Airport, California. Modern Aviation.

KMIA Miami International Airport. Signature Aviation.

KMRV Monterey Regional Airport, California. Monterey Jet Center and Del Monte Aviation.

KMTJ Montrose Regional Airport, Colorado. Atlantic Aviation.

KOAK Oakland International Airport, California. Signature Aviation.

KOPF Miami-Opa Locka Executive Airport, Florida. Signature Aviation.

KPAE Seattle Paine Field International Airport. Propeller Aero Services.

KPBI Palm Beach International Airport, Florida. Signature Aviation.

KPSP Palm Springs International Airport, California. Atlantic Aviation and Signature Aviation.

KRIL Rifle Garfield County Airport, Colorado. Atlantic Aviation.

KSAN San Diego International Airport. Signature Aviation.

KSBA Santa Barbara Airport, California. Atlantic Aviation and Signature Aviation.

KSCK Stockton Metropolitan Airport, California. Atlantic Aviation.

KSDL Scottsdale Airport, Arizona. Jet Aviation.

KSEZ Sedona Airport, Arizona. Red Rock Aviation.

KSFO San Francisco International Airport. Signature Aviation.

KSJC San Jose Mineta International Airport, California. Atlantic Aviation and Signature Aviation.

KSMO Santa Monica Airport, California. Atlantic Aviation.

KSNA John Wayne/Orange County Airport, California. Clay Lacy Aviation and ACI Jet.

KSTS Charles M. Schulz-Sonoma County Airport, California. Sonoma Jet Center.

KTEB Teterboro Airport, New Jersey. Signature Aviation.

KTEX Telluride Regional Airport, Colorado.

KTRK Truckee Tahoe Airport, California.

KTRM Jacqueline Cochran Regional Airport, California. Atlantic Aviation and Desert Jet.

KVNY Van Nuys Airport, California. Clay Lacy, Signature Aviation, Jet Aviation and Castle & Cooke Aviation.

EUROPE, DUBAI AND SINGAPORE AIRPORTS

BELGIUM

EBBR Brussels Airport. Skytanking N.V.

GERMANY

EDLN Monchengladbach Airport. Rheinland Air Service.

FINLAND

EFHK Helsinki Airport. Jetflite.

EFKS Kuusamo Airport. Airpro.

UK

EGGD Bristol Airport. Centreline.

EGGW Luton Airport. Signature Aviation.

EGKB London Biggin Hill Airport. Biggin Hill Executive Handling.

EGLC London City Airport. Private Jet Center.

EGLF Farnborough Airport. Farnborough Jet Services.

EGNR Hawarden Airport. Aviation Park Group.

EGPF Glasgow Airport. Signature Aviation.

EGPH Edinburgh Airport. Signature Aviation.

EGSH Norwich Airport. SaxonAir.

EGTK London Oxford Airport.

THE NETHERLANDS

EHAM Amsterdam Airport Schiphol. Jet Aviation.

EHRD Rotterdam The Hague Airport. Jet Aviation.

DENMARK

EKBI Billund Airport. Blackbird and JoinJet.

EKSB Sonderborg Airport. Air Alsie.

NORWAY

ENZV Stavanger Airport. Sundt Air Executive Handling.

SPAIN

GCLP Gran Canaria Airport. United Aviation.

GCTS Tenerife South Airport. United Aviation.

GCXO Tenerife North Airport. Menzies Aviation.

LEBL Josep Tarradellas Barcelona-El Prat Airport. United Aviation.

LEMD Madrid-Barajas Airport. United Aviation.

LEMG Malaga Airport. United Aviation.

LEPA Palma de Mallorca Airport. Mallorcair.

LEZL Seville Airport. United Aviation.

FRANCE

LFBD Bordeaux-Merignac Airport. AviaVIP.

LFCL Clermont-Ferrand Auvergne Airport. Business Terminal.

LFLL Aeroport Annecy Mont Blanc.

LFPP Paris-Le Bourget Airport. Jetex and ExecuJet.

LFPP Aerodrome de Paris-Saclay-Versailles.

LFTH Toulon-Hyeres Airport. Business Terminal.

ITALY

LMIC Milan Malpensa Airport. Milano Prime.

LMIL Linate Airport. Milano Prime.

AUSTRIA

LOWW Vienna International Airport. Magnum FBO.

SWITZERLAND

LSZH Zurich Airport. Jet Aviation.

DUBAI

OMDW Al Maktoum International Airport. Jetex.

SINGAPORE

WSSL Seletar Airport. Jet Aviation.



FBO network operator Modern Aviation offers SAF at its Sacramento Mather Airport location in California.

(Greenhouse gases, Regulated Emissions, and Energy use in Technologies) model, a life-cycle analysis framework used to evaluate the energy and environmental performance of technologies, will guide the 45Z credit calculation. Analysts expect Trump's new cabinet appointments to influence that model, potentially shifting incentives toward crop-based feedstocks, according to SAF Investor.

At the same time, Trump's threatened tariffs on imports from China and other countries could make imported SAF feedstocks more expensive, leveling the playing field with U.S. crop-based feedstocks. Used cooking oil (UCO) imports now account for about 60% of the UCO applied in U.S. renewable fuel production, says consultancy ADI Analytics, and most of these imports come from China.

Trump plans to nominate Chris Wright, CEO of oilfield services and hydraulic fracturing company Liberty Energy, to serve as energy secretary, and Republican North Dakota Gov. Doug Burgum as interior secretary. Both are proponents of oil and gas drilling.

LEGISLATION'S LARGESSE

While the IRA received no Republican votes in either chamber of Congress, nearly 60% of the clean energy projects announced in the first two years of the legislation, representing 85% of the investments, were based in Republican-held congressional districts, the nonpartisan group E2 reported in

August. That grounding has given rise to optimism that any rollback of SAF and renewable fuel incentives will be politically challenging.

U.S. Sen. Jerry Moran (R-Kan.) visited the SAF Coalition in late November and "discussed the need for greater legislative efforts to support the production and deployment of SAF" in the 119th Congress, which convenes Jan. 3, the coalition says. The departing 118th Congress saw the launch of bipartisan Sustainable Aviation Caucuses in both the Senate—led by Moran and other senators—and the House. Reps. Sharice Davids (D-Kan.) and Dusty Johnson (R-S.D.), both reelected in 2024, co-chaired the House group.

The SAF Coalition, a nonprofit advocacy group founded in Washington in April, lists Amazon, Boeing, several major airlines, airports, renewable fuel developers and business aviation companies NetJets and VeriJet among its 56 members. The group sees a silver lining for SAF in a Republican-controlled capital.

"The new administration and congressional landscape present huge opportunities to advance U.S. leadership and economic competitiveness," SAF Coalition Executive Director Alison Graab says.

"By supporting SAF, we are not only creating a robust domestic market, but a U.S. market that can support exports, American farmers and rural communities for years to come," Graab adds. "We're encouraged by the bipartisan recognition of SAF's potential and believe that extended and enhanced federal policies can strengthen America's leadership on SAF." ☪

BILL CAREY/AW&ST



1 | New Unleaded Avgas

Two new 100-octane unleaded fuels, Swift Fuels 100R and Lyon-dellBasell/VP Racing UL100E, could become available in 2025 for operators of piston-engine aircraft. The government-industry-backed Eliminate Aviation Gasoline Lead Emissions initiative aims to phase out leaded avgas by 2030.

GEORGE CLERK/GETTY IMAGES



2 | Spoofing and Jamming

Global Navigation Satellite System jamming and spoofing will continue to increase in intensity and sophistication.

FLEXJET



3 | Fractional Ownership

Fractional aircraft flight hours will keep growing, outpacing demand for charter and corporate flights.

AEROMECH



4 | Starlink Competition To Arrive

Gogo's Galileo satellite and 5G air-to-ground systems are scheduled to enter service in 2025—and to put a dent in Starlink sales.



FABRICE COFFRINI/AFP/GETTY IMAGES

5 | Maintenance Slots

Aircraft will travel farther for maintenance slots, especially for pre-buy inspections. Maintenance capacity will remain tight; engine maintenance, repair and overhaul turnaround times in particular will lag.

TOP 10 PREDICTIONS FOR 2025

Ten trends anticipated for private aviation.

Lee Ann Shay and
Bill Carey Washington,
Ben Goldstein Boston and
Molly McMillin Wichita



GUILAUME PUISOY/BOMBARDIER

6 | Next-Gen Tech

Expect development strides in windowless aircraft—with video screens replacing passenger windows—as well as hydrogen and electric propulsion.



CAGAN SAVIN/ALAMY STOCK PHOTO

7 | M&A Still Hot

Steady sector growth is attracting new investors that see a market ripe for consolidation and scale.



JOHN/ALAMY STOCK PHOTO

8 | USM and PMA

Business aviation operators, especially larger ones, will grow more open to used serviceable material and parts manufacturer approval parts and seek best practices from airlines for their usage.



ARCHER AVIATION

9 | AAM Certifications

Neither Archer Aviation nor Joby Aviation will have their electric vertical-takeoff-and-landing vehicles (eVTOL) certified in 2025, but Beta Technologies' Alia conventional-takeoff-and-landing vehicle will be in the U.S., while China will certify more passenger-carrying eVTOLs.



VERTICAL AEROSPACE

10 | European AAM Troubles

Vertical Aerospace will struggle to fund its program through 2025. Lilium will not find a buyer with the means to certify its aircraft. Volocopter will shift its focus to China. 🇨🇳

What's In

What's Out

A look at business aviation trends that are gaining—or losing—popularity.

Bill Carey, Molly McMillin and Lee Ann Shay

IN



New Business Jets

Possible Return of Accelerated Depreciation



Gogo 5G

Hangar Construction



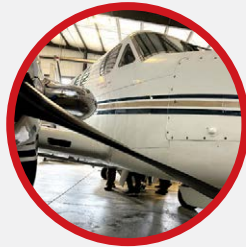
Blended SAF at FBOs

Swift 100R Unleaded Gas



Autoland Installations

OUT



SmartSky Networks 4G

Satcom Direct



Forgoing Pre-Buy Aircraft Inspections



No Backlog for Fractional Ownership Shares



Minimal Due Diligence for Back-to-Back Aircraft Transactions



Swift UL94 Unleaded Avgas



Next-Gen Workforce Complacency



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IMAGE CREDITS FROM TOP TO BOTTOM: SMARTSKY, 2, BILL CAREY/AW&ST, MEDIA PHOTOS/GETTY IMAGES, FLEXJET, IVELIN RADKOV/ALAMY STOCK PHOTO, MACHINE HEADZ/GETTY IMAGES

BACK TO BUSINESS

- > DESPITE HEADWINDS, CONFIDENCE RETURNS TO ROTORCRAFT INDUSTRY
- > LEONARDO AW609 AND BELL 525 COULD SECURE CERTIFICATION IN 2025
- > HILL HELICOPTERS HOPES TO FLY THE HX50 BY THE END OF 2025

Tony Osborne London

The rotorcraft industry appears to have returned to a steady state after the COVID-19 pandemic market doldrums.

Despite ongoing supply chain hiccups and global instability, new orders for commercial and military helicopters are rolling in, buoyed by increasing defense spending as well as demand from the energy sector for offshore flights, public safety and air ambulance sector needs and the VIP and private aviation market growth. These are driving increases in technology research and development, too. Engine manufacturers are advancing helicopter turbine developments, while airframers are investigating high-speed flight, increased autonomy, sustainable flying and advanced flight controls.

Going into 2025, two of the most long-awaited commercial helicopters might finally make their market debuts.

Previous predictions for the certification of Leonardo's AW609 commer-

cial tiltrotor have proven premature, but the FAA's publication of the final certification basis for the aircraft in October may well mean its development is in the final steps before certification, 22 years after first flight. The certification basis for the AW609 includes elements from Parts 23, 25 and 29 airworthiness standards for normal and transport-category fixed-wing and rotary-wing aircraft, respectively, potentially paving the way for type inspection authorization and the formal start of certification flights as early as the first quarter of 2025. And although the order intake is modest—with just five firm orders—Leonardo hopes to be the first to offer a high-speed commercial rotorcraft that will stimulate market interest.

Bell is aiming for the same with its twin-engine, 9.3-metric-ton 525 helicopter. Ten years after the 525's first flight, the U.S. manufacturer is marketing its fly-by-wire controls as a major step forward for aircraft safety, but that technology comes with a hefty price compared with its competitors. So far, only Norwegian en-

The Airbus H225 heavy helicopter had a bumper year for sales in 2024, with orders from the Netherlands for 12 military H225Ms and 38 from the German Federal Police.

ergy company Equinor has placed orders for the type publicly. Deliveries are planned for 2026, assuming FAA and European Union Aviation Safety Agency approvals are in place.

Several firsts also were recorded in 2024, including the initial flight of the Airbus Racer compound high-speed rotorcraft funded by the European Union Clean Sky 2 initiative.

It flew in April and quickly reached the manufacturer's targeted cruise speed of 220 kt. after just seven flights. Now the aircraft—descended from the Eurocopter X³, which first flew in 2010 and secured a 255-kt. speed record three years later—is targeting 240 kt. in the next phase of flight testing. Airbus aims to prove that its formula for high-speed flight can make rotorcraft more productive without substantial increases in cost, training and maintenance.

Beyond its high-speed efforts, Airbus is working on architectures for greener and cleaner flight. GE Aerospace revealed in July that it had been working with Airbus on a research project to develop a new turbine engine, but neither company has provided further details.

In Italy, Europe's other Clean Sky 2-funded rotorcraft, the AW609-based Leonardo Next-Generation Civil Tilt-rotor Technology Demonstrator has yet to fly, but with ground runs underway, initial flight could be imminent.

Leonardo also appears to have flown a new variant of its popular AW139 twin-engine medium helicopter in late 2024 as well. Enthusiasts took photos of the aircraft, believed to be known internally as the AW139 Mk.2, as it was test-flown from the company facilities near Milan. Changes include a longer nose, possibly to accommodate

more avionics, and a resculptured engine cowling, which may suggest a new engine or change to the configuration of the Pratt & Whitney Canada PT6s onboard.

In Russia, where the helicopter industry is focused purely on military needs to feed Moscow's full-scale invasion of Ukraine, the Mil Mi-34 single-engine light helicopter surprisingly reemerged after years on the shelf. Now fitted with a turbine replacing the piston engine that powered production variants, the Mi-34M1, which flew Oct. 15, seems to have been developed to address domestic needs for light helicopters, as sanctions have cut Russia off from purchasing Western-made rotorcraft. Reports suggest Mi-34 development was restarted after the collapse of the VRT 500 light coaxial helicopter program.

Also at the lighter end of the mar-

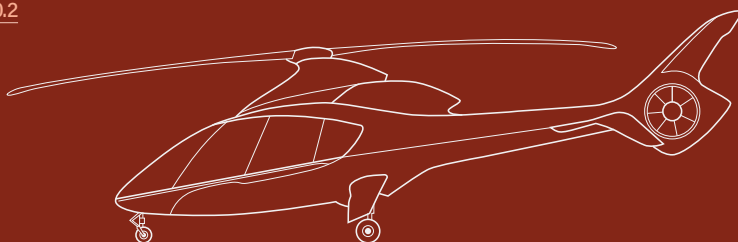
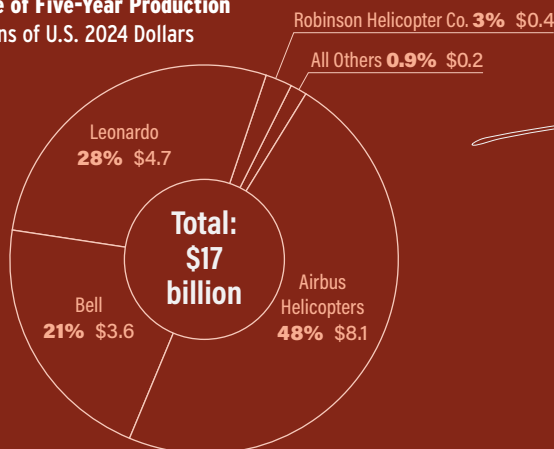
ket, UK startup Hill Helicopters has pushed the first flight of its much-anticipated HX50 single-engine turbine helicopter back one year, citing the need to expand its in-house manufacturing capability earlier than anticipated.

With 1,300 customers waiting for the rotorcraft, founder Jason Hill announced in October he would press to get the first in-house-developed GT50 turbine engine running in June 2025, paving the way for a first flight by Dec. 20, 2025.

Meanwhile, U.S. light helicopter manufacturer Robinson Helicopter Co., under new management since February, also is working on a new aircraft that may attempt to head off the Hill threat. More details about a potential Robinson newcomer are expected to emerge in March at the Verticon event in Dallas.

Civil Rotorcraft Market Share, 2025-29

Value of Five-Year Production Billions of U.S. 2024 Dollars



Snapshot

Hill Helicopters HC50

UK startup Hill Helicopters launched development of a single-turbine light helicopter in 2020. Powered by the GT50, a 500-shp turboshaft to be developed internally by Hill, the five-seater is planned to be available initially as the kit-built experimental-category HX50, followed about two years later by the certified HC50. In addition to the engine, vertically integrated Hill is developing the avionics. Hill has delayed first flight of the HX50 to December 2025, based on achieving the first run of the GT50 in June, and expects to begin production in December 2026, a delay of three years.

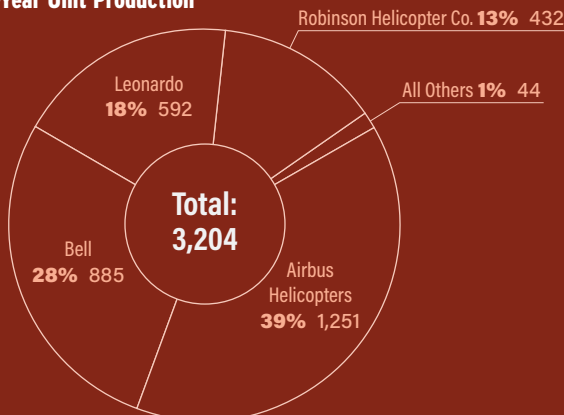
Rotor Diameter: **33.1 ft.**

Max. Takeoff Weight: **3,630 lb.**

Max. Cruise: **140 kt.**

Range: **700 nm**

Five-Year Unit Production



Source: 2025 Aviation Week Network Military Fleet & MRO Forecast.
All numbers and percentages rounded.

In addition to first flights, 2024 was a significant year for market newcomer Turkish Aerospace Industries (TAI), which finally delivered the first production examples of the T625 Gokbey twin-engine medium helicopter to the country's national gendarmerie. TAI already has delivered to Turkish customers license-built rotorcraft, including the T129 ATAK attack helicopter and T-70 Black Hawk, and its first handovers of the crewed, indigenously developed T625 are set to follow. The Turkish government is due to receive nearly 200 T625s for a range of missions in the coming years.

Uncertainty, however, surrounds the T-70 now that Lockheed Martin has stopped producing the kits that support the program in light of U.S. sanctions on Turkish entities.

In terms of military helicopters, the most notable newcomer is China's

10-ton-class attack helicopter, believed to be designated the Z-21, based on the Harbin Z-20 military utility rotorcraft. It is unclear when the new type first flew. Pictures of the aircraft emerged in March, but it failed to appear at November's Airshow China in Zhuhai, suggesting it may still be at an early stage of development.

Meanwhile, flight-testing of Italy's new Leonardo AW249 attack helicopter continues ahead of first deliveries, which are planned for 2027. And Boeing secured its largest AH-64 Apache export deal with an order for 96 from the Polish Army.

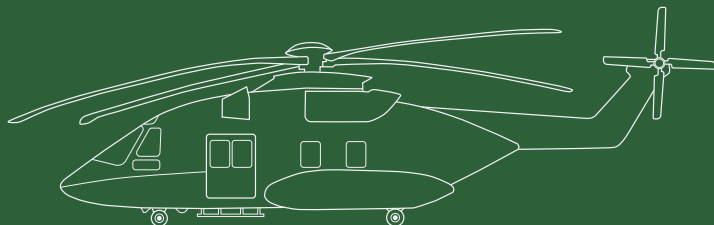
Sikorsky's Black Hawk family of helicopters—including the shipborne MH-60R—has continued to make major inroads into new markets, such as Greece, while receiving repeat orders from countries including Brazil and Sweden. The latter, like Norway,

has grown frustrated with issues around the availability of the NH-Industries NH90.

Following the U.S. Army decision last year to adopt Bell's V-280 tilt-rotor for its Future Long-Range Assault Aircraft program, the service has signaled it may take another radical step as it mulls a revamp of its training system. Nearly a decade has passed since the Army's Aviation Restructuring Initiative divested Bell-made Kiowa and Creek derivatives of the Bell 206 JetRanger in favor of the Airbus UH-72 Lakota Light Utility Helicopter for rotary-wing training.

The Army wants to reduce the cost of Lakota operations, and one option could be to replace the aircraft with a lower-cost platform certified by the FAA for instrument flight regulations, just as the U.S. Navy did with the Leonardo TH-73A Thrasher,

Military Rotorcraft Market Share, 2025-29



Snapshot

Turkish Aerospace Industries T925

Turkish Aerospace Industries displayed a full-scale mockup of the T925 at the Paris Air Show in 2023. In July 2024, the company said it had prioritized development of the 10-metric-ton-class multirole utility helicopter over the T929 heavy attack helicopter, which flew in early prototype form in April 2023. First flight of the T929, to be powered by two Ukrainian-supplied 3,000-shp Motor Sich TV3-117 turboshafts, is planned for 2026. The helicopter is being targeted at both commercial and military customers. Designed to carry 20 passengers, the T925 is intended for missions including troop transport, search and rescue, VIP transport, firefighting and medical transport.

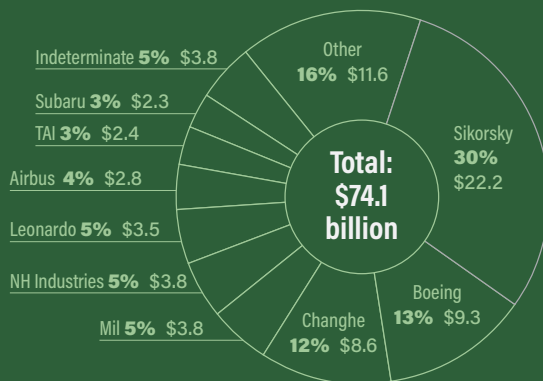
Rotor Diameter: **56.8 ft.**

Max. Takeoff Weight: **22,000 lb.**

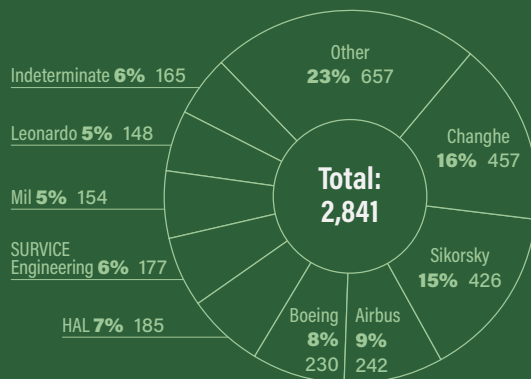
Cruise Speed: **170 kt.**

Range: **540 nm**

Value of Five-Year Production Billions of U.S. 2024 Dollars



Five-Year Unit Production



Source: 2025 Aviation Week Network Military Fleet & MRO Forecast. All numbers and percentages rounded.

based on the AW119 single-engine light helicopter.

In 2025, industry teams from Airbus, Leonardo and Sikorsky are set to deliver detailed platform concept studies to NATO's Support and Procurement Agency that could shape a new medium helicopter for the alliance's European members.

Leonardo's AW149 remains the only competitor left in the UK's New Medium Helicopter tender, but it is uncertain whether an award will proceed after the upcoming Strategic Defense Review.

NATO requirements call for a common airframe for both battlefield and naval operations, the use of an open systems architecture and the ability for the aircraft to be optionally piloted. They also include fly-by-wire controls, a maximum takeoff weight of 10-17 metric tons and an optimum cruise speed of 180-220 kt.

Despite upticks in defense spending, there is no guarantee that long-awaited

requirements will turn into acquisitions. The UK's hotly anticipated New Medium Helicopter contest became a one-horse race in September when Airbus and Sikorsky withdrew, citing their inability to deliver a bid within the budget outlined by the UK Defense Ministry. Leonardo Helicopters re-

mains the only bidder with its AW149 platform, but there is no certainty that the program will proceed following the upcoming Strategic Defense Review. 📷

Gallery See more about developments in the rotorcraft sector in 2024: [AviationWeek.com/Rotorcraft2024](https://www.aviationweek.com/Rotorcraft2024)

SIMON PRYOR/LEONARDO HELICOPTERS



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ANALYSIS

Diverging Prospects

Ben Goldstein Boston

WITH THE FIRST WESTERN AIR

taxis expected to enter service by late 2025, the prospects of leading startups on both sides of the Atlantic appear to be diverging.

In the U.S., market leaders Archer, Beta Technologies and Joby are pushing forward with certification and production road maps while looking ahead to launching certification flight testing with conforming aircraft next year.

While many electric vertical-takeoff-and-landing (eVTOL) startups have struggled to raise funds amid tight capital markets, these three companies have all managed to raise hundreds of millions of dollars in recent months. Beta closed over \$300 million in an October Series C fundraising round; Archer closed \$230 million in a private investment in public equity round in August. Both Archer and Joby have struck deals with their automaker backers—Stellantis and Toyota, respectively—to subsidize hundreds of millions of dollars in labor and production costs in the coming years. The fundraising success means all three startups are well positioned to finance the path to FAA type certification.

The three companies also are progressing with their planned mass production facilities: Beta's factory in South Burlington, Vermont, opened in late 2023; Archer's facility in Covington, Georgia, is set to open before the end of 2024; and Joby expects its facility in Dayton, Ohio, to come online in early 2025. Beta says its factory has an initial capacity for up to 300 aircraft per year, while Archer's facility can handle up to 650 per year and Joby's up to 500.

Beta expects to certify its electric conventional-takeoff-and-landing aircraft by late 2025, and the eVTOL version is expected to follow in 2026. Both Archer and Joby say they can certify by late 2026, although they also hope to launch initial passenger services in the United Arab Emirates by late 2025.

The publication of the FAA's Special Federal Aviation Regulation on powered-lift pilot licensing and operations in October has resolved key issues related to energy reserve requirements and eVTOL pilot training processes to industry's satisfaction, removing a key source of uncertainty about the sector's future operations and workforce development efforts.

That mostly optimistic outlook among leading U.S. eVTOL companies stands in stark contrast to Europe and the UK, where three of the most high-profile startups all face uncertain futures.

Germany's Lilium, which has raised more than \$1.4 billion since 2017, filed for insolvency in October after a last-

ditch attempt to obtain government loan guarantees fell through. The company remains operational as part of the German self-administration process, but major questions loom over its future as the court-appointed administrator attempts to sell off the business in whole or in part.

Fellow German startup Volocopter has fared only somewhat better. Like Lilium, it is running out of cash, and its attempt to obtain government funding was similarly shot down. Type certification of the two-seater Volocity is still expected by early-to-mid-2025. But Volocopter's cash reserves are depleting quickly, and Chinese automaker Geely is reportedly considering a deal to acquire up to 85% of the company for a valuation of under \$100 million. Whether that deal will go through—and what it would mean for the startup's future—is unclear.

Across the Atlantic, Bristol, England-based Vertical Aerospace is also in dire straits. Following a boardroom fight that spilled into public view in November, self-described distressed asset investor Mudrick Capital has agreed to inject up to \$50 million in fresh funding as part of a deal that will

award the group an ownership stake of around 70%; founder and Chairman Stephen Fitzpatrick's share will fall to 20%.

Vertical says the transaction leverages its balance sheet by converting half of Mudrick's debt notes into equity, making future capital raises more attractive to investors while extending the company's cash runway through the end of 2025. But despite its lean spending profile, Vertical will face an uphill climb in continuing to fund the program to its planned certification in 2028.

In Brazil, meanwhile, Embraer spinoff Eve Air Mobility continues to press its development program forward, with plans to make the first flight of its eponymous air taxi in early 2025. The company managed to raise \$96 million in equity over the summer, in addition to nearly \$174 million in bank loans from the Brazil National Development Bank and Citibank this autumn. A production facility in Taubate, Sao Paulo, will be capable of rolling out up to 120 aircraft per year initially. But with slow progress—Eve has still never flown a prototype—it appears unlikely that the company will achieve its goal to certify in 2026.

Certifying an eVTOL can cost up to \$2 billion, according to SMG Consulting, and few startups have the wherewithal to go the distance. Increasingly, scarce investment dollars appear to be consolidating in a small number of well-capitalized startups in the U.S., leaving European startups especially vulnerable.

If that gulf between perceived winners and losers widens in 2025, the U.S. could overtake Europe's eVTOL industry completely in the coming years. ☞



Beta Technologies expects to certify its electric conventional-takeoff-and-landing aircraft in 2025.

CHINA RACES TO AAM

➤ LOCAL INDUSTRY FORECASTS DEMAND FOR 100,000 AIR TAXIS BY 2030

➤ AEROSPACE-GRADE SUPPLY CHAIN IS EMERGING TO SUPPORT OEMs

Graham Warwick Washington

Since Beijing embraced the low-altitude economy—a term that encompasses advanced air mobility and general aviation—a nascent industry has gone into overdrive.

Dozens of startups are developing electric air taxis and uncrewed cargo aircraft at breakneck pace, supported by China's powerful electric vehicle (EV) supply chain.

China boasts the first certified electric vertical-takeoff-and-landing (eVTOL) aircraft, EHang's autonomous two-seat EH216S and AutoFlight's uncrewed cargo CarryAll. At least a dozen startups have flown, or are about to fly, full-scale prototypes (page 116).

They are aided by development costs one-seventh of those in the West—1 billion yuan (\$140 million) versus \$1 billion—estimates SMG Consulting. This could lead to vehicle costs 30-40% lower than in the U.S. and Europe.

The startups also are moving fast by leaning heavily on China's globally dominant drone industry through the development of multicopter and lift-plus-cruise eVTOLs. Only recently have designs emerged with the tilting propulsors favored by Western manufacturers, as these demand more complex flight control systems.

While the term "low-altitude economy" approximates to the idea of advanced air mobility (AAM), it is broader and encompasses small drones, air taxis and uncrewed cargo aircraft as well as helicopters and general aviation aircraft flying below 4,000 m (13,000 ft.), transporting goods as well as people.

The panoply of Chinese startups reflects this wider definition and includes vertical-, short- and conventional-takeoff aircraft, crewed and uncrewed, to carry cargo and passengers, and powered by batteries, combustion engines and even hydrogen fuel cells.

As in the West, cargo likely will be the fastest-growing use case in the short term, but while the U.S. and Europe will focus on

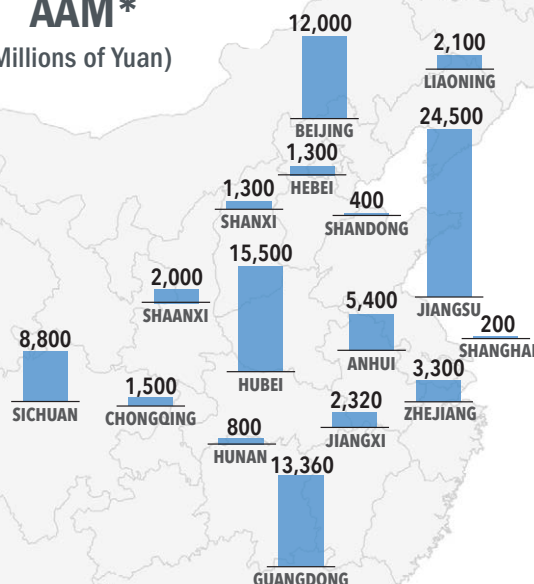
crewed aircraft, China will tackle autonomous ones, SMG's Sergio Cecutta says. Market growth will be helped by the concentration of population into megacities, such as the Guangdong-Hong Kong-Macau Greater Bay Area, where connectivity faces geographical challenges ranging from river deltas to island chains.

Multiple Chinese manufacturers have begun type certification of passenger eVTOLs with the Civil Aviation Authority of China (CAAC). While the regulator moved quickly to certify the EH216S and CarryAll under drone rules, the CAAC is following the Western model of treating passenger eVTOLs as a special class of aircraft and is not expected to certify anything before 2026.

If safety is the priority, then airspace access is the pacing

How the Provinces Are Subsidizing AAM*

(Millions of Yuan)



1 yuan = U.S. \$0.15

*Announced estimated government support (monetary and nonmonetary) for the low-altitude economy.

Source: SMG Consulting

Gallery See more about advanced air mobility developments in 2024: [AviationWeek.com/AAM2024](https://aviationweek.com/AAM2024)

factor. China’s military-controlled airspace is opening up gradually, but it will take time, Cecutta says, noting that he expects the low-altitude economy will need 3-5 years to get up and running and that air taxis will not be operating at scale in China until 2028-30.

While China’s established EV supply chain has given AAM entrants a leg up, the industry still needs to develop certifiable aerospace products, and there are signs of an aviation-specific supply chain emerging. At the same time, China’s automakers have proved willing to embrace AAM as a market.

Another unique aspect of China’s drive to develop the low-altitude economy is the role provincial and metropolitan governments are playing in providing funding, other incentives and even sales through state-owned entities ranging from economic development agencies to general aviation operators.

In addition to responding to the central government’s backing for the low-altitude economy as a catalyst for growth by transforming logistics and travel, the provinces and cities are actively competing to host air taxi and uncrewed aircraft test sites, manufacturing plants and initial commercial flight routes. 🌐

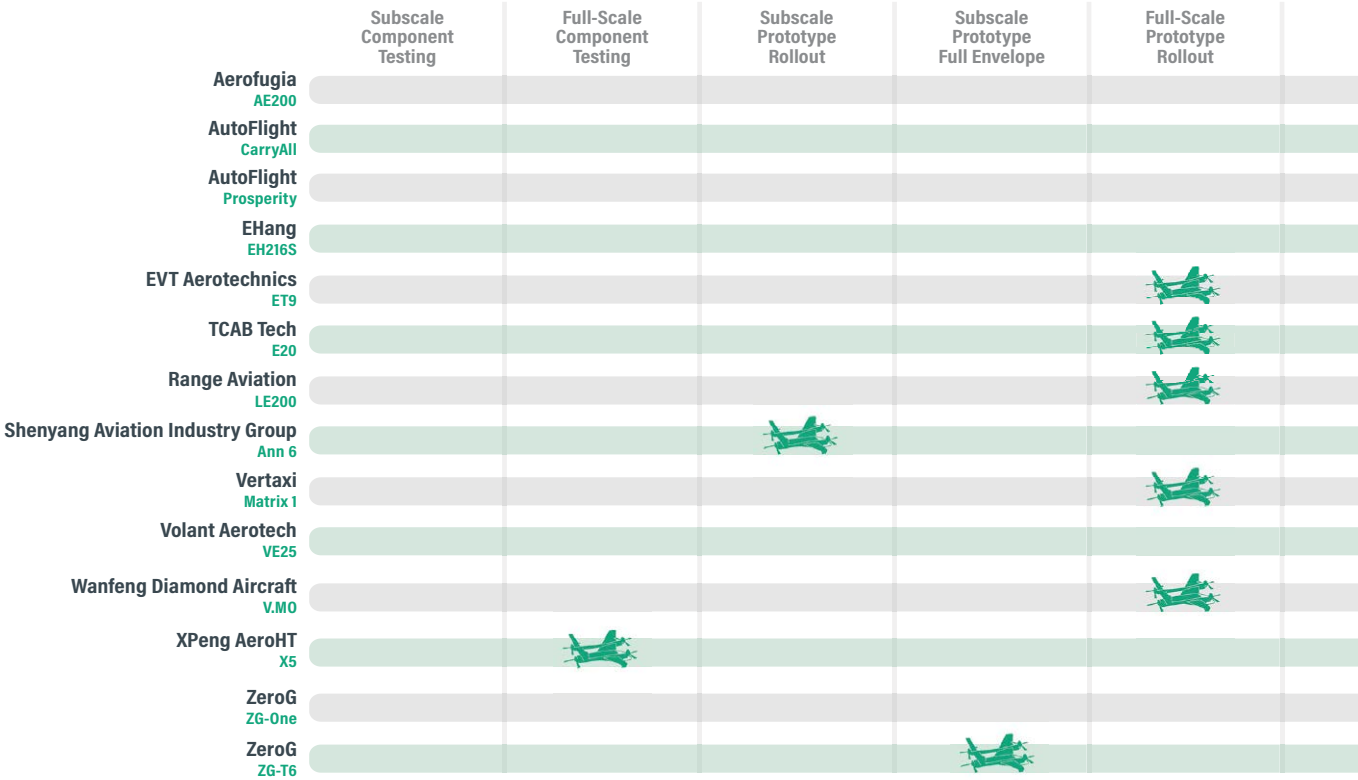
BEIJING	
CASC	Cargo UAV
CASIC	Cargo UAV
COMAC	eVTOL
Cool High Technology	eVTOL
Flightwin Tech	eVTOL/Cargo UAV
Tianmushan Laboratory	Cargo UAV
Weizhi Aviation Technology	Cargo UAV

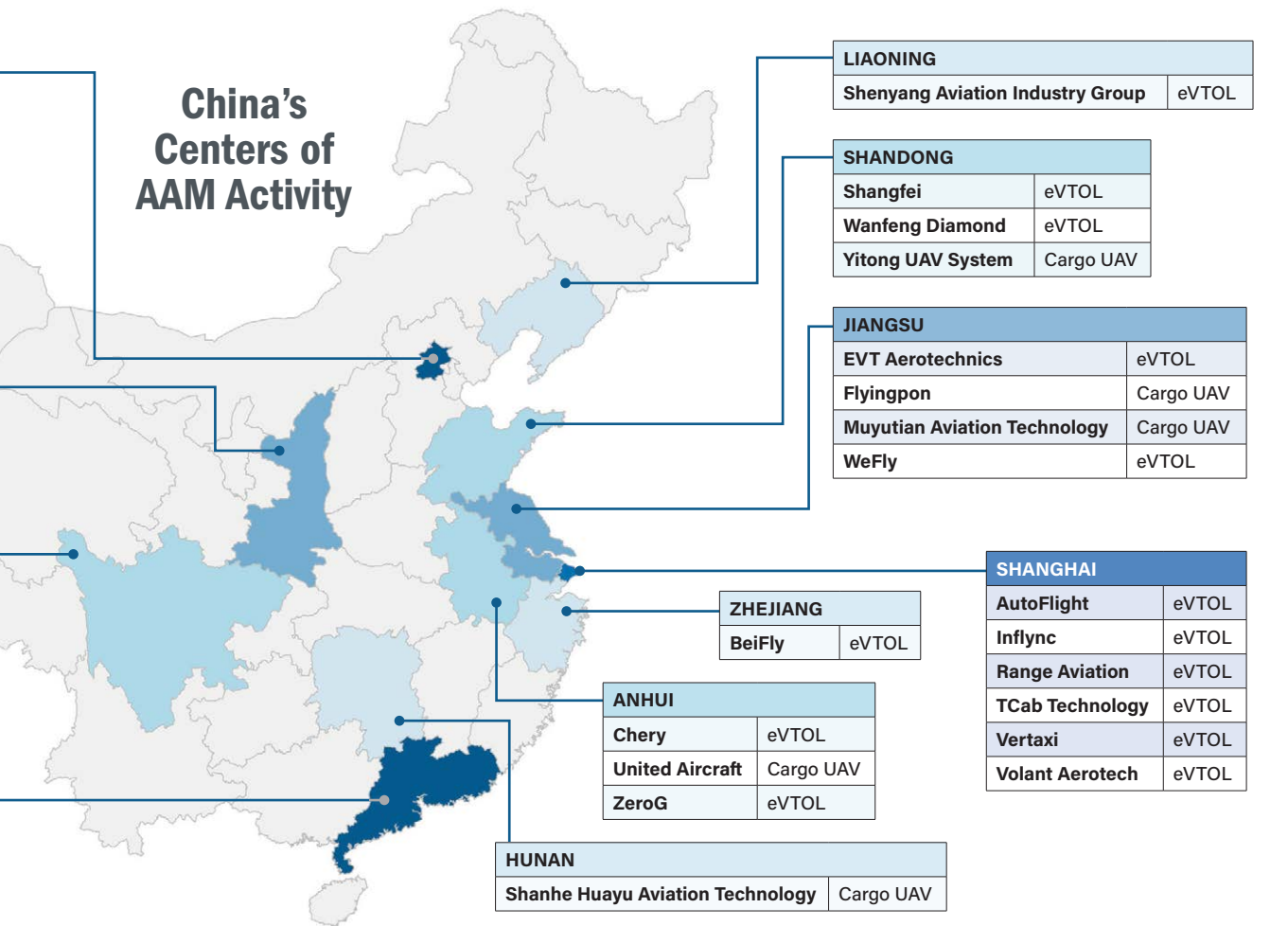
SHAANXI	
Air White Whale	Cargo UAV
AVIC	eVTOL/Cargo UAV
Dream Fly	eVTOL/Cargo UAV
TransFuture Aviation	eVTOL

SICHUAN	
Aerofugia	eVTOL
Tengden Technology	Cargo UAV
Yifei Aviation Technology	Cargo UAV

GUANGDONG	
CAIGA	eVTOL
EHang	eVTOL
GAC	eVTOL
Seagull Flying Car	eVTOL
Skyline Aviation	eVTOL
Wanli Aviation	eVTOL
XPeng AeroHT	eVTOL

Runners and Riders: Chinese eVTOL Development Progress





Source for all graphics: SMG Consulting

PREDICTIVE INTELLIGENCE

THAT DRIVES RESULTS

Make informed, strategic decisions with a 10-year outlook of the world's fleets and MRO demand with Aviation Week Intelligence Network's **2025 Commercial Fleet & MRO Forecast**.

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91.4%

Airbus and **Boeing**, the two largest manufacturers in the world, account for 91.4% of future aircraft deliveries over the 10-year forecast period. See which aircraft dominate markets while other's influence wanes.

10-Year
Outlook

Aircraft Storage

Aircraft Family

Retirements

Regions

Trends

Deliveries

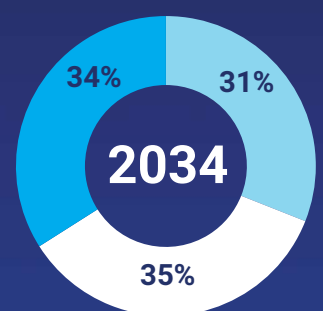
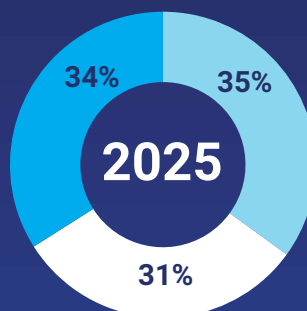
MRO

Demand

Engine Family

In-Service Fleets

In-Service Fleet by Region



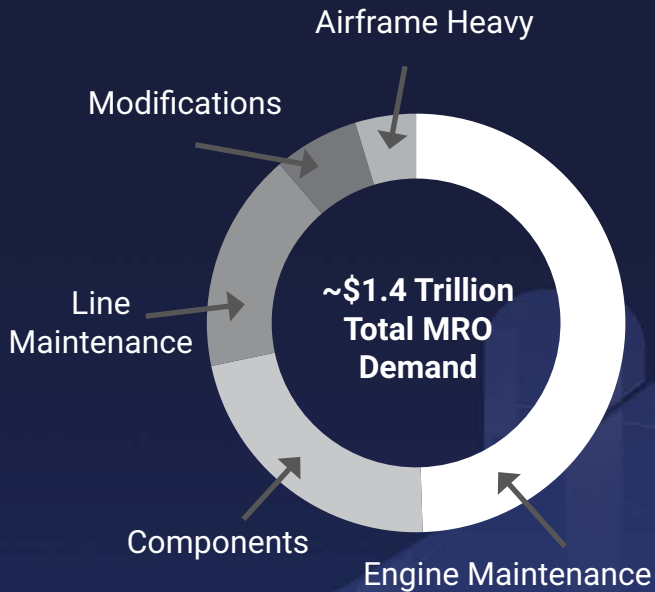
■ Americas

■ Asia

■ EMEA

Available for:
COMMERCIAL • BUSINESS
MILITARY • HELICOPTER

MRO Demand by Expense Category



Deliveries

✈️ 📈 22,000

Retirements

✈️ 📉 11,000

View expected MRO demand
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ANALYSIS

Still Here To Save the Day

Sean Broderick Washington

A CURSORY WALL STREET-ESQUE

glance at aftermarket growth projections for 2025 could lead to some inaccurate conclusions.

Yes, commercial maintenance, repair and overhaul (MRO) growth rates will slow dramatically compared with the last few years. However, demand is not going anywhere but up—and at a better clip than historical averages.

MRO providers will keep pulling double duty in 2025, managing normal demand and acute needs created by delivery delays.



PHILIPPE MASCIET/AIRBUS

The reason for the coming year-over-year growth dip is simple: Skyrocketing post-downturn growth rates following a near-complete cessation of all but mandatory work were unsustainable. Operators are catching up on deferred work and keeping pace with strong demand.

Then there is the gap-filling that older aircraft continue to provide as airframers and engine OEMs struggle to meet delivery and performance targets. Those struggles are expected to continue in 2025.

As discussed in the pages ahead, all this adds up to another strong year of commercial MRO demand in 2025—something on the order of 14-15% is a good bet (page 125).

But achieving that will not be easy. Adding shop floor capacity and skilled labor is necessary, but expansion alone will not meet projected demand. Even if it could, companies are better off examining a combination of efficiency gains and expansion to meet anticipated upticks.

Among the aftermarket watch items Aviation Week is flagging for the coming year (page 121): increased interest in module swaps to speed up engine turnaround times. FTAI Aviation is among the emerging module-swap players focused on

the most popular narrowbody engines, but it is hardly alone.

FTAI's strategy goes beyond finding ways around slow-moving engine shop induction pipelines. Its acquisition of CFM International CFM56 maintenance center Lockheed Martin Commercial Engine Solutions brought on more capacity for its growing module overhaul business and, critically, skilled labor. A major CFM56 aftermarket player, FTAI was a customer of the Montreal-based facility, which has capacity for about 300 shop visits per year. Now it has a chunk of new, controllable capacity and the workforce talent to leverage it.

While material shortages often take the blame for lagging deliveries and turn times, many see the root cause as a lack of people, not parts. "[The] industry lost too much knowledge in 2020, and as workforces have returned to appropriate levels to support the higher rates, the efficiency has been lacking," RBC Capital Markets analysts said in a research note. "We also believe there remains substantial pressure at the Tier 3 and Tier 4 level of the supply chain."

Adding more workers will help—but only as the new hires gain experience. "We believe the fundamental issue is a labor productivity and efficiency issue that will only take time to remedy itself," RBC wrote. "In our view, it is not a question of additional aid or support, but a more consistent cadence."

Such challenges mean alternative parts suppliers will continue to find opportunities. Parts manufacturer approval (PMA) hesitancy is on the "out" list. The reality is it has been for a few years, yet some still claim there are holdouts among top airlines and regulators. There are not.

But there will be some novel PMA activity. Thanks to efforts by a few innovative providers, notably Chromalloy, 2025 figures will see a fair share of critical engine PMA parts sold (page 122).

Will lessors finally begin to back off and open the door to complex PMA engine parts? It may depend on how quickly they want their engines back on wing.

Sourcing strategies bear watching beyond the engine space. Global supply chain challenges and greater emphasis on sustainability are changing how MRO providers set up their networks. One result will be more repair capabilities closer to home—and in some cases, completely insourced.

MRO executives face their fair share of challenges in the year ahead. But they also have myriad opportunities. Aviation Week has highlighted five people (page 124) who are likely to spearhead big, positive developments in 2025. Given the deep pool of talent in the global MRO ranks, they will not be alone. 🍷



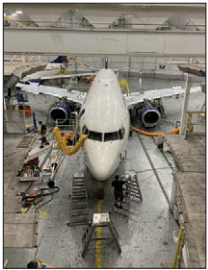
1 | Engine Module Swap Activity

Demand for engine module swaps—a cheaper and less labor-intensive method of servicing an engine than a shop visit—will be increasingly strong in 2025.

2 | A Competitive Hangar Market

MRO providers vying for facility capacity will see a more competitive hangar acquisition and leasing market, and space to build new structures also could present challenges. This will lead some

businesses to explore alternative options, such as erecting temporary hangars and maximizing existing capacity.



3 | More Engine JVs

Engine maintenance demand will continue to rise, with MRO shops and even some airlines looking to partner with engine OEMs to establish joint ventures and partnerships.



LEE ANN SHAY/AW&ST

4 | PTF Conversion Capacity

Despite the market steadying overall, capacity constraints persist in the passenger-to-freighter (PTF) market.

Following on from 2024, in which notable partnerships were disclosed, expect more MRO shops to divulge PTF conversion



partnerships in 2025 to alleviate constrained slot availability.



5 | MROs Stepping Up Localized Repair Networks

Should the industry's supply chain challenges be alleviated further in 2025, some shops likely will step up their nearshoring efforts to bring repair networks closer to home. Airline maintenance divisions will form part of this, looking to insource specific repairs.

TOP 10 PREDICTIONS FOR 2025

What could lie ahead for the commercial aftermarket.

James Pozzi London

6 | More Private Equity Deals

Considerable private equity aftermarket activity occurred in 2024 relating to the likes of STS Aviation Group and TurbineAero. Similar deals also are expected in 2025, with specific market segments—such as parts repair specialists—ripe for consolidation.



7 | Shorter TATs

Turnaround time (TAT) issues of the past five years probably will ease somewhat in 2025 as companies adjust, but they still will fall below pre-



pandemic 2019 lead times, as parts shortages are expected to persist.



8 | A Fruitful Time For Disassembly Specialists

Given a lack of parts availability, aircraft disassembly specialists should enjoy a favorable environment in the new year as parts vendors pay above average rates to acquire components from torn-down aircraft.



9 | More Asset Lease Extensions

With new-production aircraft issues set to continue, more airlines are likely to opt for lease extensions on older aircraft that will present further opportunities and challenges for the aftermarket.



10 | The Role of Artificial Intelligence Platforms

As maintenance providers and airlines look to develop more accurate forecasting models, expect developments in the use of artificial intelligence and machine learning to optimize inventory levels. In the near term, this also could play a role in predictive maintenance and capacity management. ☒

ANOTHER YEAR OF GROWTH



JOEPRIESAVIATION.NET

- AFTERMARKET GROWTH MAY SLOW, BUT DEMAND ENDURES
- COMMERCIAL AFTERMARKET STRENGTH WILL CONTINUE
- ENGINE MRO EYES EFFICIENCY AND ALTERNATIVES TO HANDLE DEMAND

Sean Broderick Washington

New aircraft production and delivery rates are ramping up steadily to the figures that manufacturers promised and on which airlines and lessors are counting. Supply chain logjams are easing, helping needed material flow more predictably to both production lines and repair stations.

These and similar encouraging trends mean pressure on aftermarket providers should begin to ease in 2025. But the return to normalization of annual growth rates—think mid-to-high single digits—will not happen overnight. Many shops will still be full, turnaround times will remain stubbornly elevated and barring a major change in the pace of aircraft retirements, the surplus parts market will continue to long for material for the most sought-after aircraft and engine platforms.

Taken together, it adds up to another strong year of growth for most commercial aftermarket players.

The consensus is that maintenance, repair and overhaul (MRO) market growth will be in the mid-teens in 2025 (page 125). Engine MRO providers, responsible for about half the global commercial MRO business, will continue to be growth drivers, serv-

ing both current-generation and legacy engines.

Safran in early December reaffirmed CFM International CFM56 shop visit projections for the near future, pegging 2025 as the likely peak year for volume, with around 2,300 engine inductions. The French company, a 50/50 partner in CFM with GE Aerospace, expects slight declines in 2026-27, with the total dropping below 2,000 in 2028.

“Although [shop visit] expectations appear to be normalizing, we continue to view the engine MRO market as having fundamental tailwinds,” RBC Capital Markets wrote in an investor note. “With delayed OEM deliveries and continued use of the existing fleet, we continue to expect growth into 2025.”

Safran’s full-year 2025 projections include mid-single-digit growth for its services business and high single dig-

Airlines are keeping more older aircraft in service longer to fill gaps created by delivery shortfalls from Airbus and Boeing.

its for spares sales, with CFM56 work to remain the main driver. This is down from recent years, a reflection of normalization following a rapid post-downturn ramp-up.

GE Aerospace is projecting its commercial services will grow in the low double digits in 2025, the company said in a December investor letter.

The two CFM partners’ bullish outlooks come as no surprise. The venerable CFM56-5Bs and -7Bs that power a share of the Airbus A320ceo family and the entire Boeing 737 Next Generation fleet have years of profitable aftermarket revenue generation ahead. About 40% of the 23,000 -5Bs and -7Bs in service have yet to undergo a heavy shop visit; in 2028, the figure will still be at least 25%, Safran projects.

Meanwhile, CFM’s Leap fleet is quickly growing and steadily maturing. Shop visits will approach 2,000 in 2025, including both heavy-workscope overhauls and hospital visits.

Safran sees the figure peaking at more than 5,000 in 2040.

Part of the Leap's rapid growth and higher peak compared to the CFM56 is in simple numbers. The Leap installed base has expanded nearly twice as quickly as that of the CFM56. CFM will have eclipsed 9,000 total Leap deliveries by August 2025, nine years after the first engines—Leap 1As on a Pegasus Airlines A320neo—entered service. The CFM56 program needed nearly 20 years to reach the same delivery total.

Another major factor driving after-market business on current-generation engines is teething. While common on new-technology engine programs, the rapid growth of the new narrowbody engine fleets means early issues affect more operators than in the past.

Pratt & Whitney will hand over its 5,000th PW1000G geared turbofan (GTF) in 2025, about eight years after the first variant entered service. Its predecessor, the IAE V2500 built by a five-company joint venture that included Pratt, surpassed 5,000 deliveries in its 14th year.

Both Pratt and CFM have battled problems that affected durability and time on wing—work that will continue in 2025.

Pratt's well-documented issue with contaminated powder metal (PM) means about 350 aircraft will be idled at any time while GTFs undergo painstakingly long wing-to-wing inspections and overhauls (*AW&ST* March 11-24, p. 16). Turnaround times of around 300 days are problematic enough; as of late 2024, Pratt was not producing enough full-life parts to replace all suspect PM parts in the in-service fleet.

New-build engines have been getting full-life parts since late 2023. Pratt parent RTX has been vague about when it can satisfy the in-service fleet's needs and eliminate unscheduled off-wing inspections to ensure the problematic parts are not failing.

CFM's Leap issues have not created as much operational disruption, but they hardly are insignificant. Installations of reverse bleed systems (RBS) designed to prevent fuel nozzle coking on CFM Leap 1A engines and prevent unscheduled nozzle swaps are ramping up steadily. The RBS is a complex kit that requires dedicated training and at least 10 hr. to install. GE has developed several training aids, including a virtual tablet-based assem-

bly diagram, to aid technicians. A Leap 1B-spec RBS is under development and is expected to be ready in 2025.

Installations of new Leap 1A high-pressure turbine (HPT) upgrade kits also will be folded into retrofit schedules. The kit, which includes new HPT Stage 1 blades, nozzles and forward inner nozzle supports, received FAA and European Union Aviation Safety Agency certification in early December. MRO shops will be the first to receive kits, followed by new-production engines in early 2025.

In the widebody arena, the outlook is simpler. Utilization is climbing thanks to strengthening long-haul demand, which in turn is driving maintenance spending. At Rolls-Royce, large engine flying hours for the first 10 months of 2024 were 102% of comparable 2019 levels, the company said in a late November trading update.

The trend offers a sample of a strong macro environment. Total revenue passenger kilometers were up nearly 11% for the first 10 months of 2024 year over year, show International Air Transport Association figures released in early December. Available seat kilometers, which drive MRO spending, were up 9.3%.

"The overall robust travel growth should be a stabilizing factor for continued aftermarket growth in our view," RBC Capital Markets wrote in an investor note. "We continue to expect sustained levels of aftermarket maintenance spending into 2025 with persisting aircraft fleet dynamics."

Aftermarket providers welcome the consistently strong demand environment, but it comes with challenges. As demand rises, so does pressure to get work done more efficiently.

GE Aerospace is among the major MRO providers deploying new technology for improving shop-floor performance. Examples include turbine

blade inspection tools (BIT) that leverage artificial intelligence (AI) to flag potential flaws for review by trained technicians. Used in place of standard borescopes, BITs put fixed-position cameras in engine ports that capture blade images as the engine is rotated manually. Images then are analyzed by the tool and, if necessary, reviewed by technicians.

The first BIT, for GENx Stage 1 and 2 HPT blades, halved the inspection time to 1.5 hr. compared to standard

borescope inspections and improved both quality and accuracy, Chief Manufacturing Engineer Nicole Jenkins says. GE has since rolled out BITs for the Leap and GEN9x.

GE in early 2025 will formally open its Services Technology Acceleration Center, a dedicated facility near its headquarters in Evendale, Ohio, that will specialize in developing such technologies and getting them out quickly to the company's MRO shops.

"This place will always, to some extent, look like it's under construction," Jenkins told Aviation Week during a late September tour. "That's very deliberate, because if we're successful, you're continuously taking technologies in, maturing them, scaling them, then pushing them out and bringing the next thing in."

Third-party providers have thrived for years finding efficient alternatives to pricier and increasingly unavailable OEM offerings. This will not be changing soon.

Talk of customers increasingly turning to parts manufacturer approval (PMA) options in response to high spares prices or sourcing challenges has become commonplace. In reality, the list of airlines that continue to resist PMA is short, with few large operators.

PMA growth is real, as financial reports from companies such as Heico underscore. Operators and MRO providers will continue to snap



Chromalloy is confident demand to keep engines flying and not waiting for spares will boost sales of its proprietary OEM-alternative parts.

up available, reliable PMA parts that fill a need. While price matters, a cheap part that does not hold up will end up costing more than the most expensive OEM alternative.

While PMA growth is undeniable, little is in the high-demand critical engine part market. Chromalloy is an exception. The company landed approvals for two critical engine parts in 2024: a V2500 Select HPT Stage 2 blade and a CFM56-5B/-7B HPT Stage 1 vane. Add in a CFM56 low-pressure turbine vane approval from 2021, and Chromalloy now has three hot-section engine parts for the two most popular narrowbody engine types in service and is working on two more.

“Chromalloy is the only company not affiliated with a large OEM with the capability and expertise to make hot-section aircraft engine PMA parts, one of the most expensive parts of aircraft engines,” RBC’s Ken Herbert wrote in an investor note.

While PMA acceptance is a given at most airlines, complex engine parts such as blades remain one area of hesitation. OEM programs that verify engine configurations as being to standard are part of the reason, since such engines typically maintain a higher residual value.

Chromalloy has produced thou-



SEAN BRODERICK/AM&ST

Widebody program delivery delays have forced operators to change long-haul fleet plans.

sands of HPT blades for older engines. The company is betting the same market forces that moved those products will benefit its latest investments, despite a hotly competitive aftermarket environment that has OEMs laser-focused on chasing services revenues.

“If there’s nothing available, and you’ve got an expensive asset sitting [waiting for parts], you become much

more open to an alternate solution to get it back on wing,” Chromalloy CEO Chris Celtruda says. “In the next couple of years, the biggest consumer of our engineering resources is completing our high-value shipset on the [CFM56] and on the V2500-Select [variants], both from a PMA and [FAA-approved repair development] point of view.”

People To Watch



Eva Azoulay
Group CEO and board member, ITP Aero

ITP Aero CEO Eva Azoulay is seeking to leverage the company’s growth and expand its aftermarket engine services and capabilities following its sale to Bain Capital in 2022. In 2024, ITP Aero made several strategic moves to grow its North American footprint. The company acquired U.S.-based engine services provider BP Aero in February, which adds capabilities such as tear-downs, component repairs and services for CFM International CFM56 and Leap engines. In October, ITP Aero opened a new production and logistics facility in Queretaro, Mexico.



Kim Ernzen
Chief Operating Officer, StandardAero

As StandardAero’s recently appointed chief operating officer, Kim Ernzen will oversee the company’s accelerating growth strategy. StandardAero is in the process of an initial public offering that seeks to raise \$1.1 billion at a valuation of

up to \$7.5 billion, and it recently acquired military MRO provider Aero Turbine. In 2024, it invested millions to roll out CFM International Leap capability at its San Antonio shop ahead of the engine platform’s forecasted dominance over the next decade.



Mahesh Kumar
CEO, Asia Digital Engineering

Asia Digital Engineering (ADE) CEO Mahesh Kumar is leading the company’s ambitious growth plans. ADE opened a massive, 14-bay hangar in Malaysia in September and is planning to build another four-line hangar close to that facility—as well as engaging in talks with Malaysia Airports Holding Berhad to acquire a 20-acre plot for another 14-bay hangar. In 2024, ADE also opened a subsidiary in Cambodia, and the company continues to develop its own digital tools for parts procurement and aircraft health management.



Abdulkhaliq Saeed
CEO, Saudia Technic
Appointed as Saudia Technic’s new CEO in August, Abdulkhaliq

Saeed will lead the company’s efforts to grow Saudi Arabia’s aviation infrastructure. The country’s Public Investment Fund has invested in Saudia Technic to open a large MRO Village in Jeddah in 2025 that will boost the company’s hangar capacity as it aims to capture more work from the growing domestic fleet. A 40-year industry veteran, Saeed previously led Etihad Engineering’s capacity expansion in Abu Dhabi and its significant third-party maintenance growth.



Soeren Stark
Chairman and CEO, Lufthansa Technik

Shortly after abandoning plans to sell a minority stake in the business, Lufthansa Technik (LHT) in 2024 announced a lofty Ambition 2030 growth plan that will involve investment of more than €1 billion (\$1.05 billion) over the next four years. Chairman and CEO Soeren Stark is aiming to grow the company’s revenue to more than €10 billion by 2030, eyeing various global investments and increased capacity. In 2024, LHT acquired Tulsa, Oklahoma-based component services provider ETP Thermal Dynamics and disclosed plans to build a new MRO facility in southwest Europe.

PHOTO CREDITS FROM LEFT: ITP AERO; STANDARDAERO; ASIA DIGITAL ENGINEERING; SAUDIA TECHNIC; LUFTHANSA TECHNIC

A Look at Projected MRO Demand Across Aviation Sectors

- > MILITARY AND COMMERCIAL MRO TO GARNER THE HIGHEST BILLS
- > BUSINESS AIRCRAFT RETIREMENTS ARE EXPECTED TO INCREASE; CIVIL HELICOPTER FLEET GROWTH PLATEAUS

Lee Ann Shay Washington

Maintenance demand is expected to be higher across aviation segments in 2025—with the commercial and military segments growing faster than civil helicopters and business aviation MRO.

Military maintenance, repair and overhaul (MRO) expenditures should be the largest in 2025—\$135.3 billion, compared with \$126.3 billion for commercial aircraft. But commercial aircraft MRO should log a higher growth rate in 2025 than in 2024—14% year over year, compared with military MRO’s 6% increase, according to the Aviation Week Network’s 2025 Fleet & MRO Forecast. Engine MRO dominates commercial aviation spending

200 more aircraft retirements in 2025 than in 2024. In addition, some 150 aircraft are planned to undergo passenger-to-freighter conversions during 2025, according to Aviation Week Network forecast figures.



turbofan engines that power long-range aircraft will generate bigger MRO expenditures, with the Rolls-Royce BR700 in the top spot for 2025.

Business aviation engine MRO demand in 2025 is forecast to generate \$3.5 billion, according to Aviation Week Network data.

North America generates the most MRO demand for both business aviation and military markets. However, the military Asia-Pacific fleet is larger, and MRO for it is growing faster.

Unlike the commercial market—which is dominated by one aircraft type, narrowbodies—the military fleet is a broad mix of bomber, fighter,

2025 MRO Forecasts	Commercial Aircraft	Business Aircraft	Civil Helicopters	Military Aircraft
FLEET SIZE	34,008	35,443	21,425	56,357
FLIGHT HOURS (MILLIONS)	94.1	8.0	9.2	13.2
NEW AIRCRAFT PRODUCTION VALUE (U.S. \$ BILLIONS)	\$239.4	\$26.2	\$3.1	\$100.0
MRO DEMAND (U.S. \$ BILLIONS)	\$126.3	\$12.7	\$8.1	\$135.3

Source: Aviation Week Network 2025 Fleet & MRO Forecast

(49%) while field maintenance drives military MRO (39%).

Breaking it down by market, the commercial aviation MRO increase is driven by higher labor, parts and production costs that continue to stymie the segment. OEM delivery rates for new aircraft still are not meeting expectations, so older aircraft that were scheduled to retire must remain in service. This results in operators investing in another C or D airframe check and more legacy engine overhauls. While this should be good news for the aftermarket, MRO capacity is tight, so longer-term planning is required.

One thing that should positively change in 2025 is an increase in used serviceable material, for which the industry has been clamoring. At the end of 2024, teardown facilities reported higher demand for dismantling services. The industry can expect about

Similar to commercial aviation, business aviation flight hours continue to climb, especially for fractional and charter aircraft. This in turn is fueling more aircraft orders and use of the existing fleet, although the market is normalizing after the flurry of growth and new entrants over the past few years.

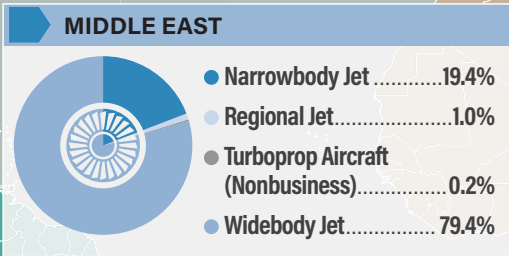
Like commercial aviation, expect business aviation aircraft retirements to increase, with more than 450 projected to exit the fleet in 2025, according to Aviation Week Network fleet data, which also indicates that retirements are likely to accelerate over the next seven years.

From an engine perspective, the Pratt & Whitney Canada PT6 will continue to dominate the in-service engine fleet; nearly 17,000 of them will be powering single-engine and multiengine turboprops in 2025. While the PT6 represents the largest in-service fleet,

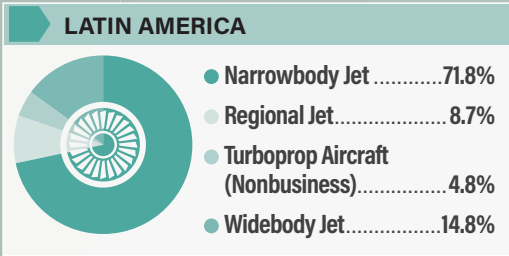
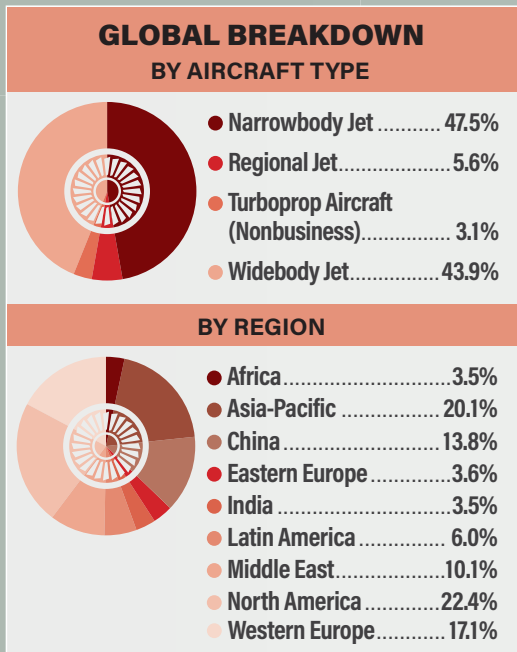
surveillance, rotary-wing, trainer and transport aircraft. That translates to a wider range of engines, but the GE T700/CT7, which powers various helicopters, is the dominant military powerplant.

MRO demand for civil helicopters is expected to generate \$8.1 billion in 2025, with components and engines accounting for 66% of that. Unlike the other segments, the civil helicopter fleet has plateaued, and the in-service fleet is expected to age, which will increase MRO costs.

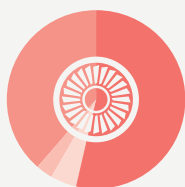
The Airbus H125/H130 will continue to be the predominant civil helicopter in 2025, with more than 4,800 in operation, representing about 22% of the civil helicopter in-service fleet, according to Aviation Week Network data. H125s/H130s, powered by the Arriel engine, are expected to generate about \$1.3 billion in MRO demand in 2025. 🌐



Global Engine MRO Demand 2025

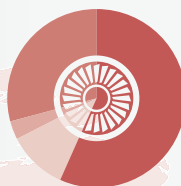


WESTERN EUROPE



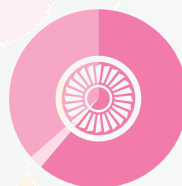
● Narrowbody Jet	53.6%
● Regional Jet	4.8%
● Turboprop Aircraft (Nonbusiness)	3.2%
● Widebody Jet	38.4%

EASTERN EUROPE



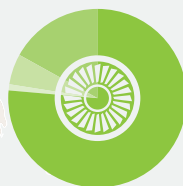
● Narrowbody Jet	56.8%
● Regional Jet	11.0%
● Turboprop Aircraft (Nonbusiness)	3.3%
● Widebody Jet	29.0%

CHINA



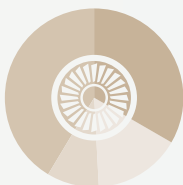
● Narrowbody Jet	61.4%
● Regional Jet	2.3%
● Widebody Jet	36.3%

INDIA



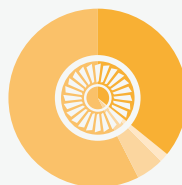
● Narrowbody Jet	76.5%
● Regional Jet	1.1%
● Turboprop Aircraft (Nonbusiness)	5.6%
● Widebody Jet	16.8%

AFRICA



● Narrowbody Jet	33.4%
● Regional Jet	15.7%
● Turboprop Aircraft (Nonbusiness)	9.5%
● Widebody Jet	41.3%

ASIA-PACIFIC



● Narrowbody Jet	35.9%
● Regional Jet	1.8%
● Turboprop Aircraft (Nonbusiness)	5.1%
● Widebody Jet	57.2%

Source: 2025 Commercial Aviation Fleet & MRO Forecast, Aviation Week Network

What's In

What's Out

A look at which trends are gaining popularity and which are losing steam in the aviation aftermarket.

Lindsay Bjerregaard

IN



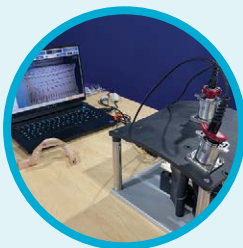
Adding Hangar Capacity



AI-Enabled MRO



Mergers & Acquisitions



Engine Shop Automation



Boosting Aircraft Recycling Capabilities



Vertical Integration



MRO AAM Partnerships

OUT



Workforce Development Complacency



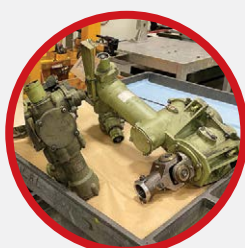
Paper Workflows



Special-Purpose Acquisition Companies



PMA Hesitancy



Parts Trapped in Repair Loops



Not Prioritizing Sustainability



Traditional Training Models

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Time for a 'Triopoly'?



The domination of the large commercial aircraft market by two companies has been going on for so long that it is easy to think that it has always been so. Boeing's 1997 merger with McDonnell Douglas cemented the Boeing-Airbus duopoly. In the ensuing decades, the airframers settled into a comfortable parity in dividing up the market. The only manufacturer that tried to challenge them, Bombardier, was promptly squashed.

But the duopoly has been roiled in recent years. Airbus has grabbed a commanding lead in sales of narrowbody aircraft, due to the optimal sizing of the A321neo and Boeing's self-inflicted wounds (page 86). Airlines and lessors are frustrated that the two companies cannot deliver enough airplanes to meet demand and, with no competition, seem to be dragging their feet on developing next-generation models. This begs the question: After nearly three decades, is the market finally ripe for a third player? If so, which company would have the best chance of succeeding?

Much focus has been on China's Comac. Conventional wisdom holds that China's rapid advances in military propulsion and space eventually will extend to commercial aviation. "The player that is ultimately going to make a difference and become the third competitor is China," then-Boeing CEO Dave Calhoun told us in 2023.

I'm not so sure. In the near term, Comac does not need to be a global player for its new C919 narrowbody to succeed. China's domestic market is big enough to soak up most of Comac's limited production capacity. Developing a truly competitive international product will require certification in the West and the creation of a global maintenance and support network, no small tasks. The ongoing decoupling of the Chinese and Western supply chains poses yet another challenge.

The company to keep an eye on in the coming years is Embraer, the feisty Brazilian manufacturer that was almost bought by Boeing and then jilted at the altar. With excellent engineers and visionary leaders, Embraer has built world-class airplanes for decades while protecting the intellectual property of its suppliers. It is certainly capable of upgauging to a bigger airplane that could challenge the duopoly. Aviation Week has learned that multiple large airlines in the U.S. and

Europe have told Embraer they will collectively order hundreds of airplanes if a new program is launched.

It also is no longer a given that Airbus and Boeing will crush any new challenger—or would need to. In 2008, the year Bombardier relaunched its cutting-edge C Series narrowbody program, Boeing forecast a market for 29,400 large jets over 20 years. Today, Boeing sees demand for 44,000 airplanes, an increase of nearly 50%. A third entrant might not be the threat that Bombardier was when it was forced to sell the C Series line (now the A220) to Airbus for \$1.

A key question, of course, is whether Embraer can play in the big leagues. It has 1/20th the revenue of

Boeing and thus would need a financial partner with billions of dollars to develop a new product. Talk has focused on investors from the Middle East, particularly Saudi Arabia. Another challenge is that Embraer's business model relies heavily on outsourcing major components. Can an aviation supply chain that is struggling to keep



EMBRAER CONCEPT

up with the demands of two OEMs support a third? Are the technologies for a game-changing product mature enough? Embraer surely is looking long and hard at those questions.

Finally, we should not rule out the possibility of a market disruptor. Innovative California upstart JetZero is developing a blended wing body aircraft that could be used as both a military tanker and a civil airliner targeting the underserved midmarket segment. The U.S. Air Force has awarded the company a \$235 million contract to support development of a full-scale demonstrator that is scheduled to fly in 2027.

Of my many visits to Embraer, I vividly remember a trip with then-Editor-in-Chief Tony Velocci in 2010. The company was considering an upgauged aircraft that would have competed directly with Airbus and Boeing. Embraer's leaders knew that to succeed they would need a game-changing product. "What we will do will take us to a very competitive airplane, that I can assure you," one of them told us.

Embraer wisely decided to hold off on challenging the duopoly. Fifteen years later, though, the chess board looks different. Keep your eye on this company. The years ahead could get very interesting. ☛

—Joe Anselmo, editorial director,
Aviation Week Network

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