STARTS AFTER **PAGE 34**

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56 *The compact combustion capability of rotating detonation engines is helping to fast-track early applications of the propulsion technology.*

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FEATURES

ON THE COVER

Boeing subsidiary Aurora Flight Sciences is building the Control of Revolutionary Aircraft with Novel Effectors (CRANE) X-plane for DARPA, as shown on the cover, to demonstrate how active flow control can influence aircraft design and performance. Defense Editor Steve Trimble's coverage begins on page 40. Aurora Flight Sciences photo.

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FEEDBACK

"Going Nuclear" by Guy Norris *(Aug. 14-Sept. 3, p. 16)* drew letters from several readers. Excerpts from them and a response by Norris follow.

WORRISOME ATTITUDE

I am a strong proponent of nuclear power and have been following the DRACO project with great interest. But the article "Going Nuclear" includes some comments I found very disturbing.

In the article, NASA's Space Nuclear Technology Portfolio Manager, Anthony Calomino, states that the uranium fuel in the reactor would not be radioactive before the reactor is turned on for the first time. He also states that debris generated by a launchpad mishap would not be "any worse than the debris that would be produced by the turbomachinery." Both those statements are false.

All uranium is radioactive, even "depleted uranium," which as pure U238 is mildly radioactive in gamma and beta and a fairly heavy emitter in alpha radiation. U235 is about three times more radioactive than U238, and this fuel would be enriched to 20%. While most alpha radiation isn't harmful when exposed to externally, it is massively harmful if it gets into the human body through ingestion or inhalation. Both could happen if the fuel is not stored in a way that could contain a failure like a rocket exploding and thus allows fuel particles to drift over a populated area.

While NASA has a stellar record when it comes to making sure radioactive payloads on its rockets are safely stored and handled to prevent public exposure in the event of an accident, I worry that the attitude of Calomino could put safety at risk or create a complacent attitude at the DRACO project. An accident would seriously damage the reputation of a promising new technology.

Rees Shuman, Seattle

OPTIMAL ANALYSIS

I read "Going Nuclear" with interest, as I have worked on space nuclear and commercial nuclear power systems since the mid-1960s.

The launch safety analysis should include a spectrum of credible accidents, including large fires and explosions and the hazards associated with radiological and toxic chemical releases. For example, the analysis should include consequences of soluble uranium uptakes by workers or members of the public and potential accidental release of contaminated liquids to surface water. The radiation doses associated with accidental airborne releases of high-assay, low-enriched uranium will most likely dominate the final determinations of the severity of accidental releases.

The results of the radiological and toxic chemical accident analyses should be compared to the performance criteria specified in 10 CFR 70.61, "Radiological and Chemical Consequence Exposure Levels," as used by the Nuclear Regulatory Commission to judge the acceptability of Nuclear Material Safety and Safeguards facilities.

A safety review of the proposed space nuclear reactor's Safety Analysis Report and Probabilistic Risk Assessment should be performed by the U.S. Nucelar Regulatory Commission. NASA, DARPA and the Energy and Defense departments do not have the required nuclear safety expertise and organizational structure to perform an independent evaluation of the reactor safeguards needed for protection of the public, workers and the environment.

Andrew R. Marchese, Las Vegas

FROM NERVA TO DRACO

Once again, Guy Norris comes through with the outstanding article "Going Nuclear," which matches his "Nuclear Options" *(May 3-16, 2021, p. 42)*. Having worked on the Nuclear

Guy Norris responds:

It is correct that the uranium fuel will be radioactive prior to launch. However, in terms of launch safety, radioactivity is technically not the key metric—it is rather radiotoxicity, or the difference between the strength and type of radiation versus how it impacts the human body. The gammas and betas mentioned by Mr. Shuman are, from uranium, both weak and infrequent, and nuclear specialists tell Aviation Week the impact on the body would be less than the radiation a person would experience going on a walk outside.

While uranium, being an alpha emitter and heavy metal, is harmful to ingest, uranium of any isotope is nowhere near as toxic as something like plutonium (or polonium, which has been used as a poison), given its much longer half-life. The half-life of uranium is around 700/4,500 million years for U235/U238; it is 87 years for Pu238 or 138 days for Po210. Radiotoxicity is broadly proportional to half-life, shorter being worse. The health impact from uranium usually comes from polluted ground water and ingestion over many years, not a single exposure to a small quantity that landed in the ocean following a launch abort. Even this is largely due to uranium's effect as a heavy metal on the body (chemical toxicity) more than its radioactive nature (radiotoxicity), according to the U.S. Centers for Disease Control and Prevention's Agency for Toxic Substances and Disease Registry.

From a safety perspective, per the National Security Presidential

LOCKHEED MARTIN

Memorandum NSPM-20 referenced in the article and Space Policy Directive-6, the launch will need to demonstrate it can be conducted in a way that, even under very unlikely accident scenarios, the health and safety of the public will not be jeopardized.

On a related note, program sources inform Aviation Week that the fuel being manufactured for DRACO will be an exceedingly robust, dense ceramic designed to take the massive forces acting on a nuclear thermal propulsion reactor core during operation. Thus, even during launch-abort events, the core will not plausibly vaporize and disperse over a wide area (like a hypergolic propellant would, for example).

Both DARPA and NASA are exceedingly aware of the negative effect that any type of radiation release or health impact from a launch would have on the program, as are regulatory agencies such as the FAA, Nuclear Regulatory Commission and Energy Department. It will not be trivial to mitigate all these concerns, but that is the charter of the program.

Engine for Rocket Vehicle Application (NERVA) program for 10 years, I feel privileged to have lived long enough to possibly see this program, now called DRACO, become an aerospace reality.

The team at BWX Advanced Technologies (BWXT) has an exciting opportunity to place nuclear propulsion at the forefront of space travel. How will BWXT test the new engine? Tabitha Dodson, DARPA's DRACO program manager, says in the article that it is not possible to test the engine on the ground. All the NERVA engines plus the Rover series were tested on the ground at Jackass Flats, Nevada. When designing the reactor for NERVA the Westinghouse Astronuclear Division, located at Large, Pennsylvania, performed fuel testing, two-phase flow characteristics, thermal testing, etc. The reactor was built at the Large facility and shipped by rail to Jackass Flats, where there were fuel facilities for liquid hydrogen, assembly buildings for hot reactor disassembly and test facilities. All those facilities have been torn down and dismantled. It will be interesting to see how BWXT accomplishes these tasks without test facilities.

I am 84 now and very anxious to see the BWXT DRACO program become a reality with a very robust nuclear rocket engine. I wish the engineers and scientists at BWXT all the success in the universe in applying all the research done since the early 1950s in making the nuclear rocket engine for the new Mars travel vehicle.

John F. Ellis, Warrendale, Pennsylvania

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

WHO'S WHERE

Shawn Hendricks has joined *Orbit Fab* as its inaugural chief operating officer. He was senior vice president for operations at Terran Orbital, and before that a director at L3Harris. During his military service, he was a program director in the U.S. Navy and military assistant to the deputy director of the Defense Security Cooperation Agency, among other roles.

DZYNE Technologies has hired U.S. Army Col. (ret.) **Christopher C. Miller** as interim chief revenue officer. He was a member of the company's board of directors. In the public sector, he served as acting U.S. Defense Secretary from November 2020 to January 2021, and previously was director of the National Counterterrorism Center.

Alastair Willson has been hired by *Avia Solutions Group* as CEO of the recently acquired Synergy Aviation, to be rebranded as Ascend Airways, and chairman of the board of subsidiary KlasJet. He was CEO at Titan Airways.

Volatus Infrastructure has announced a new leadership team, with **Dan Sloat** as CEO, **Bob Johnson** as chief commercial officer and **Nicolas Zart** as chief strategy officer. Sloat is the founder of the Advanced Air Mobility Institute and an expert in unmanned aerial systems (UAS) traffic management. Johnson has worked as an urban air mobility strategic advisor at his consulting firm, as well as in the Georgia Department of Transportation Advanced Air Mobility Working Group. Zart joins from Vertical Flight Society, where he was director of strategic development.

Gunnar Kleveland has been appointed president and CEO of *Albany International*, taking over for Bill Higgins who retired Sept. 1. Kleveland joins from Textron Specialized Vehicles, where he held the same positions.

Embraer has hired **Carlos Naufel** as vice president for services and support. He was technical director at Azul Linhas Aereas and previously worked at Embraer in technical solutions from 2000-2019.

Eastern Airlines has promoted **Brian Newhart** to director of operations from chief pilot. **Ian Masson** succeeds him, moving up from captain. Before joining the company, Newhart worked at American Airlines and Piedmont Airlines; Masson previously worked at Dynamic International Airways.

Andre Robert has joined *Electric Power Systems* as vice president for program management. He was vice president for business development and GE programs at ST Engineering.

Woolpert has hired **Aaron Smith** as program director. He was state aviation manager for the Florida Department of Transportation.

Lisi Aerospace CEO **Emmanuel Viellard** has been named chairman for the *International Paris Air Show*, succeeding Patrick Daher.

Di Reimold has been appointed vice president for civil aviation at the *Aerospace Industries Association*. She was deputy vice president for flight program operations at the FAA. Before that, she was head of global policy, safety and flight operations at the International Air Transport Association.

Stacey Bechdolt has been appointed director of engineering and air safety at *Air Line Pilots Association*. A private pilot and aviation attorney, she also serves as president and founder of the Aerospace Education Resource Organization and a board member at Civil Air Patrol, the CAP Foundation and the Laura Taber Air Safety Foundation.

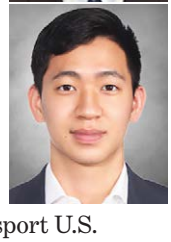
Clear-Com has hired **Preston New** as business development director for military, aerospace and government. He worked for eight years at L3Harris, most recently as senior account manager for U.S. Air Force satellite communications, following 21 years in the U.S. Air Force.

Scott Powell has joined *Boom* as senior vice president for Symphony, the propulsion system for its Overture airliner. A veteran engineering leader, he spent almost 40 years at Boeing, including its aerospace and defense divisions.

Law firm *Seyfarth Shaw* has hired **Joe Wonderly** as an attorney for its labor and employment department from Alaska Airlines, where he was senior corporate counsel. He was previously an associate at Davis Wright Tremaine.

GIFAS, the French Aerospace Industries Association, has reelected Airbus CEO **Guillaume Faury** as chairman.

Matthew Smith has been hired by *AIR*, an Israeli electric vertical-take-off-and-landing vehicle developer, as director of certification and airworthiness from the MIT Lincoln Laboratory, where he was deputy program manager. He brings extensive experience in FAA certification and as the lead organization designation authorization administrator, as well as heading the engineering department at Gulfstream Aerospace.



The *Air Charter Safety Foundation* has brought on **Alexander Evans** and **Andrew Ha** as assistant director of safety and programs administrator, respectively. Evans joins from Atlas Air, where he worked as a senior passenger service representative, including helping transport U.S. armed forces. Ha was an intern at Allegiant Airlines, and previously a military battalion squadron leader for the Republic of Korea armed forces.

Jeff Geraci has returned to *ACR Electronics* as general manager and

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

vice president of sales for ARTEX Products. He was vice president for sales and marketing for EDMO Distributors, before which he held several leadership positions at ACR Electronics.

U.S. Air Force Acquisition and Technical Officer (ret.) **Randall Walden** has been elected to *The Aerospace Corp.* board of trustees. Before retiring from the Air Force, he most recently served as director and program executive officer for the Rapid Capabilities Office.

Scientific Systems has brought on U.S. Air Force Gen. (ret.) **Charles Corcoran** as a strategic advisor. Prior to his retirement, Corcoran was assistant deputy chief of staff for operations at U.S. Air Force headquarters, before which he commanded the branch's Warfare Center at Nellis AFB in Nevada. He also serves as senior fellow for the Mitchell Institute for Aerospace Studies and sits on the board of directors at the Missile Defense Advocacy Alliance.

Bluestone Investment Partners has appointed **Rene LaVigne**, **Tom Mutryn**, U.S. Army Gen. (ret.) **Gustave Perna**, **Teresa Smetzer** and U.S. Air Force Col. (ret.) **Jen Sovada** to its board of advisors. LaVigne is concurrently president and CEO of Iron Bow Technologies. Perna is founder and CEO of Perna Consulting, as well as board member at several different companies. While in the Army, he was most notably chief operating officer of Operation Warp Speed. Sovada is president of public sector at SandboxAQ, with extensive intelligence and cybersecurity experience in the U.S. Air Force. Mutryn and Smetzer, now retired, were chief financial officer of CACI International and CEO of Smetzer Associates, respectively.

AWARDS

Donald E. Franklin of Jacksonville, Florida was designated a *Wright Brothers Master Pilot* by the Federal Aviation Administration for his more than 50 years of military and civil flying.

The *National Aviation Hall of Fame* has inducted six new members into its Class of 2023: **Velta Benn**, a pioneering female aviator and flight examiner; **Cornelius Coffey**, the first African American to establish an aeronautic school; **Angela Gittens**, director general of ACI World and leader in airport management; **Fred Haise**, Apollo 13 astronaut; **Ed Stimpson**, a leading advocate for general aviation; and **Kathryn Sullivan**, a former NASA astronaut and administrator of the National Oceanic and Atmospheric Administration.

In addition, Rep. **Sam Graves** (R-Mo.) and Sen. **Jerry Moran** (R-Kan.) have received the Congressional Leadership Award in recognition of their service to aerospace and aviation.

FIRST TAKE

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GENERAL ATOMICS AERONAUTICAL SYSTEMS

DEFENSE

LongShot, an air-launched, missile-firing uncrewed aircraft demonstrator funded by DARPA, will enter flight testing in 2024, says developer General Atomics Aeronautical Systems (page 40).

Industry partners in the three-nation Global Combat Air Program to develop a sixth-generation fighter—the UK's BAE Systems, Japan's Mitsubishi Heavy Industries and Italy's Leonardo—have reached a collaboration agreement enabling them to work on a trilateral basis.

Lockheed Martin is proposing the assembly of Sikorsky S-70M Black Hawks in the UK by StandardAero in a bid to win the country's New Medium Helicopter competition.

BAE Systems and L3Harris Technologies have delivered the first Gulfstream G550-based EC-37B Compass Call electronic attack aircraft to the U.S. Air Force for testing.

The U.S. Coast Guard has flown a prototype missionized Leonardo HC-27J outfitted with radar, sensors and a U.S. Navy-developed Minotaur mission system.

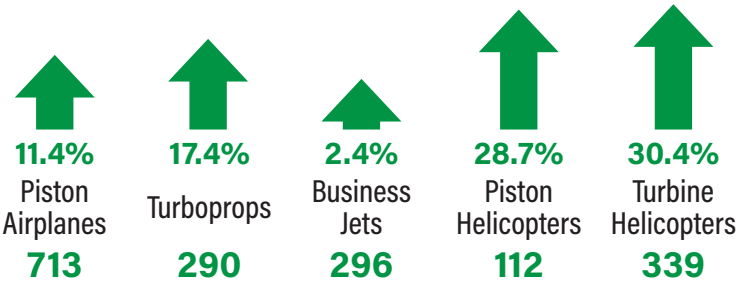
Iran appears to have received Yakovlev Yak-130 advanced jet trainers from Russia, possibly in return for one-way attack drones to support Russia's war in Ukraine.

DARPA has selected Boeing to lead a flight demonstration of an advanced divert and attitude control system for a future interceptor against hypersonic glide vehicles.

COMMERCIAL

A Ural Airlines Airbus A320 made an emergency landing in a wheat field 110 mi. from Novosibirsk, Siberia, on Sept. 12 after a hydraulics failure on approach. No one was hurt.

Gathering Momentum



The general-aviation manufacturing industry's results for the first six months of the year show increased aircraft deliveries across all segments when compared to the first half of 2022, with shipments up by more than 10% for fixed-wing aircraft and 30% for helicopters.

Source: General Aviation Manufacturers Association

Required inspections on higher-time PW1100G geared turbofans could ground 650 Airbus A320neos at one time early next year, Pratt & Whitney parent RTX disclosed Sept. 11 (page 18).

Vietnam Airlines confirmed its intent to order 50 Boeing 737-8s on Sept. 11, during U.S. President Joe Biden's visit to Vietnam.

Safran Aircraft Engines announced it will double Leap engine blade production in China as it opened a new factory at its Guiyang facility on Sept. 1.

Lufthansa Group has rebranded Eurowings Discover as Discover Airlines ahead of a fresh push into the German long-haul leisure market (page 29).

A software update caused a systemwide technology issue that briefly grounded all departing United Airlines flights in the U.S. on Sept. 5.

Russian government-owned carrier Aeroflot and subsidiary Aurora Airlines have placed orders for locally made Yakovlev aircraft: 28 MC-21-310 narrowbodies and 42 SJ-100 regional jets.

VIEW FROM WASHINGTON

U.S. Air Force: Not Ready for War

The U.S. Air Force is not, as an organization, prepared for a large-scale war and must look at overhauling its structure and how it can quickly deploy its forces, Air Force Secretary Frank Kendall said Sept. 11 at the Air and Space Forces Association's Air, Space & Cyber Conference outside Washington.

Kendall added that he has ordered a review of the service's structure. The service is optimized for the counterterrorism fight it faced over the past couple of decades as opposed to a possible conflict in the Indo-Pacific.

"The Air and Space Forces must change or we'll fail to prevent, or lose, a war," Kendall said. "The war we need to be most ready for—if we want to optimize our readiness to deter or respond to the pacing challenge—is not the type of conflict we have been focused on for many years."

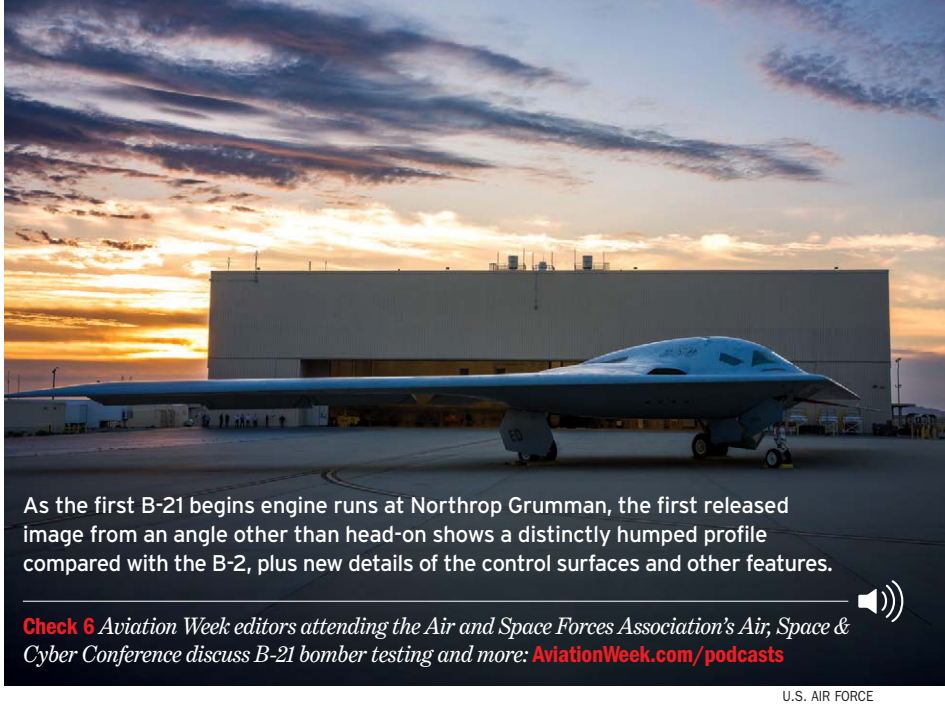
Kendall also directly targeted Sen. Tommy Tuberville (R-Ala.), who has placed a blanket hold on all Defense Department general and flag officer promotions to protest a Pentagon policy to reimburse service members who travel for an abortion.

President Biden has nominated Michael Whitaker to lead the FAA. A former FAA deputy administrator, he is now chief operating officer of electric vertical-takeoff-and-landing (eVTOL) developer Supernal (page 22).

TECHNOLOGY

Volocopter and Bristow Group are to launch air mobility services in the U.S. and UK, with a firm order for two VoloCity air taxis and options for up to 78 more.

India launched its first solar observation satellite, Aditya-L1, on Sept. 2 on the PSLV-C57 rocket.



As the first B-21 begins engine runs at Northrop Grumman, the first released image from an angle other than head-on shows a distinctly humped profile compared with the B-2, plus new details of the control surfaces and other features.

Check 6 *Aviation Week editors attending the Air and Space Forces Association's Air, Space & Cyber Conference discuss B-21 bomber testing and more:* **AviationWeek.com/podcasts**

U.S. AIR FORCE

Bristow has secured early delivery slots for five of U.S. startup Elroy Air's Chaparral hybrid-electric uncrewed VTOL cargo aircraft.

Germany's H2Fly has completed the first flights of a hydrogen-electric aircraft using cryogenic liquid-hydrogen storage with the piloted HY4 demonstrator.

The European Union Aviation Safety Agency has submitted its proposed rules for the operation of eVTOL aircraft for adoption by the EU (page 23).

The FAA has postponed by six months, to March 16, its Remote ID requirement that small drones broadcast their location and identification to ground receivers.

SPACE

An undisclosed number of satellites for the U.S. National Reconnaissance Office and Space Force's Silent Barker program to track objects from geosynchronous orbit were launched by an Atlas V on Sept. 10.

Japan launched its SLIM lunar lander on Sept. 7 on an H-IIA rocket along with the XRISM X-ray imaging and spectroscopy satellite.

Telesat has signed a 14-flight contract with SpaceX to deploy its planned Lightspeed constellation of 198 MDA-manufactured broadband satellites beginning in 2026.

POTOMAC MANAGEMENT RESOURCES/INTERNATIONAL AVIATION CLUB

AWARDED

The 2023 L. Welch Pogue Award was presented to **Rodney Slater** (center), former U.S. Transportation Secretary, on Sept. 12 by the Aviation Week Network and the International Aviation Club of Washington (IAC), in recognition of his outstanding contributions to the safety and liberalization of U.S. and global air transportation. The award was presented by IAC President Bob Letteney (left), Delta Air Lines' vice president for international government affairs, and Karen Walker, Air Transport World editor-in-chief and Aviation Week Network group air transport editor-in-chief.

75 YEARS AGO IN AVIATION WEEK

Eleven months after U.S. Air Force Capt. Chuck Yeager broke the sound barrier flying the Bell X-1, the world's fastest aircraft was featured prominently on our cover—in an advertisement. The Goodyear Tire and Rubber Company of Akron, Ohio, was touting its equipment on the X-1. "Designed to fly at a top speed of 1700 mph under the full 6,000-pound thrust of its four-unit rocket engine, the X-1 has the strongest airframe ever built," noted the ad on the front of our Sept. 20, 1948, edition. "Naturally wheel gear must be super-safe, too, so Goodyear All-Weather tires, Goodyear Single Disc Brakes and Goodyear magnesium-alloy wheels were specified." An ad on the cover was nothing new: To survive the Great Depression, the magazine began selling off the showcase position to advertisers in 1931.

And there they remained until 1956, when the magazine's editors finally reclaimed the coveted spot.

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

GOING CONCERNS
MATTHEW FULCO

Embraer-China Tie-Up

BRICs see how they can **fly higher together**

EMBRAER HAS WAITED PATIENTLY for its chance in China . . . very patiently.

The company still has only a tiny 2% share of the world's second-largest commercial aviation market. The Airbus-Boeing duopoly—more so Airbus these days—continues to dominate the Middle Kingdom's skies. Even would-be national champion Comac slightly edges out Embraer with a 2.2% market share.

Yet chances are Embraer's fortunes in China are set to improve, buoyed by a convergence of favorable commercial and geopolitical trends. As Aviation Week recently noted (*AW&ST* Sept. 4-17, p. 36), China's decision to certify the E195-E2 is significant—a sign that in the years ahead the narrowbody aircraft could figure into Beijing's broader civil aviation strategy along with the E190-E2, which was approved at the 2022 Zhuhai Airshow.

Embraer is increasingly sanguine about China, as seen in its Market Outlook 2023 published in June. In that report, the Brazilian company forecast that over the next two decades, the revenue per kilometer growth rate in the Asia-Pacific (APAC) region, including China, will be the highest of any region at 4.4%. Embraer also predicted that APAC will account for 25.8% of global jet deliveries, second only to North America.

GORDON ZAMMIT/ALAMY STOCK PHOTO

Embraer aims to cultivate a niche in an increasingly mercurial business environment for commercial aviation, one in which calls for self-sufficiency are growing louder as ties with the West fray. Following the debut commercial flight of the C919 in May, the state-owned *Beijing Daily* opined, "We finally broke the West's aviation monopoly."

Fortunately for Embraer, Brazil is geopolitically neutral in China's eyes—a fellow BRICS (Brazil, Russia, India, China and South Africa) country and member of the Global South that shares some of Beijing's antipathy toward the advanced economies that make the rules in international affairs and that seeks a larger role for developing countries on the world stage.

The first clear sign that Embraer's patience in the China market would pay off soon came in April during Brazilian President Luiz Inacio Lula da Silva's state visit to the country. Beijing and Brasilia released a joint communique on April 14 that said "both parties recognized the importance of strategic exchanges between the two countries in the aerospace sector" and "welcomed the partnership between Embraer and Chinese airlines."

Ties between the countries were not strained per se during the preceding presidency of conservative populist Jair Bolsonaro, but Lula's left-leaning politics and ambivalence toward the U.S. better align with China's worldview. During his visit, Lula lambasted the U.S. dollar's paramountcy in global trade and accused the International Monetary Fund of "asphyxiating countries' economies."

Brazil's support will be crucial to China as it tries to transform BRICS into a competitor of the G7 with a common currency of its own. Lula said in April that he supports creating a common BRICS currency in the same vein that Europeans created the euro.

At the same time, commercial trends in China's aviation market favor Embraer. Beijing wants to increase the international connectivity of airports in second- and third-tier cities—particularly within Southeast Asia. With a maximum of 146 seats, the E195-E2 can serve that purpose.

The Embraer jets also do not compete directly with Comac's smaller ARJ21 or larger C919, a point highlighted in an August press release by Arjan Meijer, president and CEO of Embraer Commercial Aviation. The Brazilian company's jets offer "complementary capacity to China's indigenous ARJ21 and C919 aircraft," he said.

Embraer has wisely made its potential construction of a final assembly line in China contingent on adequate E2 orders while shopping around to see if India—another important future market for the Brazilian company—can offer more attractive terms.

While New Delhi has big ambitions for its aviation sector, China needs the investment more. Manifest economic travails and the Communist Party's growing focus on national security have shaken the confidence of multinational companies in China. The country received just $4.9 billion in foreign investment in the second quarter, the lowest level in 25 years. U.S. Commerce Secretary Gina Raimondo channeled corporate frustrations when she told her hosts in Beijing in August that U.S. companies have complained to her that China is becoming "uninvestible."

If China can agree on a deal with Embraer for a final assembly line, it will be able to better combat that narrative while putting some teeth into its lofty proclamations about its shared interests with Brazil.

For its part, Embraer is poised to make inroads into the APAC region, with China as a key growth market. Conditions are ripe for what Chinese leader Xi Jinping would describe as "win-win cooperation."

LEADING EDGE
GRAHAM WARWICK

THE BATTERIES THAT ELECTRIC aviation needs are coming. Silicon anodes, solid electrolytes, lithium-metal—advanced battery developers are targeting aviation as an early market, offering higher performance and safety as a steppingstone to the high volumes and low costs necessary for the automotive market.

But these advanced aviation batteries have yet to achieve the production maturity needed to provide the quality assurance and traceability required by aircraft manufacturers. High-energy cells have still to be produced in volumes that can be integrated into high-power packs that can be certified.

Pedal to the Metal

Safran and Cuberg team on **lithium-metal batteries** for electric aviation

In a significant step toward that goal, Safran's Electrical & Power has teamed with Cuberg to develop aircraft energy storage systems based on Cuberg's lithium-metal batteries. Safran is already developing electric propulsion units, turbogenerators and power distribution systems, and the companies plan to offer integrated powertrains for electric and hybrid-electric aircraft.

Lithium-metal replaces the graphite anodes used in conventional lithium-ion batteries, increasing the energy density. Cuberg, a subsidiary of Swedish battery manufacturer Northvolt, has developed a 20-amp-hour lithium-metal pouch cell with a specific energy of 400 Wh/kg. Using these cells, Cuberg is producing a battery module with a specific energy of 280 Wh/kg.

This is up to 40% higher than comparable modules based on lithium-ion cells, the company says. Cuberg is already developing both cell- and module-level improvements to increase performance. "That next generation we have previously announced as getting to 450 Wh/kg at the cell level and 350 Wh/kg at the system level, probably in the 2026-27 time frame," says founder and CEO Richard Wang.

Where leading electric vertical-takeoff-and-landing (eVTOL) aircraft developers such as Joby Aviation and Archer Aviation are using automotive lithium-ion battery technology, Cuberg is targeting "fast followers" aiming to bring vehicles to market by 2027-28 with next-generation technologies, he says.

While companies such as Joby, Archer and Beta Technologies are developing their own electric motors and battery packs, Cuberg and Safran are looking to that next wave.

"We believe there will be a second generation of aircraft where they're looking at advanced batteries and powertrain solutions, because the first generation had to vertically integrate as there was no supply chain," he says.

Lithium-metal batteries face challenges with cycle life caused by lithium dendrite growth with repeated charging and discharging. Cuberg has developed a liquid electrolyte that suppresses dendrite growth. Lithium-metal cells also swell when charged, requiring them to be pre-compressed and packed in an elastic foam that allows them to swell in a controlled fashion, Wang says.

In addition to its high energy density, Cuberg's cell has low internal resistance, reducing temperatures during fast charging and high discharge pulses for VTOL. This makes passive cooling of the battery pack possible, he says. And the thermal runaway behavior is different from lithium-ion.

"Our cells are more resilient in that you have to drive them to a higher temperature before they go into thermal runaway. This is the nature of the stable electrolyte. But as they go into thermal runaway, you do have pretty energetic materials," he says. This drives module design. "Being able to eject the lithium metal without damaging any other cells is another key design we've been able to achieve."

CUBERG

Cuberg is making about 400 cells a week in its research and development facilities, enough to make 6-7 eVTOL battery packs a year. The company plans to expand to pilot scale within the next six months, 3-4 times that volume and enough to power a few tens of aircraft per year.

"We are currently on contract with an eVTOL aircraft company for a flight-test campaign by the end of next year. We are delivering the first prototypes and then flight-test hardware should be delivered in the second quarter of 2024," Wang says.

Over the last 12-18 months, Cuberg's focus has been on productization and maturation, scaling up to a large cell with the high reliability and quality control required to produce batteries for aviation. "We've got the 20-amp-hour cell to where every single cell we're making is behaving close to identically. And as we integrate the cells into a system, all of them cycle consistently over hundreds of cycles," he says.

Teaming with Safran will take the next step. "We're delivering the packs, and they're integrating them into their powertrain and integrated energy systems," Wang says. And Safran brings the certification experience and aftermarket expertise to finally bring advanced battery technology to aviation.

AIRLINE INTEL

JENS FLOTTAU

Stop Waffling

Why Bank of America wants Boeing to **launch a new airplane**

ONE REASON BOEING IS RELUCTANT to greenlight development of a new narrowbody airliner is a fear of irking investors.

After all, why commit up to $20 billion before the company has fixed a myriad of ongoing problems: quality glitches on the 737 MAX and 787; boosting production rates to increase cash flow; certifying the 737-7, 737-10 and 777X. Not to mention longstanding woes in its defense and space businesses.

But one prominent Wall Street veteran, Bank of America Securities Senior Aerospace and Defense Analyst Ron Epstein, is sending a strong message to the contrary. In a new research note, Epstein lays out in great detail why building a new aircraft is in the best long-term interest of Boeing—and the investment community. The wait-and-see attitude that the company's management has been taking is only making things worse, he says.

PAUL A. SOUDERS/GETTY IMAGES

Epstein's assessment of the 737 family, which entered service with Lufthansa in 1968, is brutally frank. "In our view, while the longevity of the 737 is impressive, the aircraft is now a bit of an anachronism," he writes. "Operating the aircraft is like driving around in a 1968 Chevy Impala with a semi-modern dashboard. It is important to note that the 737 is the only currently manufactured commercial aircraft without fly-by-wire controls, which are a staple in modern aircraft control system design."

Epstein adds that the 737 was never intended to be a long-term solution. Rather, it was developed in the 1960s as a bandage to help the company compete with McDonnell Douglas' DC-9. "Boeing continues to ride on the coattails of its past glory," he adds.

Epstein argues that if Boeing sticks with the status quo, it will be relegated to less than 40% of the narrowbody market—a sector that used to be split fairly evenly with Airbus. That is pretty much where the MAX is right now. While Boeing has been able to secure some substantial orders of late, that is probably more a reflection of Airbus' lack of delivery spots and high pricing than a sign of Boeing's fundamental turnaround.

Of course, some argue that 40% of a really big market is not a bad place to be, even in a duopoly where the other guy has 60% or more. But that ignores the margin pressures that come with being a distant second. Customers will demand greater discounts because they know Boeing is under pressure. And suppliers will be less willing to give discounts when the higher volumes of Airbus' competing A320neo program are more attractive. There are therefore plenty of reasons for Boeing to get moving, Epstein says.

He also does not buy Boeing CEO David Calhoun's argument that the technologies needed to give a new airplane a competitive edge are not mature enough. "We disagree with Boeing's assessment that 20-30% efficiency gains are not possible given currently accessible technology," Epstein writes. "We conservatively project that a clean-sheet model could be roughly 40% more efficient than current aircraft, with most of these gains derived from engine improvements."

Boeing also faces new pressures in the lower end of the narrowbody segment, given that Airbus is expected to launch a stretched A220-500 (or A221) within the next two years. But a new aircraft at the top end of the current narrowbody market would have major potential, Epstein argues. He sees a market for around 6,500 aircraft in the 150-300 seat category with a range of up to 6,000 nm—well above what Airbus targets for the A321XLR (4,700 nm). Boeing would have to invest $15-20 billion and need seven to eight years for development, Epstein estimates.

A notional Bank of America concept is for a high-wing, open rotor aircraft powered by sustainable aviation fuel. The elements of such a design are being worked on in various programs. Boeing has been selected for the NASA truss-braced wing demonstrator program, and General Electric and Safran are working on the open rotor concept in their Revolutionary Innovation for Sustainable Engines program. Interestingly, Epstein suggests a 2-2-2 cabin configuration—in essence, a small twin-aisle design. Such an aircraft would likely be aerodynamically less efficient than a standard 3-3 layout that could be somewhat narrower, but that would be offset by shorter boarding and deplaning times particularly for the larger models and greater passenger appeal.

While those design decisions may be something for down the road, Epstein's message is abundantly clear: Do something, and fast.

THE DEW LINE

STEVE TRIMBLE

AS TAIWAN WAITS FOR LOCKHEED Martin to deliver the first of 66 newly built F-16V fighters next year, the government in Taipei faces a tough decision over whether to build a mostly indigenous next-generation fighter.

The first phase of a broad, decade-long research and development period for Taiwan's Advanced Defense Fighter (ADF) will expire in 2024, covering early technology work on the aircraft design, engines, subsystems, weapons and sensors.

A follow-on phase would convert those technical evaluations and designs into working prototypes, with a requirement for significantly increased outlays from Taiwan's swelling—albeit still limited—defense budget.

With the Taiwan International Aerospace and Defense Industry Exhibition held Sept. 14-16 in Taipei, the country's defense industry leaders were publicly lobbying for the government to launch the ADF program soon. Ma Wan-June, president of Taiwan's Aerospace Industrial Development Corp. (AIDC), started his campaign for follow-on ADF funding in June.

In an interview with Taiwan's Liberty Times national newspaper on June 9, Ma called for steady, long-term support from the government for the ADF program. In the absence of consistent long-term funding, Ma warned, the program would be forced to advance in more expensive, high-tempo bursts.

Ma's interview came a week after Taiwan's National Chung-Shan Institute of Science and Technology (NCSIST) delivered a rare public update on the Vega Project, which is attempting to develop an indigenous military fighter engine.

Zhang Zhongcheng, dean of the NCSIST, told the Legislative Yuan that the Vega Project will be complete by the end of this year. The 10-year-old project developed 12 engine technologies, including indigenous capabilities for hot-forged advanced turbine components, Zhang said. Taiwan had co-developed with Honeywell the F125 turbofan engine for the AIDC F-CK-1 Ching Kuo, the Taiwanese "indigenous" fighter developed with assistance from U.S. companies. But Taiwan's industry produced only cold-forged components for the F125, leaving hot forgings and the overall design to Honeywell.

Although the Vega Project advanced the capabilities of Taiwan's industry, significant time and investment are required to develop the capability to design a full-scale, modern fighter engine, Ma told the Liberty Times in June.

The timing to launch an indigenous fighter program is ideal for domestic industry. Deliveries of the AT-5 Brave Eagle, a single-engine advanced jet trainer derived from the twin-engine F-CK-1, are peaking this year, and production will end after 2026. AIDC's overall finances have seldom been better; 2023 sales are set to match or exceed last year's record. Meanwhile, Taiwan's overall defense budget soared to more than NT$505 billion ($15.8 billion) in 2023, a 69% increase from $9.51 billion in 2018.

"Now is the time for moving on to develop the next-generation [ADF]," Ma told the Focus Taiwan News Service on Aug. 27.

As President Tsai Ing-wen's administration enters its term-limited final year in office, a go-ahead decision has been slow in coming, however. The decision could depend on the outcome of a presidential election in January; a candidate from Tsai's Democratic Progressive Party holds a firm lead over opponents in opinion polls so far.

For the government, the domestic industrial benefits and security of an indigenous solution may seem compelling. Taiwan launched the F-CK-1 development program 40 years after the U.S. severed diplomatic relations with the island. The U.S. would later sell F-16s—and France Dassault Mirage 2000 fighters—to Taiwan after the Tiananmen Square massacre in 1989 set back relations with mainland China, but the precedent of the 10-year withdrawal has not been forgotten.

On the other hand, Taiwan's defense sector has many needs, and an advanced, indigenous fighter would draw resources that could be spent elsewhere. The Overall Defense Concept (ODC) proposed in 2018 by now-retired Adm. Lee Hsi-Ming calls for Taiwan to move away from expensive weapon systems, especially advanced fighters that require vulnerable air bases and runways from which to operate. Lee's successors have backed away from the ODC's absolutist approach, favoring a stockpile with a mix of advanced and simpler weapon systems to counter a Chinese aviation threat.

Build or Buy?

Follow-on to **Advanced Defense Fighter** R&D phase would lead to prototypes

SAM YEH/AFP/GETTY IMAGES

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BAD SURPRISE

> PRATT & WHITNEY DETAILS GTF REPAIR SCHEDULES

> UP TO 650 A320NEO-FAMILY AIRCRAFT COULD BE GROUNDED IN 2024

Sean Broderick, Michael Bruno and **Christine Boynton** Washington and **Jens Flottau** Frankfurt

One way to understand the effect of the shockwaves reverberating from Pratt & Whitney's worsening geared turbofan engine woes is to look at MTU Aero Engines' market capitalization. The German engine manufacturer is an 18% partner in the consortium that builds the PW1100G engine powering about 1,350 Airbus A320neo-family aircraft. MTU lost a quarter of its value—about $3 billion—in the two days following a Sept. 11 investor call by Pratt parent RTX outlining needed repairs to 3,000 PW1100G and V2500 engines.

MTU's experience is symbolic because the Munich-based company is not directly responsible for its worst devaluation since it started trading as a public company nearly two decades ago. And it has plenty of company. The aftershocks are also hitting a good part of the Airbus A320neo operator base, sending airlines such as Wizz Air, IndiGo, Lufthansa, Spirit Airlines and Turkish Airlines scrambling to deal with fallout that will likely ground parts of their fleets through 2026.

For Pratt, there are immediate financial consequences. Longer term, it faces the risk of losing further market share on the Neo program to CFM International's Leap 1A, which already has been selected by more operators. The durability issues that have been hampering the geared turbofan (GTF) for years have also led to a cooling of the Airbus-Pratt relationship. Airbus is known to be seriously considering CFM as a second engine provider for the A220 program if, as expected, it launches a stretched A220-500 (or A221).

In its Sept. 11 update, RTX revealed the extent of the issue by defining a "fleet management plan." The plan is complicated, but can be put succinctly: It's bad.

Some 3,000 engines, including PW1000Gs of all types and IAE V2500s, built from mid-2015 through mid-2021, may have parts with contaminated powder metal (PM). Cracking from PM contamination has been found in high-pressure turbine (HPT) Stage 1 and 2 disks, or hubs, installed in the powerplants. Pratt is also inspecting some high-pressure compressor (HPC) disks built at the same time, RTX revealed. Most of the affected engines are PW1100Gs found on A320neo-family aircraft.

Clogged engine overhaul shops and a fast-tracking of necessary inspections on higher-time PW1100G GTFs will likely drive repair turnaround times to up to as many as 300 days per engine and could ground 650 Airbus A320neos at one time early next year, RTX disclosed. According to Aviation Week Network's Fleet Discovery database, 1,354 Pratt-powered A320neo-family aircraft are currently in service, parked, stored or in parked/reserve status.

Fleet groundings will "average" 350 at any given time through 2026,

Lufthansa will have to ground an average of 20 of its A320neos throughout 2024 to accommodate PW1100G repairs.

LUFTHANSA

according to RTX President and Chief Operating Officer Chris Calio.

The effect on airline operations will be profound. Lufthansa CEO Carsten Spohr, who was in Washington for the U.S. Chamber of Commerce Aerospace Summit in mid-September, used the opportunity to express his annoyance at the news, which caught most operators by surprise.

For Lufthansa, the accelerated GTF removals are expected to result in the grounding of 20 of its A320neos at "any given time next year," Spohr said. In addition to extending the operation of existing Airbus A320ceo aircraft to offset grounded Neos, the carrier projects it will need to wet-lease an additional 40-50 aircraft next summer.

The PW1100G repairs hit an already stressed airline industry. "It used to be difficult to be a salesperson, and it used to be easy to be a procurement manager—now it's the other way around," Spohr quipped. "The supply side is a huge mess. . . . We could sell a lot more seats if there were more aircraft available."

The same is true for Wizz Air, which has 49 affected aircraft and is slated to cut its planned capacity by 10% in the second half of 2024. Air New Zealand, which counts 16 A320/321neos in its fleet of 106 aircraft, is expecting that reduced engine availability will have a "significant impact" on its schedule starting in January.

IndiGo is the worst affected. The Indian low-cost carrier has 136 Neos built during the critical period. About 50 are already on the ground due to existing durability issues. The airline is urgently seeking as many A320ceos as possible on the secondhand market to battle further capacity shortfalls.

Affected airlines are also bristling over Airbus' insistence that Pratt continue to deliver new PW1000G engines to its final assembly lines at the contractually agreed flow so that it can proceed with a planned production A320neo ramp-up. That leaves Pratt with scant room to come to the aid of airlines with large numbers of parked aircraft.

Calio confirmed the company has no plans to divert spare engines from its pool of planned deliveries to Airbus. If more spare engines become available, it will be from an overall boost in PW1100G output, he suggested. "The best thing that we can do to help operators is continue to produce the spare engines that are in the plan and try to ramp that to the extent that we can, but [also] drive the industrial ramp needed for maintenance, repair and overhaul (MRO) output," he said.

In a Sept. 12 note to investors, Melius Research analysts said Airbus is well-protected financially. "If Pratt can't meet its commitments to Airbus, it will likely owe Airbus compensation," they wrote.

Financial analysts say it remains to be seen how big of a hit RTX will ultimately take. The company holds a 51% share in the GTF program. It is the largest aerospace and defense provider by annual sales, has cut $1.5 billion from its 2025 free cash flow projection, but still expects to achieve $4.3 billion free cash flow this year in the end.

Just $600 million or so is seen coming from the cost of inspections and rework. The rest, roughly 80% of the total charges, is to compensate aircraft operators for time lost to shop visits. But they may not be the only ones seeking payback. "We think the GTF risk-sharing partners are likely to push back on RTX's request for partners to cover 49% of the cost of this issue," the Melius analysts noted.

MTU is one of those partners. It expects profits and revenues to fall by $1 billion this year because of the issue. The company said it "will initiate measures with the aim of limiting the aforementioned effects as far as possible." More than 30% of commercial aircraft are equipped with technology from MTU, which manufactures aircraft engine components, assembles engines and provides MRO services.

In July, Pratt had announced that

PW1100G-Powered A320neos Built in Fourth Quarter 2015 through Third Quarter 2021

Operator	Number of Aircraft
IndiGo	136
Wizz Air	49
Spirit Airlines	48
Air China	47
GoAir	45
Sichuan Airlines	45
Volaris	44
Lufthansa	43
S7 Airlines	38
All Nippon Airways	33
Turkish Airlines	31
Viva Aerobus	28
Shenzhen Airlines	27
Vueling Airlines	25
China Southern Airlines	24
JetBlue Airways	21
Juneyao Airlines	20
VietJet Air	20
Vietnam Airlines	20
Qingdao Airlines	19
Hawaiian Airlines	18
Air Astana	17

Operator	Number of Aircraft
Cebu Pacific Air	15
Air New Zealand	13
Scoot Tigerair	12
Air Transat	10
Hong Kong Express Airways	10
Aegean Airlines	9
Middle East Airlines	9
Tianjin Airlines	9
Air Macau	8
Philippine Airlines	8
China Express Airlines	7
Swiss International Air Lines	7
China West Air	6
JetSmart Airlines	6
LAN Airlines	6
TAM Linhas Aereas	6
Anadolujet	4
Marabu Airlines	4
China Airlines	2
Tigerair Taiwan	2
Volaris El Salvador	2
Air Caledonie International	1

Source: Aviation Week Network Fleet Discovery

previous PW1100G parts inspection intervals, developed after the problem was first uncovered in 2020, were not aggressive enough to flag cracks that the contamination can cause. It said as many as 1,200 engines would need to be pulled in the next year, including up to 200 by Oct. 1. Some of the checks would overlap with scheduled shop visits, reducing unplanned disruptions and costs.

The revised figures now lower the number of engines that need immediate attention but narrow the removal window. The result is higher costs for Pratt and its PW1000G partners as its already full overhaul network faces a wave of engines that require extensive work scopes.

"Since our call in July, we've now developed a holistic fleet-management plan that ensures the continued safe operation of the fleet while balancing the impact to our customers," RTX's Calio said.

Under the plan, Pratt will pull 600-700 engines in the next two years in addition to about 500 already scheduled for overhauls. Most of the accelerated removals will come by "early 2024," Calio said. This includes 137 that must be pulled by the end of September. Problem parts in this batch have never undergone a more extensive inspection that Pratt developed to help flag PM "inclusions," now used on both new parts and those coming in for inspections.

Pratt is developing service bulletins that outline the plan. Its most recent bulletin, calling for the highest-risk engines to be pulled from service this month, was mandated by the FAA and other regulators. Some engines are slated to undergo more extensive overhauls than normally called for, including replacement of both HPT and HPC disks. This will contribute to extended turnaround times.

"It makes sense to replace the compressor disk at the same time," Calio said. "This is why the work scopes are heavier. It will ultimately give the engine a longer run and be the least disruptive to the operators in the long term."

Part availability would determine how many engines get new disks. Both the HPT and HPC disks are now being inspected every 2,800-3,800 cycles, depending on engine thrust ratings. The parts under scrutiny have a new, reduced life limit of 5,000-7,000 cycles.

Pratt was working to add PW1000 overhaul capacity to help address the engine's durability issues before the severity of the HPT disk problem became clear. It said in April that it had 12 shops globally that could handle PW1000 work and planned to add seven more by 2025. The timelines for opening these new shops are being accelerated where possible to help offset the ramifications of the PM issue.

Aviation Week Fleet Discovery shows about 260 PW1500G-powered A220s and PW1900-powered Embraer E2 were built when PM-contaminated disks were produced. About 980 PW1100G-powered A320neos were built, as well as 450 V2500-powered A320ceo-family aircraft. Pratt has a plan in place for the V2500-powered fleet and is confident it is sufficient to detect any issues.

Latest Issue Slows 737 MAX Deliveries But Not Ramp-Up Plans

- SOME FASTENER HOLES REQUIRE INSPECTIONS AND REPAIRS
- ABOUT 200 UNDELIVERED UNITS NEED THE WORK

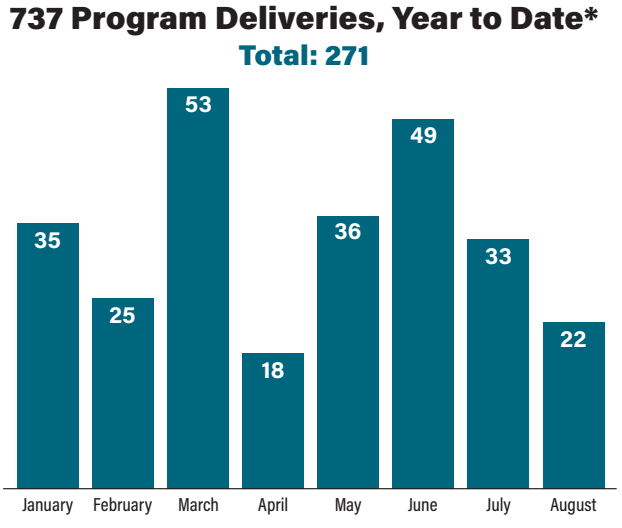
Sean Broderick Washington

An extra several weeks' work to inspect and repair fastener holes in more than 200 Boeing 737 MAXs will likely slow deliveries into the fall, but both Boeing and Spirit AeroSystems, which produced the nonconforming parts, insist the program's planned production-rate ramp-up is not at risk.

Boeing must inspect about 75% (160) of the 220 undelivered 737s in its inventory as of July 31 to ensure that hundreds of aft pressure bulkhead (APB) fastener holes are not too large, Chief Financial Officer Brian West confirmed during a Sept. 7 Jefferies investor conference.

Spirit has another 39 APB sections in its inventory that must be checked as well, Spirit CEO Tom Gentile said at the conference. Holes found to be too large must be redrilled and filled with a properly fitting fastener.

The issues affects some 737-7s, 737-8s and 737-8-200s. All affected aircraft must be inspected and, if necessary, repaired before delivery; the 737-7 must be certified before any deliveries begin.



Note: Boeing's full-year guidance is for 400-450 737 deliveries
*Data through Aug. 31
Source: Boeing

The added predelivery work, which began in August, contributed to reducing Boeing's 737 August deliveries to 22, West revealed, well below July's 33 and the average figure of 35.5 recorded for the first seven months of 2023. September's total will likely be even lower—perhaps just 15, he suggested—before deliveries begin to tick up. "The third quarter will be about 70 [deliveries]," West said. "[That is] obviously . . . impacted by this latest fuselage item."

Despite the near-term slowdown, West said, Boeing is not changing its full-year guidance of 400-450 737 program

deliveries. If the company posts 70 third-quarter deliveries, it will have to average 38 per month in the fourth quarter to reach the bottom end of the range. The 38-per-month figure is what Boeing was targeting for the second half of 2022 before the latest production problems disrupted its supply chain.

Boeing also plans to keep to its output schedule. The company is not changing its plans to keep monthly 737 production at the recently reached figure of 38 per month and to step up to the 50-per-month range by middecade.

"In the near term, [the APB issue] will impact deliveries, but we have no intention of changing the master schedule," West said. "The demand signal is strong, and we have to make sure everyone is coordinated on the longer-term stability in that master schedule. So we're not changing it."

West added that the yo-yoing of delivery totals is partly a function of having so many undelivered aircraft exposed to potential rework scenarios. Boeing built up an inventory of more than 450 737 MAXs after the model was grounded globally for about 21 months following two fatal accidents.

SEAN BRODERICK/AW&ST

The company halted deliveries as soon as the March 2019 grounding took effect, but kept building aircraft. Any nonconformances discovered must now be fixed not only in production but also on affected aircraft in inventory before the FAA will allow them to be delivered. Boeing expects to have most of the 737 inventory delivered by the end of 2024.

"Fast-forwarding to this 2025-26 time frame," West said. "We're post-recovery, and we have a [nonconformance] pop up. We're not going to have over 200 airplanes [in] finished-goods inventory that we have to worry about. That will be gone. If we find something, we'll fix it fast and it will be much less disruptive."

West said the APB work would "likely" take longer per airframe than vertical stabilizer rework required on some aircraft following discovery of a separate Spirit production-quality problem in April (*AW&ST* May 22-June 4, p. 26). Fixes on those aircraft are taking up to two weeks, the company said.

"This is different. It's a bit more complicated. It's more involved," West said. "There are hundreds of holes that get inspected. There's an X-ray inspection process step that's required, and it's a very critical part of the airplane."

Gentile said Spirit's 39 units include some partial assemblies. Each APB has about 500 machine-drilled holes that might need work. Spirit has set up two inspection stations and six repair stations to do the work, which includes an X-ray to determine whether repairs might be needed. Suspect holes get their fasteners removed for a closer inspection.

"If there's no issue with the hole—and often there isn't—we just put in the same-size fastener," Gentile said. "If there is an oblong hole, what we do is . . . drill it out again, so it's a little bit bigger, and then put in a larger fastener."

Gentile said Spirit's 39 units will be done by November. Boeing's work on completed aircraft is expected to take longer per unit because the problem area is more difficult to reach.

"It is 100% the most important thing we're working on right now," West said. "We've got literally armies of people from Boeing and the supplier working on this issue and to drive stability in their factory."

Boeing said in August that in-service aircraft with the problems face no immediate safety-of-flight issue. It is not clear how many delivered aircraft have nonconforming APB fastener holes.

Despite the added resource demand, supply-chain headaches and a new labor agreement that wiped out mandatory weekend overtime, Spirit is on pace to boost 737 MAX shipset production to 42 units per month by year-end and to stay at that pace through 2024.

Boeing will see its completed 737 inventory rise for several months as it works through aft pressure bulkhead repairs.

"We're going to end this year at 42 aircraft per month, and we're going to be at 42 aircraft per month all of next year, as will Boeing," Gentile said. "We are now about aligned with Boeing in terms of production rate."

Boeing is working to stabilize at 38 737s per month, up from 31 at the start of the year, with an eye on its 50-per-month, middecade target. The company has not laid out a time line for interim rate increases. Gentile's commentary suggests that Boeing is targeting 42 per month in early 2024.

"We typically are about six months in advance of them because we're earlier in the production process," Gentile said. "We're just . . . starting the cycle at 42 [per month]."

Spirit's output increase comes amid "additional pressures on supply chain and labor," Gentile said. "We see a lot of small suppliers who, because of the cash conversion cycle, have to hire labor [or] get long-lead material in advance, and that puts them under some cash pressure. We also see shortages of raw material and even fasteners—some basic things. That creates disruption across the supply chain."

The knock-on effect is often material shortages in Spirit's facilities that force the company to spend money to address the gaps. "In the last 18 months, we've had $200 million of charges in the supply chain that we've had to cover either by dual sourcing, in-sourcing or providing cover," Gentile said. "It's getting a little bit better, but it's still a pinch point as we go up in rates. It's putting pressure on the system."

Safety Leaders,

> PATRICK KY LEAVES EASA AS EXECUTIVE DIRECTOR AFTER 10 YEARS

> BOTH FAA AND EASA NOW RUN BY ACTING HEADS

Jens Flottau Frankfurt and **Sean Broderick** Washington

Patrick Ky's last day at the European Union Aviation Safety Agency after 10 years was still action-packed. On Aug. 31, the agency published proposed rules for the operation of air taxis in Europe, indicating its leadership in global aviation safety regulation.

The publication marked the end of Ky's two five-year terms, during which he transformed the agency and ensured that it would be at least on a par with the U.S. Federal Aviation Administration (FAA). The FAA's fundamental crisis, evolving after two Boeing 737 MAX accidents showcased grave oversight deficiencies, among other issues, was the European Union Aviation Safety Agency's (EASA) and Ky's moment. The regulator requested changes to the MAX's flight control architecture and redundancy that were also adopted by the FAA. EASA later redefined its role in the 777X's certification process and took a much closer look at the Boeing and FAA proposals. Certification of the 777X is still in progress.

It is a process that both organizations now must complete without permanent leaders. The FAA has been without a permanent administrator since March 2022, when Steve Dickson stepped down. Now EASA as well is going to be run by an acting executive director, Luc Tytgat, presumably for a period of at least several months. He has been director of strategy and safety management since 2015, after joining EASA from the European Commission (EC).

"I am honored to be entrusted with leading EASA through this transition period," Tytgat said. "My task in the coming months is to ensure that the agency continues to deliver on its many projects and that our operational and reputational position remains intact, so that the new executive director can begin the new role at full speed."

Patrick Ky is stepping down, as required by law, after two five-year terms as EASA's executive director.

The void at the top of both agencies comes as key programs remain to be certified on both sides of the Atlantic and while policy decisions on new industry sectors such as urban air mobility are being considered.

While Boeing is working on completing 777X certification, Airbus has the A321XLR and the A350F in the regulatory pipeline. A321XLR fire protection around the new rear center fuel tank has been a contentious issue for almost two years, but Ky and his team managed to settle the main parameters with Airbus before his departure. EASA's intervention weighed heavily—quite literally. Further tank insulation will add to the aircraft's empty weight, challenging the range performance promised by Airbus.

"We were faced with five major tragedies: [the shooting down of Malaysia Airlines Flight 17, the Germanwings crash, the Boeing 737 MAX crisis, the COVID-19 pandemic and the Russia-Ukraine war]," Ky told Aviation Week in a wide-ranging interview in March reflecting on his tenure (*AW&ST* March 27-April 9, p. 40). "After each of those crises, EASA had to adapt itself to the new reality to be flexible enough to change our internal policies, our organization, our way to deal with the circumstances.

"We added value in creating safety during the COVID crisis. We worked a lot on national health and safety protocols. Those things did not exist in our mandate before. We had to work with our doctors and our safety experts. From a governance perspective, when I arrived at EASA, there was a lot of tension with the national authorities. Ten years later . . . we have a very strong partnership between EASA and the member states of the European Union, which is good for safety."

The EASA role is a five-year posting, with the possibility of an extension for a further five years.

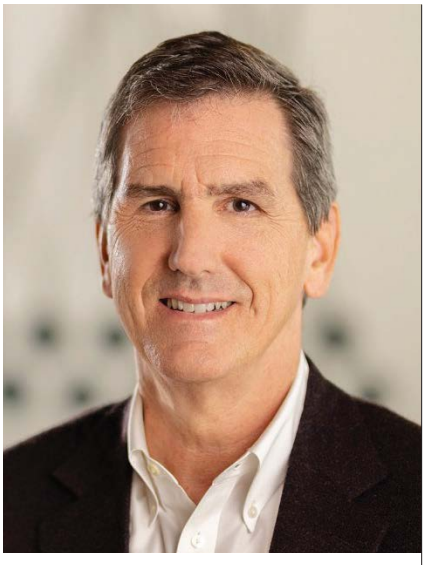
The job description specifies that EASA's management board will appoint the new executive director from a list of candidates provided by the EC. The successful candidate will be EASA's third head—Ky and his predecessor each served 10 years at the helm of the agency, which was created in 2003.

That shortlist is to be established through a process that includes a preselection panel, interviews—including with the EC's Consultative Committee on Appointments—and further assessments before a final tally of the most suitable candidates is communicated to EASA's management board, which may decide on additional interviews before making a decision.

Candidates could also be required

Anyone?

SUPERNAL



Michael Whitaker was nominated Sept. 7 as the next FAA administrator.

to deliver a statement before the relevant committee or committees of the European Parliament.

EASA's changes come amid ongoing uncertainty at the top of its U.S. counterpart. The Biden administration on Sept. 7 nominated its latest candidate to fill the FAA's top slot, putting former FAA official and longtime industry veteran Michael Whitaker up for consideration by the Senate.

The FAA has been without a Senate-confirmed administrator since Dickson stepped down halfway through his five-year term. Billy Nolen, who was associate administrator of aviation safety (AVS-1), took over as acting administrator when Dickson left, but departed this June to take a leadership role with aspiring urban air mobility aircraft manufacturer Archer Aviation. He was replaced by current acting administrator Polly Trottenberg, who moved over from her role as Transportation Department deputy secretary.

But U.S. law governing how Senate-confirmed roles can be temporarily filled limits Trottenberg's tenure to 210 days, meaning she must return to the Transportation Department by Oct. 25. At that point, if the Senate has not confirmed a new permanent administrator, current FAA Deputy Administrator Katie Thomson would step in as acting administrator, Trottenberg and Thomson told FAA employees in an Aug. 16 memo.

"As I've said from Day One, my role as acting administrator is temporary in order to provide support and stability during this transition," the memo said. "And we will continue efforts to see that the FAA has a Senate-confirmed leader, and the White House is closing in on naming a nominee soon."

The memo's contents were first reported by *Politico*.

The earlier Biden administration nominee chosen to fill the top FAA slot following Dickson's departure, Denver International Airport CEO Phil Washington, withdrew earlier this year amid a stalemate between lawmakers. Washington's detractors contended that his two years in the industry did not give him enough experience to be civil aviation's most important U.S. official. Whitaker, currently chief operating officer of Supernal, Hyundai's electric advanced air mobility aircraft developer, has three decades of industry experience, including three years as the FAA's deputy administrator during the second Obama administration term.

Another top priority for both the Senate and the House of Representatives is agreeing on new funding parameters and program priorities for the FAA (*AW&ST* May 8-21, p. 18). The current set of marching orders expires Sept. 30, meaning Trottenberg's departure could come just as lawmakers are juggling a temporary extension and digging into the details of a final agreement.

While the FAA's top slot has been a revolving door, the agency has now solidified its top career safety executive position. It confirmed on Aug. 28 that David Boulter would officially assume the AVS-1 role. Boulter, who joined the FAA in 1997, had been serving as the acting AVS-1 for more than a year.

Boulter's position was one of about a dozen acting roles among the agency's 63 positions listed in its "high-level" organizational chart. The number of acting roles has dropped some from midyear, when 15 of the top slots were filled with executives not officially granted permanent status.

—With Helen Massy-Beresford in Paris

EASA Submits eVTOL Operating Rules for EU Adoption

- EASA DOES NOT ACCEPT POWERED-LIFT AIRCRAFT DEFINITION
- TYPE RATING AND PERFORMANCE-BASED RESERVE REQUIREMENTS PROPOSED

Graham Warwick Washington

The European Union Aviation Safety Agency's proposed rules for the operation of vertical-takeoff-and-landing aircraft, including air taxis, emphasize the continuing differences in approach by Europe and the U.S. to regulating the emerging industry.

The agency submitted its proposed rules, called Opinion 03/2023, to the European Commission (EC) on Aug. 31 for adoption. Its refusal to follow the FAA in accepting the term advanced air mobility (AAM) and in adopting the same definition of powered-lift aircraft only serves to illustrate the gap that exists between the two regulators.

The opinion proposes a comprehensive set of operational requirements for piloted electric vertical-takeoff-and-landing (eVTOL) air taxis, including flight crew licensing, rules of the air and air traffic management. The

proposed rules also establish criteria for the certification and maintenance of drones—a mixing of uncrewed aircraft and air taxis that is another way in which the European Union Aviation Safety Agency (EASA) differs from the FAA.

"With this, we will achieve a harmonized regulatory framework to ensure the safe, sustainable and secure introduction of VTOL operations," said outgoing EASA Executive Director Patrick Ky. "This is the last piece of regulation required to enable the launch of VTOL and air taxi services for innovative air mobility." Ky left the agency Aug. 31.

EASA wants to have its eVTOL operating rules in place in time to enable Volocopter to launch initial commercial air taxi services in Paris in 2024.

VOLOCOPTER

Justifying its use of the term "innovative aerial services" (IAS) and the subset "innovative air mobility" (IAM) instead of the widely accepted "advanced air mobility," EASA says the FAA's definition of AAM only involves the transportation of people or goods and not other potential applications, such as sensor-equipped drones. EASA also notes the concepts of IAS and IAM have been adopted at the political level by the EC.

In contrast to the FAA's chosen definition of powered-lift aircraft, EASA introduces the new category of "VTOL-capable aircraft" (VCA). Rejecting the powered-lift aircraft definition, EASA says "such a category is only relevant for the purpose of flight crew licensing, while no airworthiness or operational requirements [for powered-lift aircraft] exist in the current regulations."

EASA plans to type-certify eVTOL air taxis under its Special Condition for VTOL, which was established in 2019. Meanwhile, the FAA in 2022 pivoted to certifying eVTOLs under Part 21.17(b) as a special powered-lift category—a class of aircraft it first defined two decades ago—and is now adding the definition to existing regulations.

The European regulator says rotorcraft and helicopters are excluded from its proposed definition of VCA because they have one or two rotors, while a VCA relies on lift or thrust units for VTOL operation. Traditional two-rotor tiltrotors such as Leonardo's AW609 are excluded from EASA's proposed rules, whereas the FAA's powered-lift Special Federal Aviation Regulation (SFAR) will apply to the AW609 civil tiltrotor.

EASA also notes that, as with all applicable EU aviation regulations, the VCA definition applies whether the aircraft is crewed or uncrewed—another key difference from the FAA's approach. Piloted eVTOLs are further defined as "manned VTOL-capable aircraft" (MVCA).

The opinion proposes a performance-based reserve requirement, equivalent to the energy required to execute a go-around maneuver. The representative time to perform a go-around with degraded vehicle performance is to be established during initial certification and can be defined for a go-around to a vertical and a conventional landing.

This contrasts with the FAA's proposed SFAR, which would require powered-lift aircraft to meet the same prescriptive reserve requirements as fixed-wing airplanes: 30 min. for daytime visual flight rules (VFR) operations, and 45 min. for nighttime VFR and day or night instrument flight rules operations. Industry is pressing the FAA to adopt a performance-based requirement, arguing its proposal could double or triple the battery size required in an eVTOL.

On flight crew licensing for eVTOLs, EASA proposes that applicants who hold a commercial pilot license for airplanes or helicopters be entitled to be issued a type rating for a VCA. Pilots would be able to use flight simulators to obtain type ratings.

In contrast, the FAA is proposing that pilots must first obtain an underlying powered-lift category certification in a simple aircraft, then a type rating in a more sophisticated aircraft. This does not align with International Civil Aviation Organization (ICAO) standards, industry says.

Arguing that the lack of powered-lift-rated FAA check pilots and suitable dual-control aircraft for training create significant headwinds, industry is pressing the FAA to allow a powered-lift type rating to be added to an existing airplane- or helicopter-category pilot certificate. This would align with ICAO and EASA protocol and procedure.

EASA's proposals were published for public comment from June-September 2022, and the final proposal reflects that input. This includes EASA's defense of its decision to use predefined routes for the initial rollout of crewed eVTOLs.

Noting comments from manufacturers that such requirements would not be needed and would hinder market development, EASA says predefined routes of the type now flown by helicopters are necessary over urban areas to respect ground risk requirements and minimize the risk of collision between VCA.

The FAA is proposing the use of corridors—cooperative areas of low-altitude airspace within which operators of appropriately equipped eVTOLs will abide by industry-defined operating practices and share information—with flow management to be performed by third-party service providers.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Redressing Europe's Rail-Air Imbalance

- FRANCE TO REINFORCE AIR TICKET TAX TO INVEST IN RAIL
- GREENPEACE REPORT SHOWS PASSENGER RAIL SERVICES ARE TWICE AS EXPENSIVE AS AIR TRAVEL ON AVERAGE

Helen Massy-Beresford Paris

As Europe aims for net zero—in part by significantly decarbonizing the transportation sector—aviation's role in climate change compared with other modes of transport is coming under ever closer scrutiny.

MARK STEVENS/ALAMY STOCK PHOTO

Low air fares compared with train travel are in the spotlight.

Politicians and environmental groups are highlighting the fact that rail—a greener alternative to many flights within the region—costs a lot more than air travel. "Many people are shocked that it is often cheaper to take the plane than the train," French Transport Minister Clement Beaune told RMC radio on Aug. 7.

Boosting rail service is a significant part of Europe's broader climate objective of reaching net zero by 2050. The European Commission has pledged to double high-speed rail traffic across Europe by 2030.

Beaune's comments—and updates from airline CEOs highlighting a booming summer season—underscore that discrepancy in cost, a major barrier to encouraging more people to travel by less-polluting, climate-friendlier rail.

A Greenpeace study released in July also flagged the discrepancy between air fares and train travel, demonstrating that the EU and national policies are encouraging European citizens to fly instead of taking the train.

The study compared the cost of flight and train tickets on 112 cross-border and domestic routes in Europe at nine different times and found that tickets for trains were on average twice as expensive as for flights and about four times as expensive in the UK and Spain.

Flight tickets were less expensive than train tickets on 71% of the routes analyzed, and only 23 routes were almost always cheaper by rail. The study found that low-cost airlines operated 79% of the routes analyzed.

Greenpeace EU climate campaigner Lorelei Limousin said in July: "Airlines benefit from outrageous fiscal advantages. Low-cost airlines, in particular, have exploited every loophole and trick in the book. Ten-euro airline tickets are only possible because others, like workers and taxpayers, pay the true cost. For the planet and people's sake, politicians must act to turn this situation around and make taking the train the more affordable option." Greenpeace also said the overall climate impact of flying, including non-CO_2 emissions, can be more than 80 times worse than taking the train.

Train travel, of course, cannot replace all flights, but when it can, even airlines are now increasingly touting the benefits and forming partnerships with their former rail operator rivals.

But carriers are unlikely to support plans to impose greater taxes on air tickets and invest the proceeds in the railways, which is exactly what France intends to do.

Greenpeace wants national governments to introduce climate tickets—affordable and simple long-term tickets valid on all means of public transport in a country or a defined region.

The nonprofit also criticized airlines' kerosene tax exemption, reforms of which have stalled, arguing that no equivalent energy exemption exists for rail operators.

Beaune said progress is being made there, too. He told RMC he is confident that a kerosene tax at a European level would be implemented within the next few months, and that France is leading the way on discussions.

The Greenpeace report was released as heatwaves and wildfires raged in southern Europe, forcing many tourists to evacuate, particularly from the island of Rhodes, Greece, shining a spotlight on the leisure flights that had transported them on holiday. Although some airlines had to cancel bookings and add repatriation flights, other carriers shrugged off concerns.

Ryanair CEO Michael O'Leary said at the time that he did not see any dip in demand related to the wildfires. On the contrary, O'Leary pointed to a growing demand to sunny destinations as the UK and Ireland faced a rainy summer, and that gave him confidence that Mediterranean growth would continue over the next decade.

Perhaps seeing the writing on the wall, Air France-KLM and Lufthansa Group, among others, have increasingly been teaming up with rail operators in recent years to offer seamless rail-air connections.

Meanwhile, demand patterns are shifting among airline networks. Air France's domestic network is shrinking, perhaps not too surprisingly in the home of the TGV high-speed train.

Air France-KLM CEO Ben Smith described domestic demand during the company's quarterly results in May as "the one dark spot in our network" and said that on some routes a big transfer to rail was already underway. The airline is cutting capacity expeditiously to align with that trend.

French Flight Schools Are Facing Financial Challenges

- MANY TRAINING ACADEMIES PROVE TO BE UNSCRUPULOUS
- AUTHORITIES FAIL IN SUPERVISION

Thierry Dubois Lyon

The financial troubles of PFT Aero, a France-based flight school for professional pilots, are another symptom of the predicament that part of the country's training sector faces. Repeated bankruptcies—often leaving students with neither a diploma nor a refund—point to dubious activity and unacceptably fragile organizations in the sector. DGAC, France's civil aviation authority, is accused of evading its supervisory duty defined by European Union Aviation Safety Agency (EASA) regulations. Meanwhile, pilot unions struggle to protect students.

Airways College, a flight school operating from Agen in southwest France, went into liquidation in April 2021, effectively depriving more than 200 students of the training they had paid for. Most of them seem to have found solutions, thanks to support from DGAC and PFT Aero—the company that took over Airways College and is also known under the parent company name Paris Flight Training.

Agen's bankruptcy court declared PFT qualified in July 2021. That same court sent PFT into receivership this July. According to a source close to the case, PFT still operates one or two aircraft for its 100 students. Between 60-70% of them are ex-Airways College students. PFT Aero's judicial situation was first reported by French aviation news website Aerobuzz and financial daily *Les Echos*.

In France, some entrepreneurs are trying to ride the wave of global pilot demand by creating flight schools, a job-seeking pilot explained. The never-ending release of bullish pilot demand forecasts drives the recruitment of would-be pilots. In fact, demand is largely driven by North America and the Asia-Pacific region, the pilot added.

State-run national aeronautics and aviation university ENAC has a prestigious pilot-training organization. Capacity, however, is limited to a couple dozen new students per year. Air France has its own pilot course, which is also very restricted in its number of seats. Therefore, hundreds of students may seek to enroll in private courses, which total 270,000 flight hours per year.

"Some of them are financially solid, such as Epag, Esma and Mermoz Academy," says Thierry Oriol, a board member at the SNPL France ALPA pilot union. "But some of those schools are not run by good, professional administrators. Their management team is made of aviation enthusiasts." All too often, that is the best-case scenario.

Training to become a professional pilot costs close to €100,000 ($107,000). "Too many flight schools have based their economics on fraudulent schemes," says Geoffroy Bouvet, president of the APNA pilot union. "They fund flight hours with the payments of those students who are not in the flight phase yet. That is close to a Ponzi scheme."

Students might be misled, despite the legal requirements with which the training organization must comply. Or, given the amount at stake, they might feel under pressure.

The law allows a training organization to ask for a maximum 30% payment up front. The rest should be paid as the student progresses.

"Some flight schools corrupt that principle," Bouvet says. "They ask for the remaining 70% to be paid over the next 18 months. However, after 18 months, some students have barely started flying. If a student requests a refund of the training they have not received—which they are entitled to, by law—the company cannot pay."

A common but illegal practice is offering a discount to those paying the entire amount up front. Typically, the student is encouraged to pay €80,000 when enrolling instead of a total €100,000 if payments are spread over two years.

Even startup schools with genuine intentions might be underfunded. "Banks do not lend to those companies," Bouvet says. "Some of the schools that subcontract flight instruction to existing ATOs [approved training organizations, under EASA rules] choose the one offering the better kickback." Some schools also benefit from public subsidies, as local authorities seek to support job creation.

ALSIM

A training organization may ask for a maximum 30% payment up front, according to the law. The rest should be paid as the student progresses.

DGAC's oversight of ATOs has long been superficial in the financial domain, Bouvet and Oriol complain. "The people in charge of approving an ATO are pilots, and they focus on the training program," Bouvet says. "They are neither economists nor lawyers, and the required checks in finance and lawfulness are nonexistent."

He recommends DGAC create an operations license for ATOs so that the business plan would be scrutinized.

PFT Aero and DGAC could not be reached for comment.

Asia-Pacific Airlines Are Gradually Closing the Recovery Gap

> THE REGION'S INTERNATIONAL CAPACITY IS AT 79% OF 2019 LEVELS

> EUROPEAN, NORTH AMERICAN AND GLOBAL AVERAGES ARE HIGHER

Adrian Schofield Auckland

Airlines in the Asia-Pacific region have accelerated their international capacity recovery in recent months, although they still trail carriers in other major global regions by a significant margin.

International demand in Asia has undoubtedly surged back, as evidenced by soaring average fares and airline profits. Carriers have tried to keep pace by returning more of their parked fleets to service and purchasing or leasing additional aircraft, but supply remains constrained in many international markets.

Systemwide seat capacity in the Asia-Pacific region recovered to 97.3% of 2019 levels for the week of Aug. 28, according to data from CAPA – Centre for Aviation and OAG. This overall statistic is driven in large part by domestic capacity, which is running 6.7% ahead of 2019 levels.

International capacity also has been on a healthy growth track, albeit from a lower base than domestic. Asia-Pacific international seat capacity has recovered to 79% of 2019 levels for the week of Aug. 28. This is an improvement from the 59.7% recovery rate at the start of 2023 and 73.6% at the beginning of May.

The Association of Asia-Pacific Airlines (AAPA) reports that demand has been rising even more strongly than capacity.

The group says international passenger numbers for Asia-Pacific airlines were 146.6% higher in July versus the same month in 2022. This represents a recovery of 81.4% compared to July 2019.

International demand as measured by revenue passenger kilometers increased 107.6% year-on-year in July, with capacity up 98.8% in terms of available seat kilometers. The average load factor rose by 3.6 points to 83.7%, which AAPA says was in line with 2019 levels.

The industry group says robust recovery trends have continued into the second half of 2023. Factors include "sustained growth in major Asian economies fueling the appetite for international travel" and the return of travel into and out of China.

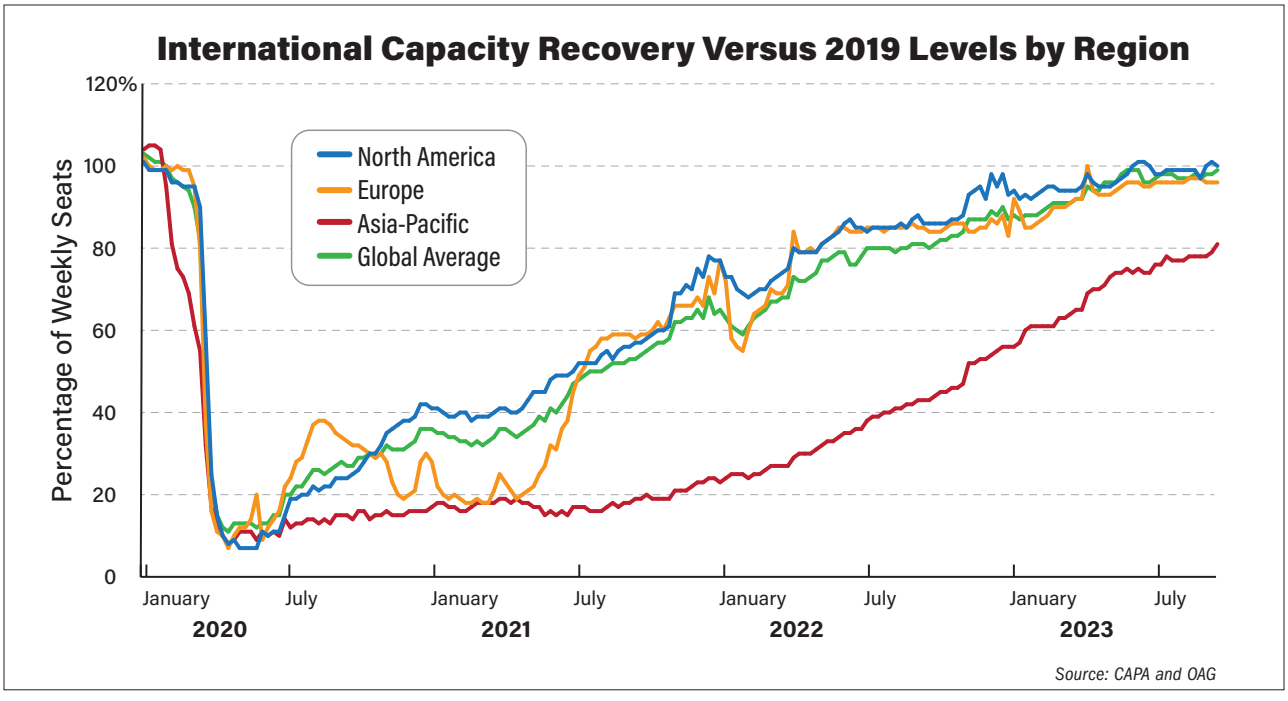
AAPA predicts demand will remain high, although with possible clouds on the horizon. These include uncertainties in the wider macroeconomic environment and increased living costs, both of which could affect travel spending habits.

The International Air Transport Association (IATA) confirms the Asia-Pacific region had the highest growth rate in traffic and capacity in the second quarter, particularly in international sectors. IATA notes the Asia-Pacific international recovery had a late start, as it only began gaining momentum toward the end of last year.

The accompanying chart, using data from CAPA and OAG, illustrates how international capacity recovery in the Asia-Pacific region has lagged that of other regions since the beginning of the pandemic.

However, that gap has narrowed considerably during the course of 2023, with a rate of increase much steeper than in Europe or North America.

For the week of Aug. 28, international capacity was at 96% of 2019 levels for Europe and 101.1% for North America, according to CAPA data. The global average was 98%.



This means the Asia-Pacific recovery rate of 79.1% is now less than 17 percentage points behind Europe and less than 20 points behind the global average.

The difference between the Asia-Pacific and global averages was 42.3 points in the week of Nov. 29, 2021, and 38.2 points a year ago in the week of Aug. 29, 2022. So the gap has more than halved over the past year.

Spurring this improved recovery have been markets in the Northeast Asia subregion such as Japan, Hong Kong and mainland China, which were relatively late to ease travel restrictions.

Weekly international seat capacity in Northeast Asia has risen to 65% of 2019 levels as of Aug. 28. Although the increase has plateaued somewhat since July, it is still significantly above the 47% recovery as of March.

In contrast, Southeast Asia's international seat capacity is at 78.7% of 2019 levels, with the Southwest Pacific at 87.4% and South Asia tracking slightly ahead of 2019 levels.

Asia-Pacific carriers have been increasing their presence at international airports this year.

JOEPRIES/AVIATION.NET

The major Northeast Asian markets—including Japan and mainland China—still have the most room for improvement. These were some of the largest sources of leisure travelers before the pandemic, so their importance cannot be overstated.

International capacity in the Asia-Pacific region should continue to rise more quickly than the other main regions in the short term. However, it may be longer before it reaches full recovery. Several of the Asia-Pacific airlines cut back their widebody fleets during restructuring, so even when all parked aircraft are activated, they will still have smaller fleets than before the pandemic.

Lufthansa Repositions Its Low-Cost Units

- AFFILIATES EUROWINGS AND DISCOVER REACH PROFITABILITY AFTER YEARS OF LOSSES
- CITY AIRLINES IS SET TO LAUNCH AS HUB-FEEDING CARRIER

Jens Flottau Palma de Mallorca, Spain

If there is one name indicative of Lufthansa Group stumbling in the low-cost market, it is Eurowings. For years, Eurowings and predecessor Germanwings have been piling up hundreds of millions of euros in annual losses, with frequent management changes and the units torn apart between strategy tweaks and group discipline. The only good news was that at least Eurowings was occupying markets that Lufthansa absolutely did not want to leave to Ryanair and EasyJet.

It has been a very costly exercise that could not be sustained in the long run, particularly after the COVID-19 pandemic forced the group to focus on cash and survival. Now, more than three years after the biggest crisis in its history unfolded, Lufthansa's two existing low-cost units are beginning to show the results of a deep restructuring, and a third affiliate is being set up.

Before the pandemic, Eurowings was asked to do several things simultaneously. The carrier, formerly a regional operator, was tasked with taking over all nonhub flights from German bases such as Hamburg, Stuttgart and Berlin—which were inherited with a legacy Lufthansa route structure and a customer base that was predominantly business travel-oriented. It was not an ideal setup for an airline that was supposed to deliver high double-digit unit cost reductions. To make matters worse, the group also decided that Eurowings was supposed to take on some long-haul flying that Lufthansa itself could not operate profitably. In a complex arrangement, former Brussels Airlines Airbus A330s placed into a new German unit were flying the services on behalf of Eurowings. The strategy seemed to be: Deal with everything we, Lufthansa Airlines, have failed in.

That arrangement has long been dismantled. Eurowings discontinued the long-haul business and went through a deep transformation that took three years. And a new affiliate was set up to focus on long-haul leisure flying. The carrier was branded Eurowings Discover initially—a major marketing campaign to introduce a new brand was deemed inappropriate when the group had only survived through extensive state aid. With that phase now over, Eurowings Discover has been renamed Discover Airlines to avoid confusion with its sister airline. Crucially, both Eurowings and Discover expect to be profitable for the first time this year.

Jens Bischof has led Eurowings since early 2020. One of the first decisions the former Sun Express CEO made was to shut down the strategy department. "The only strategy was to survive," he recalls. He then brought his senior executives together to align behind a new concept. Eurowings was going to increase its focus on leisure customers—which now make up 60% of its business, up from 40% in

2019. That shift meant the airline had to redefine its network and drop many of the domestic and city routes it had inherited from Lufthansa.

Eurowings also opened bases outside of Germany, in Palma de Mallorca, Spain, Prague and Stockholm. The airline entered into partnerships with Volotea and Smartwings. Another major alliance is to follow with another European carrier.

Eurowings also was able to reduce unit costs by a significant double-digit percentage, Bischof notes.

The carrier's fleet consists of around 120 units during the peak summer season, with around 20 aircraft on wet lease from operators such as AirBaltic or Avion Express. One of the decisions the airline made was to define the dimension of its own fleet by its requirements for the winter season, when it drops all the wet leases and only operates its own 100 aircraft, minus those in heavy maintenance.

But the fleet is the one item that must be addressed in the coming years, requiring both significant negotiating skills about how aircraft are deployed inside Lufthansa Group and competition for the added capacity is all but guaranteed.

Discover Airlines also appears to have found an operating model that works. The airline expects to be profitable for the first time this year and is slated to grow its fleet to 28 aircraft in 2024—23 of which are to be based in Frankfurt and five in Munich. The carrier plans to fly 13 Airbus A330s, a mix of -200s and -300s, from the Frankfurt base. Munich long-haul services are to start in 2025. Discover is modeled around Edelweiss, which has been successfully operating long-haul leisure flights from Zurich as a Swiss International Air Lines affiliate for years. Discover and Edelweiss are now also run by a joint CEO, Bernd Bauer.

The last piece in Lufthansa's low(er)-cost setup is going to be a carrier called City Airlines. The unit, which has received its air operator certificate, is to fly European and domestic feeder services at Lufthansa's hubs in Frankfurt and Munich, routes currently operated by the legacy airline. The Lufthansa pilot pay scheme is such that—unlike at U.S. majors—narrowbody pilots can reach the highest salary levels,

DISCOVER AIRLINES

Discover Airlines, formerly operating as Eurowings Discover, plans to grow its fleet to 28 aircraft from 23 in 2024.

massive capital investment. Eurowings is spending around €1.5 billion ($1.6 billion) to introduce 13 Airbus A320neo-family aircraft through 2024, including five A321neos. The new aircraft would not only be essential because of their lower fuel burn compared to the existing fleet. They are also expected to allow Eurowings to grow on medium-haul routes that are less seasonal. In October, the airline is set to launch Dubai services from both Stuttgart and Berlin using 180-seat A320neos. Eurowings opted against deploying the 232-seat A321neos because of significant payload limitations returning from Dubai against the jet stream. Additional long routes are planned to follow, among them to destinations in Spain's Canary Islands in the winter.

Further fleet renewal is going to be needed. Eurowings still operates 38 150-seat A319s that are too small for the leisure markets they serve and uneconomical in terms of unit costs. Bischof says he hopes to either swap them with other Lufthansa Group units that can use them in hub feeder roles or get a share of Lufthansa's existing A320neo order or future deals. But given that Lufthansa Airlines and several other affiliated carriers also need new aircraft, stiff internal making it challenging to serve the feeder network profitably.

What is more, the future of regional affiliate Lufthansa CityLine has become more uncertain. Lufthansa Airlines had terminated an agreement with pilots that guaranteed a minimum fleet during the pandemic, contending that it was not going to be reachable anyway. Because of the move, an earlier framework deal with pilots has become active again. According to the deal, Lufthansa CityLine must stop flying aircraft larger than 95 seats in 2027. The carrier has an active fleet of 12 Airbus A320-family aircraft, according to Aviation Week Network's Fleet Discovery database. Among the aircraft are three A321Fs that CityLine operates on behalf of sister company Lufthansa Cargo. It also has 26 Mitsubishi CRJ900s and seven Embraer 190s. The CRJ900s and E190s are too small to feed the hubs, at least on trunk routes.

Should there be no agreement on relaxing the scope clause, the Airbus narrowbodies would have to be moved to another unit. Given their high operating costs, they are unlikely to go back to Lufthansa Airlines. This is where City Airlines could come into play, too.

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WHERE AVIATION'S FINEST MEET

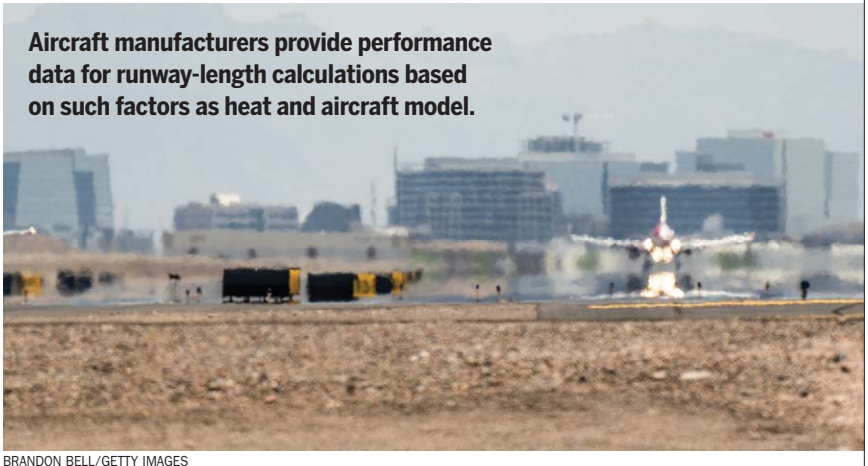
This Summer Gave U.S. Airlines a Glimpse of What Might Come

> CARRIERS MUST WORK HARDER TO PREPARE FOR SUMMER TRAVEL

> EXTREME HEAT MIGHT FORCE AIRLINES TO CHOOSE BETWEEN LIGHTER PAYLOADS AND SHORTER LEGS

Christine Boynton Boston

Soaring temperatures recorded across swaths of the Northern Hemisphere this past summer broke official records for June and July. The two months were Earth's hottest June and July in 174 years of National Oceanic and Atmospheric Administration recordkeeping.



Aircraft manufacturers provide performance data for runway-length calculations based on such factors as heat and aircraft model.

BRANDON BELL/GETTY IMAGES

With drier conditions in play, the season was also hallmarked by wildfires. Airlines aided evacuation efforts as operations were disrupted in parts of the Mediterranean and North America. In Canada, more than 6,000 fires burned more than 15.5 million hectares (38.3 million acres), in what officials say was the country's worst-ever wildfire season. In short, summer 2023 offered a glimpse of the increasing challenges airlines will likely face in a warming climate.

"In line with what has been expected from past climate projections and [United Nations Intergovernmental Panel on Climate Change] reports, these events are not rare anymore," notes a study on July's extreme heat in North America, Europe and China from World Weather Attribution. "Unless the world rapidly stops burning fossil fuels, these events will become even more common and the world will experience heat waves that are even hotter and longer-lasting."

Fort Worth-based American Airlines, for example, is putting "a heck of a lot more work" into summer preparedness, CEO Robert Isom said during a second-quarter earnings call, including preventative maintenance for auxiliary power units, cooling readiness on jet bridges and aircraft as well as protecting team members out on the ramp.

"The heat that we're facing this year in the country, these are records, and it is something that impacts certainly our aircraft, any machinery . . . and it's also really hard on our people," Isom said. "We're really taking this seriously, and we're going to have to as we go forward."

Since June 1, more than 300 excessive heat warnings have been recorded in the U.S., according to National Weather Service data.From June 30-July 30, Phoenix recorded 31 consecutive days of temperatures above 110F, the National Oceanic and Atmospheric Administration (NOAA) reported, breaking the 1974 record of 18 days.

"We did have one day when the temperatures were so high in Las Vegas that it caused temperature warnings—caused the fuel in the aircraft to exceed a temperature warning—which actually made us cancel flights," Frontier Airlines CEO Barry Biffle said during an Aug. 1 earnings call.

Aircraft weight adjustments can become necessary as temperatures rise and air density decreases. To plan for this, aircraft manufacturers provide performance data for runway-length calculations. Just how high the heat scale goes up differs by aircraft and OEM.

Boeing's 737 MAX airport planning document illustrates several scenarios: Put a CFM Leap 1B25-powered 737-8 on a dry, approximately 8,400-ft. runway at sea level, with no wind in 59F "standard day temperature" conditions with its air conditioning off, and it can have a maximum takeoff weight of 182,200 lb., the guidance last updated in March shows. The same aircraft faces an approximate 3,200-lb. weight reduction when the temperature is 104F on a runway just shy of 12,000 ft., and an approximate 17,200-lb. reduction at 122F on a runway just over 12,000 ft.

Factoring in climate projections, airlines might increasingly face a choice: sacrifice payload or range.

Current sustainability reports from the Big Four U.S. carriers characterize extreme heat as mainly a medium- and long-term risk. Southwest Airlines projects rising annual average temperatures and extreme heat waves to be among the climate hazards affecting all of its regions in the 2030-50 time horizon, while a risk analysis from Delta Air Lines projects physical climate effects to be largely negligible at 21 strategically important airports.

A common factor among all four reports are strategies for mitigation and management, including monitoring efforts, investments, and health and safety protocol.

Some go further, noting operational factors beyond their own control. A potential need for extended runway lengths is one observation from Southwest. In its sustainability report, American also observes a need for more resilient aircraft and engines. With American's experience in hot-weather hubs, such as Phoenix, Miami and Dallas, the airline intends to have a say.

"Over the next five years, we plan to incorporate the projected impacts of climate change into aircraft purchasing plans, routing and scheduling," American writes. "We will also work with airframe and engine manufacturers to develop aircraft that meet the technical specifications required for operation at airports with sustained high temperatures."

Industry Adapts to Ongoing Constraints as Traffic Recovers

- CONTINUED SUPPLY CONSTRAINTS ARE A UNIFYING THEME
- IT'S NOT JUST ABOUT THE HARDWARE—IT'S ALSO THE PEOPLE, EXECUTIVES SAY

Christine Boynton Washington

By 2025 or 2026 a "huge gap between demand and supply" of aircraft could close, projects Airbus CEO Guillaume Faury.

"But a lot of things are in flux and keep moving," he cautioned at the Global Aerospace Summit on Sept. 12, noting that passenger traffic has largely returned to 2019 levels. "It takes a lot of time and a lot of effort and pain to do the ramp-up in the global environment that we're in."

The OEM delivered 863 commercial aircraft in 2019, but just 661 in 2022. Today, "there's probably more demand than supply for flight tickets," Faury said. "That's why the seats are quite expensive at the moment. It's different for the supply of planes; we're still very far away from where we were in 2019."

But Airbus says the plans it has for this year and next are solid, with Faury calling them "quite consistent with the shape of the supply chain."

"We are adapting our ambitions to what the supply chain can deliver," he said. "The challenge is to find the right pace." By 2026 on the Airbus side, production will include around 30 aircraft a month being manufactured in North America, he added.

Operating through and around continued supply constraints was a unifying theme at the summit hosted by the U.S. Chamber of Commerce.

One of the most recent challenges to emerge is the geared turbofan (GTF) inspection timeline updated by RTX on Sept. 11, which will result in higher-than-expected numbers of grounded GTF-powered Airbus A320s throughout 2024-2026 (see page 18).

Lufthansa, one of the airlines affected, projects a "significant impact." CEO Carsten Spohr said he expects the issue to ground 20 of its A320neos at "any given time next year." In order to fly its network next summer, the company plans to extend the operation of existing Airbus A320ceo aircraft while also wet-leasing an additional 40-50 aircraft.

"The demand is [as] strong as I've ever seen it but the supply side is a huge mess, let's be honest," Spohr said at the summit. "We could sell a lot more seats if there were more aircraft available."

Describing the GTF's more than 8,000 separate parts involving roughly 3,000 suppliers, RTX CEO Greg Hayes detailed an ongoing collaboration for improvement.

HERVE GOUSSE/AIRBUS

Conversations with Pratt & Whitney on compensation for the GTF issues have just begun, Spohr told reporters at the summit. Additional financial relief may also come through the company's maintenance, repair and overhaul arm, Lufthansa Technik, which will both support Lufthansa engines and offer their services to RTX subsidiary Pratt & Whitney and their global customers.

Lufthansa, which plans to take delivery of about 200 new aircraft through 2030, is also contending with lengthy delivery timelines (*AW&ST* March 13-26, p. 38). "We are waiting for almost every aircraft right now from every supplier," Spohr said, pointing to the broader supply chain in addition to OEMs. "Sometimes the aircraft is finished and the engines are done, but the seats are not there."

But it's not just the hardware, Spohr said: "We are also looking for people." For RTX, which faces a $3 billion pre-tax charge this quarter related to the GTF fleet update, a workforce shortage is something their CEO describes as one of the biggest challenges in the industry today—an issue that is both complex and far-reaching.

"I actually don't worry about attracting talent so much at RTX," Chairman and CEO Greg Hayes told summit attendees in Washington on Sept. 12. "What I do worry about is those 14,000 suppliers I have and their inability to hire, train and retain the talented workforce that you need for the aerospace ecosystem. And that to me is, I think, about the biggest challenge in aerospace today.

"It's not the major companies—we have the balance sheet, we have the technology, we have the people," Hayes continued. "It is those 14,000 suppliers that I share with every other aerospace and defense company out there, and the health of those suppliers is wholly dependent on their ability to attract talent."

Describing the GTF's more than 8,000 separate parts involving roughly 3,000 suppliers, Hayes detailed an ongoing collaboration for improvement.

"We cannot be successful if our suppliers can't be successful," he said. "We've got about 600 people out in the supply chain every day, helping our suppliers to get better . . . and doing all the work necessary so that they can evolve as we do."

TEXTRON

Textron and Leonardo have teamed up for the first time to offer the M-346N to the U.S. Navy.

U.S. Navy Steams Ahead on a New Trainer

- SERVICE EMPHASIZES HARSH, CARRIER-LIKE OPERATIONS IN SOLICITATION
- TEXTRON AND LEONARDO ANNOUNCE TEAMING AGREEMENT

Brian Everstine Sparks, Nevada

The U.S. Navy wants to move on quickly from its troubled T-45 Goshawk trainer toward the next-generation Undergraduate Jet Training System, but new requirements for the latter aircraft may slow the replacement process.

For years, the service has debated whether a future trainer—which would also be used for Marine Corps pilots—must be able to operate from a carrier like the T-45 does. Operational aircraft such as the Lockheed Martin F-35 are capable of autolanding on the ship. An Undergraduate Jet Training System (UJTS) request for information (RFI) released in mid-August provides a compromise: The future trainer would not be designed to go to the ship, but would need to be able to endure repeated unflared landings to practice the carrier flight profile.

This would require further engineering and development for the announced candidate aircraft, likely stretching out the program.

"The government assumes the development of [Field Carrier Landing Practice (FCLP)] is the main schedule driver," the RFI states.

While the Navy has trickled out multiple UJTS solicitations in the past five years, service officials say they are now pressing ahead to speed up the replacement. During a panel discussion at the Tailhook Symposium here on Aug. 26, then-Commander of Naval Air Forces Vice Adm. Kenneth Whitesell, who is retiring, said former Chief of Naval Operations Adm. Mike Gilday told the command to "get out of the T-45 as fast as possible."

The RFI calls for an assumed contract award in 2026, for a minimum of 145 aircraft at a full-rate production of 25 per year. This would make the UJTS competition the service's second largest aviation acquisition effort, behind its sixth-generation F/A-XX program.

During the Tailhook Symposium, three competitors for the UJTS were on display, including one previously unannounced industry team.

Textron Aviation Defense and Leonardo are teaming up to offer the M-346N, a modified version of the M-346 operating in several countries including Italy, Poland and Singapore. It is the latest iteration of the M-346 proposed for U.S. services after Leonardo alone offered it for the U.S. Air Force's T-X program. Textron says it is focusing on M-346N for the training role, while its similar Scorpion is a possible entrant for other light attack programs.

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AVIATION WEEK NETWORK

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MAINTENANCE CHECK

GTF Network Getting Busier

Extra removals "will obviously put additional pressure on the fleet."

Another blow to the Pratt & Whitney geared turbofan (GTF) engine program came on Sept. 11, when parent company RTX (formerly Raytheon Technologies) detailed the extent of its fleet management program, which accelerated engine removals for inspection. Leaders say they completed a "holistic fleet management plan" that should take care of parts riddled with powdered metal problems during manufacturing, which can lead to cracks.

The financial impact to the PW1100 program will be $6-7 billion. The cost breaks down into two buckets, with about 80% being customer support—from the time an engine is taken off wing until it's back on wing, plus operational disruption costs—and 20% for additional shop visits, mostly for labor and materials, says Neil Mitchill, RTX executive vice president and CFO.

This latest news identifies 600-700 engines needing removal from service by 2026, with most coming off wing between now and early 2024.

This group of engines will require three actions. First, high-pressure turbine (HPT) discs must be inspected between 2,800-3,800 cycles, depending on the engine's thrust rating. Many engines are reaching this cycle limitation, "which is the driver behind the majority of the incremental removals in 2023 and 2024," says Chris Calio, RTX president and COO. Second, part lives of compressor and turbine discs in this engine group will be reduced to 5,000-7,000 cycles. Lastly, high-pressure compressor (HPC) discs must be inspected.

These extra 600-700 removals "will obviously put additional pressure on the fleet" because the news comes at a time when about 10% of the fleet is already on the ground "because of high MRO turn times due to material constraints, which also results in longer times between engine removal and induction into our MRO shops," says Calio.

Obviously, adding shop visits to an MRO network already stretched thin will "create more congestion in our MRO network," he says, citing the OEM's estimate of 250-300 days of downtime for each of these engines.

"As a result, we are now forecasting an average of 350 aircraft on the ground for the GTF-powered A320 fleet from 2024 through 2026, with a peak of 600-650 aircraft on the ground in the first half of 2024," says Calio.

Because the affected parts were made before third-quarter 2021, when Pratt & Whitney improved the powder metal production process, company executives say it will be able to deliver new GTF engines to Airbus as planned, as well as planned spare engines. That puts the onus on the MRO side.

To alleviate this situation and provide engines able to meet their full certificated lives, the company plans to install new HPT and HPC discs when they come in for shop visits.

But to meet the MRO requirement, the key is "driving the industrial ramp needed for MRO output," says Calio.

In an industry still hindered by parts availability, that isn't going to be easy.

RTX's GTF fleet management overall requires about 3,000 engines to be inspected.

Expect at least one service bulletin to come out in the next 60 days.

—Lee Ann Shay

See Sean Broderick's in-depth article on the subject, pages MRO 18-19.

Access *InsideMRO* Online
Go to: AviationWeek.com/MRO

Highlights

Air France, Airbus Consider A350 Component Support Joint Venture

Air France and Airbus have entered into exclusive negotiations over a 50-50 Airbus A350 component maintenance services joint venture aimed at better meeting the growing long-term maintenance needs of the A350 as the worldwide fleet increases.

The agreement is set to cover supply chain management, repairs and the creation of a worldwide pool of aircraft components. The agreement would bring together the expertise of AFI KLM E&M and Airbus, the two parties said.

JEAN-BAPTISTE ACCARIEZ/AIRBUS

Aviation Week Network Fleet Discovery database shows Air France has 21 A350-900s, plus 20 A350-900s and four A350Fs on order.

Both partners would transfer aircraft components assets into a joint pool under the deal, which the parties hope to have operational by the first half of 2024, subject to approval from authorities.

Airbus and Air France noted that there are more than 1,000 A350 aircraft on order and 550 currently in service worldwide.

Boeing, Joramco Partner on P2F Conversions

Boeing has partnered with Jordanian MRO provider Joramco to establish a passenger-to-freighter conversion line at its main base in Amman.

The line will focus on Boeing 737-800 passenger-to-freighter (P2F) conversions at Joramco's facilities in the Jordanian capital. Joramco says it will be the first MRO supplier in the Middle East to support future Boeing freighter conversions of both domestic and foreign aircraft.

Once established, the operation will support 737-800BCF customers across the Middle East, Europe, North Africa and the Commonwealth of Independent States.

An industry source with knowledge of the deal told Aviation Week on Aug. 22 that a time frame for setting up the conversion line in Amman has not been announced but is expected in the near future. Potential annual throughput at the facility has also not been revealed, "but the target is to have it as a nose-to-tail conversion line," the source said.

Scandinavian Airlines Selects Magnetic Creative for Seat Modifications

Scandinavian Airlines has tapped Magnetic Group's design and manufacturing services subsidiary, Magnetic Creative, for an interior modifications project on its Embraer E190 aircraft.

Under the collaboration, Magnetic Creative has obtained a European Union Aviation Safety Agency supplemental type certificate to install an in-seat power supply system. The modification also includes replacing existing passenger seats with new Safran Z110 seats reconfigured in a single-class, 122-passenger, all-economy layout of passenger accommodation.

As part of the project, Magnetic's team manufactured parts in-house and delivered part kits for the final assembly. Magnetic says the Part 21J modification takes two weeks and physical installation takes approximately 18 days.

Contracts

Aeronautical Engineers was selected by the Democratic Republic of the Congo's **Serve Air** to convert its first Boeing 737-800 to freighter configuration. Commercial Jet is performing modifications in Dothan, Alabama, for redelivery in November.

AJW Group extended its power-by-the-hour deal with Pakistan-based carrier **Airblue** for five Airbus A320s and five A321s.

Boeing has won a $94 million **U.S. Defense Department** contract to modernize two Boeing 777-300s in Ardmore, near Oklahoma City, for the Indian government.

Joramco extended its Boeing 737 heavy maintenance deal with **Ryanair** for five years. It will operate up to six maintenance lines in Amman, Jordan.

Kellstrom Aerospace announced investments and partnerships for parting out CF6-80C2 and CFM56-7B/-5B engines and Boeing 737 and Airbus A321 airframes to expand its USM inventories.

SWISS-AS was chosen by **Swiss International Air Lines** and **Edelweiss Air** to provide its AMOSeTL electronic technical log solution for more than 100 aircraft.

TAT Limco won a $7.5 million contract to repair Boeing 747 thermal components for an unidentified European cargo airline.

TGIS Aviation selected **Rusada's** Envision fleet management software to support its new line of continuing airworthiness management organization services.

Knafaim Holdings and **Nayak Aviation Services** are forming a joint venture to provide line maintenance at Ben Gurion Airport in Tel Aviv. The agreement includes a future option to extend the partnership to other airports in Israel.

Contract Source: SpeedNews

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Boeing's Bad Bulletin

A poorly written Boeing bulletin mandated by regulators as part of a requirement to perform 777 structural inspections must be reworked, and operators must conduct more checks to ensure the inaccurate maintenance instructions did not introduce new risks on modified aircraft.

Boeing in October 2021 highlighted the original issue—potential cracks in certain structural parts near center fuel tanks—in a complex, 968-page "requirements bulletin" to operators. The bulletin, prompted by a report of a cracked front spar lower chord found on a 777-300ER undergoing an underwing longeron replacement, divided hundreds of 777s of all variants into nine groups, with multiple aircraft configurations in each group.

The manufacturer recommended inspections at various intervals depending on the aircraft model and configuration. The FAA mandated the checks in September 2022. Other regulators, including the European Union Aviation Safety Agency, adopted the FAA airworthiness directive (AD).

In late 2022, Boeing discovered problems with its 2021 bulletin. The most critical involved insufficient detail on removing and replacing fastener covers, or caps, located inside fuel tanks. The caps serve as protection against a lightning strike triggering a spark and a potential fuel tank explosion.

For some airplane groups, Boeing did not clearly explain the cap removal and replacement process. For others, the bulletin references a Boeing "standard overhaul practices manual" that specifies using caps that are too thin. Boeing's instructions also listed airplanes that did not need inspection—and omitted a few that did.

Boeing in late 2022 informed the FAA and affected customers about the bulletin errors. The company has yet to complete a full revision of the instructions due to the issue's complexity.

"The manufacturer submitted an initial report of errors in the requirements bulletin affecting cap sealing instructions in late 2022," the FAA says. "However, given the length and complexity of the requirements bulletin, detailed and complete documentation of these errors was not received until late July 2023."

The FAA is requiring new inspections on many 777s after Boeing published incorrect service information supporting a previous set of checks.

BOEING

The FAA decided to tackle the highest-risk problem—potential noncompliant fastener caps in center fuel tanks—with a new AD based on Boeing's preliminary revisions shared with operators. In the meantime, Boeing will complete a full revision of the original instructions.

The Aug. 31 AD lays out new instructions for removing and replacing fastener caps as part of the structural inspections, or adding them where they are needed but were not required by the September 2022 directive. The directive was immediately adopted as a rule, bypassing the draft view and public comment process afforded to less pressing requirements.

For aircraft that have already undergone the work mandated last year, the new AD gives operators either 90 or 180 days from its Sept. 15 effective date, depending on certain parameters, to verify fastener caps are compliant and make any needed modifications.

"Fastener cap seals interior to the airplane's fuel tanks are a critical lightning-protection feature," the FAA said. "This is particularly true for the center wing fuel tank, which typically contains flammable fuel vapors more frequently than the main wing fuel tanks. . . . If these seals are not replaced properly, and the associated fastener has poor electrical bonding to the airplane structure for any reason, the fastener may spark during a lightning strike and cause a fuel tank explosion." Noncompliant caps pose risks for aircraft regardless of whether they have flammability reduction or ignition mitigation systems installed, the agency noted, though the risk is greater for aircraft without them.

The directive also removes 777-200s without center fuel tanks from the applicability list and clarifies which 777 freighters (777Fs) need the work. Design changes implemented starting with line number 1743—a 777F delivered to China Cargo Airlines in July—addressed the original issues, the FAA says.

Boeing says it "fully supports" the AD, "which is consistent with guidance we have shared with operators previously."

—Sean Broderick

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AVIATION WEEK NETWORK

ARSA UPDATE

International Understanding

AN ARSA MEMBER RECENTLY SOUGHT ASSISTANCE in providing clarity to international customers about approvals issued by designated engineering representatives (DER). Apparently, these non-American businesses doubted that DER-approved repairs held the same authority as an approval issued by the FAA.

Promoting that understanding requires confirming some key international aviation concepts. Global regulatory responsibility is assigned by the International Civil Aviation Organization according to the Chicago Convention, which gives authority to oversee maintenance to the civil aviation authority under which the aircraft is registered, i.e., the state of registry. Each aircraft may only hold one registration at a time—there are no "dual citizenships" for aviation equipment.

Some countries have laws allowing the civil aviation authority to recognize another state's aviation safety regulations without any additional action required. Other states share oversight responsibility through bilateral aviation safety agreements. The technical and implementation procedures associated with those agreements establish the parameters for the "home country" to act as an agent for a foreign authority. Under these arrangements, as in the bilateral agreement between the U.S. and European Union, an entity must meet the requirements of the geographic civil aviation authority, plus certain special conditions, to maintain or alter a foreign-registered aircraft.

Based on this framework, the ARSA member's request is contingent on support being needed for a U.S.-registered aircraft or an aircraft registered in a state for which FAA approval would be acceptable. With that understanding, we can turn to the American aviation safety regulations in Title 14 of the Code of Federal Regulations.

Under U.S. rules, when a repair or restoration action results in or will result in a major repair, the technical data supporting the action must be approved by the FAA. The FAA has the authority to delegate a finding of compliance to another "person," such as an individual engineer or a company. The FAA administers its delegations under 14 CFR Part 183 and internal directives, such as Orders 8100.8, 8100.15 and 8110.37.

Order 8110.37 is "a handbook of procedures, technical guidelines, limitations of authority, and tools and resources for [DERs]. It was written for all DERs and the FAA staff who manage them." Delegations to engineers and to engineering companies are based upon knowledge, experience, continued education and other information required by the agency to establish the authority delegated.

With respect to actions that will result in major repairs, Order 8110.37 Revision F makes it clear that an approval issued by a duly authorized DER is an FAA approval:

> *4. DER Authorities.*
>
> *a. DER approval. It is the applicant's responsibility to show that engineering data will demonstrate their design complies with applicable airworthiness requirements. When a DER finds the engineering data shows compliance to those requirements, it is referred to as a DER approval. * * * For repairs and alterations, a specially delegated DER can approve some or all of the technical data intended to be used for a major repair or major alteration.*
>
> *b. DERs may approve or recommend approval of engineering technical data within the limits of their authority by means of FAA Form 8110-3 where delegated. (Revision F, page 2-2, August 31, 2017.)*

Hopefully, spreading this information worldwide will help the industry and other civil aviation authorities and customers understand that DER approval is FAA approval.

While we spread that word, it is worth noting that the message also must be made clear within the borders of the U.S. ARSA and some of its key members have been working for years to sort out resistance from the Defense Department against accepting DER-approved repairs (and PMA parts) for use on fleets of commercial derivative aircraft (CDA).

The FAA, through its civil aviation oversight, has already determined whether these repairs are compliant and fit for use on the aircraft on which CDA are based. Still, the Defense Department requires previously approved parts and repairs to go through the cumbersome Source Approval Request (SAR) process, wasting government resources and taxpayers' money while ignoring the civil aviation sector's outstanding safety and reliability record. Since SARs are rarely granted, the Defense Department loses the benefit of the cost savings associated with industry-developed technology.

Educating customers and governments will smooth business transactions, save money and incentivize the industry's inventiveness.

Sarah MacLeod is a managing member of Obadal, Filler, MacLeod & Klein and a founder and executive director of the Aeronautical Repair Station Association. She has advocated for individuals and companies on international aviation safety law, policy and compliance issues for more than 30 years.

Asia-Pacific Ascends

Single-aisle MRO spending in the region is set to grow more than 50%

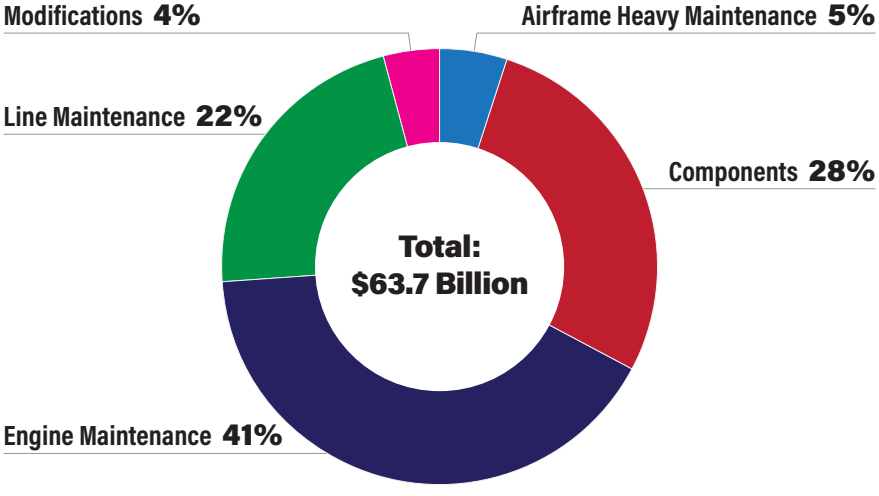
Christian Albertson

Aviation Week's 2023 Commercial Aviation Fleet and MRO Forecast projects that the Asia-Pacific region will account for 13% of the global narrowbody MRO market over the next decade, with more than 16,000 MRO events anticipated by 2032 and a healthy 8.8% compound annual growth rate.

The Asia-Pacific narrowbody fleet is forecast to climb to more than 5,000 active aircraft in 2032 from just over 2,400 in 2023—a 113% increase. This fleet expansion and commensurate utilization are projected to drive MRO spending up more than 61% by 2032.

The Airbus A320 will capture the of largest share of narrowbody MRO expenditures with 29.4% of the total market, according to the forecast, followed by the Boeing 737-800 with 25.4% and the Airbus A321neo with 11.1%.

Asia-Pacific Narrowbody MRO Demand



Source: Aviation Week Network 2023 Commercial Aviation Fleet & MRO Forecast

Malaysia Airlines

Mohd Nadziruddin Mohd Basri, CEO of Aviation Services at Malaysia Aviation Group and Eke Nazri Rahim, chief operating officer at MAB Engineering, discuss Malaysia Airlines' focus on diversifying capabilities and leveraging digitalization to position itself as a competitive MRO provider in the Asia-Pacific market.

Mohd Nadziruddin Mohd Basri, CEO of Aviation Services for Malaysia Aviation Group

Eke Nazri Rahim, COO of MAB Engineering

LUFTHANSA

What are the key elements of Malaysia Airlines' maintenance strategy?

Nadzir: A key part of our strategy is to ensure that our service enables operational excellence. We are looking at diversifying our competencies and our capabilities. We are not just looking at airframe maintenance but also at component repairs. Additionally, we are looking at developing people. We have developed comprehensive in-house training programs to ensure that we have a continuous pipeline of skilled workers. It is very important to ensure that we have a strong talent pipeline to support our growth strategy.

Eke: During the pandemic, we capitalized on digitalization and technologies to make us more efficient. But there still is the challenge of sustainability: How do we minimize or eliminate waste, and how do we repurpose things? We are also thinking about our carbon footprint. For instance, the carbon footprint is bigger if we send components to the U.S. for repair. So if we want to perform those repairs in-house, we need to develop new capabilities to reduce our carbon footprint.

What percentage of Malaysia Airlines maintenance is carried out by MAB Engineering and how much is outsourced?

Eke: MAB Engineering performs all of the base maintenance and line maintenance activities for Malaysia Airlines. We also have component repair shops. The engine maintenance work is outsourced.

How is Malaysia Airlines leveraging digitalization to enhance its aircraft maintenance operations?

Eke: In the post-pandemic landscape, digitalization is the key. One of our beliefs is that digitalization is master of the universe. We have one MRO enterprise resource planning system that integrates everything. We have a "big data" warehouse—Skywise—from which we build a workflow. Additionally, we also have Power BI and some machine learning to provide us with the crystal ball to really embrace predictive maintenance.

One of the areas that we are embarking on is paperless maintenance. Currently we are working closely with the regulators, and we are on the final lap of getting an approval from the Civil Aviation Authority of Malaysia. We are the first organization in Malaysia that is implementing a whole-paperless maintenance process.

Our dream is that instead of pulling the information from staff, we push the information [they need to them], including relevant manuals, to improve productivity. We are exploring mobility and have partnered with an unnamed service partner to co-develop a solution. If everything goes well, this could go live in 2024.

Are there any updates on the smart hangar concept?

Eke: We would like to go into the concept of human-led operations and digital record keeping. Furthermore, we would like to develop 3D printing, which could help offset supply chain problems. The challenge is to get regulatory approval. It could be helpful to partner with a Part 21 design house, and we would need POA—production overhaul approval. We would like to engage with a provider that is able to supply us the skills and technical knowledge to develop this. We could also partner with any university to help us with this.

In May, MAB Engineering was appointed as an authorized repair center by Spirit AeroSystems for nacelle and flight control surfaces repair.

What benefits does MAB Engineering anticipate with this appointment?

Eke: Our recent partnership with Spirit AeroSystems will help us grow. Today we are only rated on level two repairs, but with this partnership,

Airline Fact File

HEADQUARTERS: Sepang, Malaysia

FLEET: The airline operates a fleet of 67 aircraft, comprising six Airbus A350s, 20 A330s and 41 Boeing 737s. Malaysia has orders in place for a total of 40 aircraft, consisting of five ATR 72-600s, 10 A330s and 25 737s. Deliveries for the 737s are scheduled to start in third-quarter 2023, after several delays.

IN-HOUSE CAPABILITIES: With regulatory approval from more than 12 authorities around the world, MAB Engineering, the airline's engineering and maintenance division, provides line and base maintenance services for several Airbus, Boeing, ATR and De Havilland Canada aircraft. The company also provides component repair (C-rating) services for safety equipment, wheels and brakes, avionic instruments, aircraft propellers, engines and APUs. Specialized services include fleet technical management, borescope inspections, European Union Aviation Safety Agency Part-21 DOA, and interior and exterior cleaning.

HANGARS AND LINE STATIONS: MAB Engineering has four hangar facilities located at its home base in Sepang and Subang, Malaysia, with a total of 10 aircraft bays for widebody and narrowbody aircraft. The company also offers line maintenance services across 17 stations throughout Malaysia.

we will be able to reach level three. Spirit AeroSystems brings technical expertise and tooling to help us acquire level three. We are appointed as an authorized repair station and with that, there are certain baseloads that will come to us. Hence, it brings us greater market opportunity as well as greater revenue.

Spirit AeroSystems is a giant in terms of repair capabilities. If you look in the region, there are a lot of Boeing 737 and Airbus A380 aircraft operators. Today, with this partnership, we can develop Boeing 737 authorized repairs that we can bring to the market. We have certain numbers of repairs that are coming to our center.

How does Malaysia Airlines address supply chain-related challenges in its aircraft maintenance operations?

Eke: It is difficult to get the parts because logistics are a lot higher-priced due to inflation, and it is getting more expensive to get the parts. The supply chain is a real challenge. But we are living in a world where information is the key. We have Skywise as our big data warehouse. So there are a lot of insights, and we can turn this information into demand planning. With this information, we can communicate effectively with our suppliers. Additionally, for us to be correct about lead times and turnaround times, we have changed our provisioning model. Also, we have a pooling arrangement not only with our providers but also with certain OEMs to ensure that we have the right parts at the right time and in the right place.

With ongoing labor shortages, what measures have been taken to ensure a pipeline of skilled technicians?

Nadzir: We have established training programs with various colleges and approved training organizations. We have also developed an accelerated apprenticeship program, and those who already have their basic license can also join us. We have our own training school and have collaborated with the department of skill development. This partnership enables us to have a program that prepares our graduates to explore other areas of the industry if they wish. The program gives us access to government funding. That means the students can apply for scholarships, and it helps to reduce their financial burden.

We are also continuously looking at how to retain our staff. Therefore, we do periodic salary reviews and continuous benchmarking with what the market is offering. We always try to ensure that we are among the best-salary employers in Malaysia. We try to make a good environment for our employees. We emphasize safety and the positive work culture to ensure that there is a good work-life balance.

How does Malaysia Airlines anticipate the market to evolve in the coming years? How has the company positioned itself to meet the growing MRO demand in the region?

Nadzir: According to an International Air Transport Association report, approximately 40,000 aircraft will be entering into service over the next 15-20 years. We are actively monitoring market developments for both the demand and supply side. We are making sure that we have enough resources to accommodate the growing demand. One of the things we are looking at is growing our hangar capacity. We are looking at both organic growth options and if there is an opportunity, then potentially an acquisition. We are considering developing partnerships in the region and building more component repair shops. We strongly believe that the demand will be there, and we need to be ready for it.

Eke: The Asia-Pacific is one of the fastest-growing markets, and we are well-positioned in this region. There are a lot of opportunities for us. The post-pandemic landscape has changed, and we need to innovate in terms of new capabilities and services. Today we are concentrating on airframe-related services. For us to be competitive, we need to master the three key metrics: time, cost and quality. That is why we need to expand on our higher-value-added services.

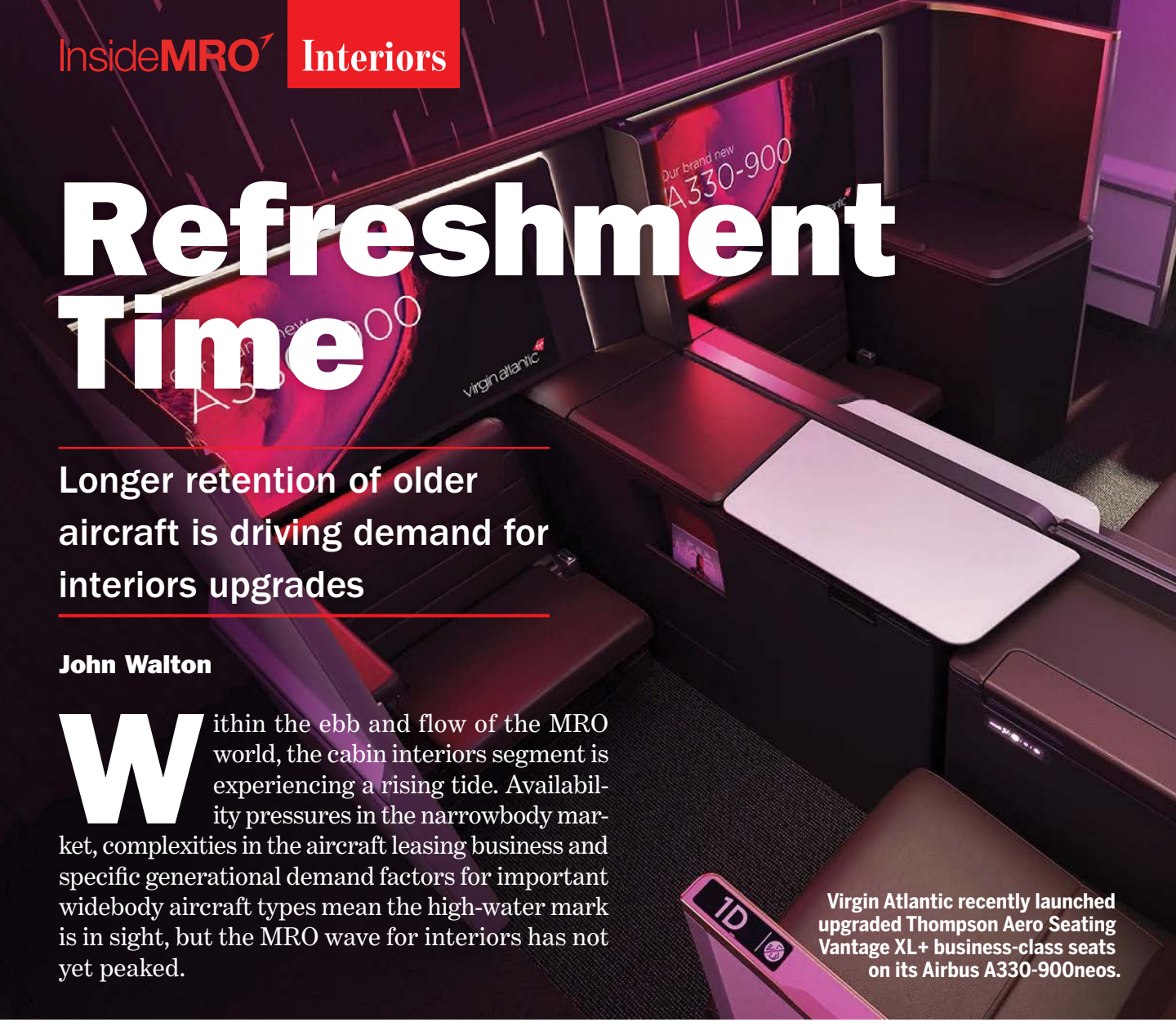
Thus, we are looking into the components segment. Along with becoming competitive in terms of our product offerings, there is a need to strengthen our operational key performance indicators. That is how we will be able to differentiate ourselves—being an efficient and reliable service provider in the region. For us, the most important thing is customer intimacy and how we can build the customer relationship using digital technologies.

Refreshment Time

Longer retention of older aircraft is driving demand for interiors upgrades

John Walton

Within the ebb and flow of the MRO world, the cabin interiors segment is experiencing a rising tide. Availability pressures in the narrowbody market, complexities in the aircraft leasing business and specific generational demand factors for important widebody aircraft types mean the high-water mark is in sight, but the MRO wave for interiors has not yet peaked.



Virgin Atlantic recently launched upgraded Thompson Aero Seating Vantage XL+ business-class seats on its Airbus A330-900neos.

At a macro level, narrowbody availability pressures—related to the Boeing 737 MAX grounding, delays in certifying the MAX 7 and MAX 10, production delays for the longer-range versions of the Airbus A321neo and the A320neo family's ongoing engine production and reliability woes—are driving retention of older aircraft.

"As we look to the long term, Boeing sees a demand for over 42,500 new jet deliveries over the next 20 years, with 76% of those being for single-aisle airplanes," says Chris Shindle, Boeing's senior leader for cabin, features and experiential marketing. "We have seen airlines hold on to airplanes longer since some of the usual paths for fleet exit weren't as viable during the pandemic."

The consequence, Shindle says, is that "near-term demand in the industry has outpaced supply, with both Boeing and Airbus affected by supply chain issues. In addition to taking deliveries of new 737 MAXs and A320neos, operators have retained their older, prior-generation airplanes, like 737NGs and A320ceos, to meet this strong demand. Many carriers have continued to invest in their older products with the intent of keeping them in their fleets longer than originally planned."

This situation varies somewhat depending on regional factors and can have knock-on effects on other regions. In the U.S., for example, fleets of 737NGs and A320ceos that were expected to be replaced by newer MAX and Neo aircraft have been retained, which means that the older equipment that would have cascaded down for sale or lease in emerging and developing markets has not done so.

IMPACTS TO LEASING AND ACMI MARKETS

Consequential effects are also being felt within wet leasing and ACMI (aircraft, crew, maintenance and insurance) operations, explains Denis Brailsford, head of asset management at appraiser IBA.

"Where there is a lack of aircraft, ACMI leases have traditionally been used," Brailsford says. "This was common in the charter holiday market, with ACMI operators filling some of the capacity. With the lack of supply, we are seeing ACMI operators being used more extensively by full-service carriers, with Swiss and SAS heavily reliant on ACMI suppliers." Airlines struggling with new-engine reliability issues are also turning to the ACMI market, he says.

THOMPSON AERO SEATING

With airlines retaining older aircraft longer, this "is driving more comprehensive reconfiguration activity," says Doug Rasmussen, HAECO Cabin Solutions' president and group director. He says "airlines that postponed new aircraft orders are the most impacted by this trend."

HAECO is seeing more demand for interior reconfigurations for Airbus A320s and Boeing 737s narrowbodies as well as A330 and 777 widebodies. "The trend started in North America, Europe and the Middle East but has now started to extend to the Asia-Pacific," he adds.

The reconfiguration—and in some cases retention—of smaller widebodies like the Boeing 767 and Airbus A330 is linked to the narrowbody supply shortage. Some airlines that had expected to operate the A321XLR version of the A320neo family are left to either postpone their plans or run flights with their smaller widebodies. While many of these have lower financing costs, there are substantial impacts on markets elsewhere.

To some extent, pressures from longer-term ACMI contracts in certain markets have been reduced due to the overflight bans of Russia following that country's 2022 full-scale invasion of Ukraine. For example, since the ban has structurally altered Finnair's polar route business model, the airline has been doing a notable amount of ACMI flying for other carriers, including British Airways.

To be sure, ACMI flying creates inconsistencies between the onboard product advertised and the product passengers actually see. While the passenger experience differences between services on a British Airways A320 and one operated by Titan Airways, Avion Express or Finnair may be minimal, they exist.

For example, IBA's Brailsford highlights that "connectivity and in-seat power is becoming the norm and as a result can be a differentiator between rival airlines."

Given these concerns, light-touch refits adding these options are becoming increasingly attractive.

BOEING 787 UPGRADE CHALLENGES

Interior modifications and upgrades of early 787 deliveries are peaking, with substantial pressure on MRO providers as airlines seek to update their interiors. From the passenger experience perspective, early-build 787s in particular suffered from numerous program delays. These include the three-year delay from the initial intended entry into service in 2008, four years after program launch in 2004, as well as the grounding of the aircraft in 2013 for battery issues, compounded by the Rolls-Royce Trent engine problems that prevented some airlines from using their fleets a few years later. The result of these delays, in cabin terms, was that early-build 787s configured in the early to mid-2000s launched only in the mid-2010s, and in some cases without the opportunity to upgrade their seats.

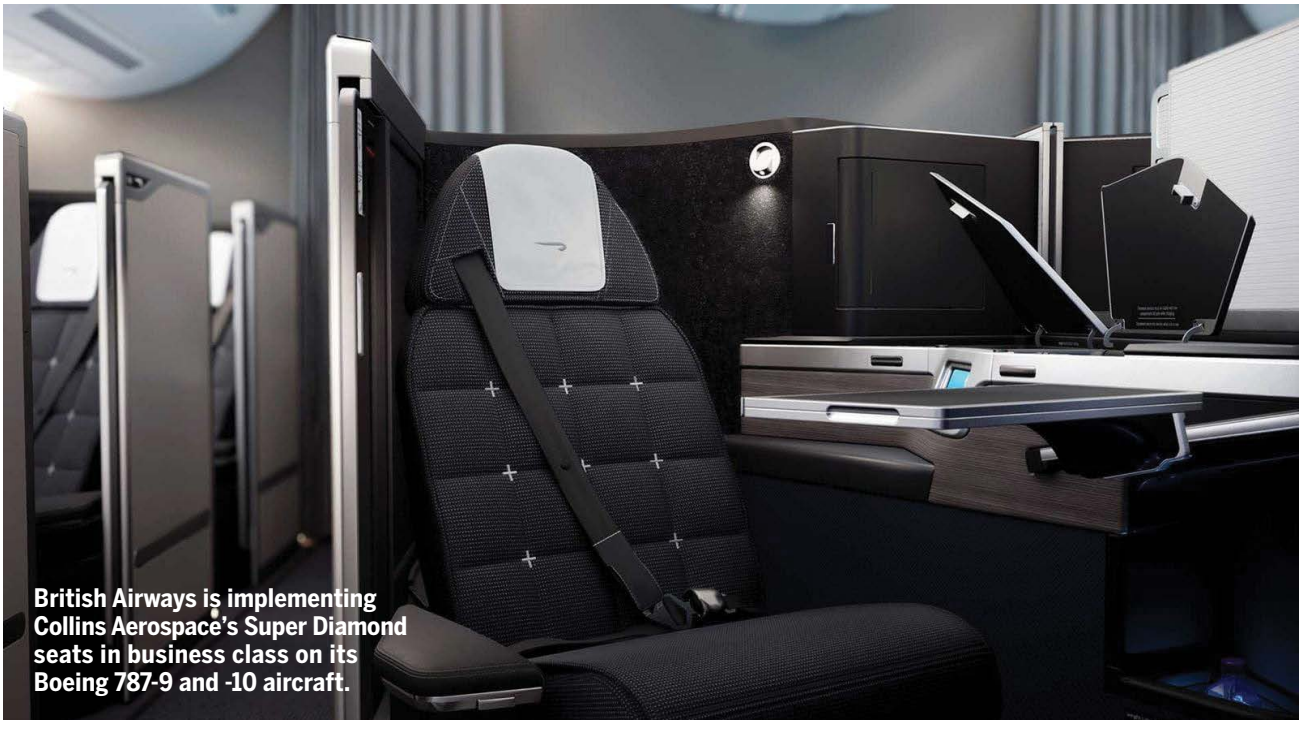
The consequences were particularly acute in business class, where expectations accelerated quickly from the mid-2000s standard of fully flat beds without direct aisle access to the mid-2010s standards of direct aisle access for every passenger.

Brailsford highlights what he calls the "vast difference" between Virgin Atlantic's Upper Class Suite direct-aisle access product on its A330-300 fleet, which was designed in the early 2000s, and the Thompson Aero Seating Vantage XL+ seat recently launched on its A330-900neo.

"The same can be said for British Airways and its business-class products on the 787-9 and 787-10," Brailsford says. The aircraft are being line-fit with the Collins Aerospace Super Diamond seats in an outward-facing herringbone pattern with direct aisle access, while the airline's earlier 787s are still flying with yin-yang forward-backward seats manufactured by Collins in the mid-2000s.

Airlines experience pressures that constrain cabin upgrades, Brailsford explains, because they "are a costly investment for what may be a short period of time. Most aircraft leases run for a 12-year period, with cabins lasting around 8-10 years. Therefore, it is difficult for operators to justify major upgrades without extending lease terms." He adds that if operators extend lease terms, the airlines not flying the latest-technology aircraft face impacts to their image—and so do lessors.

"Newer-style cabins are more remarketable and therefore, if in the correct configuration, can improve future lease rentals," Brailsford says. "However, this is highly subjective,



British Airways is implementing Collins Aerospace's Super Diamond seats in business class on its Boeing 787-9 and -10 aircraft.

COLLINS AEROSPACE

as some operators will want their own cabin installed to match their current operations, meaning these changes may not be accepted."

Some airlines may own some or all of the intellectual property within their business- and first-class seats, while no-compete clauses are relatively common within launch customer contracts for business-class products, which means that reconfiguration to the onward operator's standard business class—or a more generic product—is required.

More widely, "we have noticed a growing interest in major reconfiguration programs for older 787s," HAECO's Rasmussen says. "Given the numerous new technologies that

Lufthansa and other Airbus A380 operators are bringing those widebodies back into service, creating pressure for cabin retrofits.

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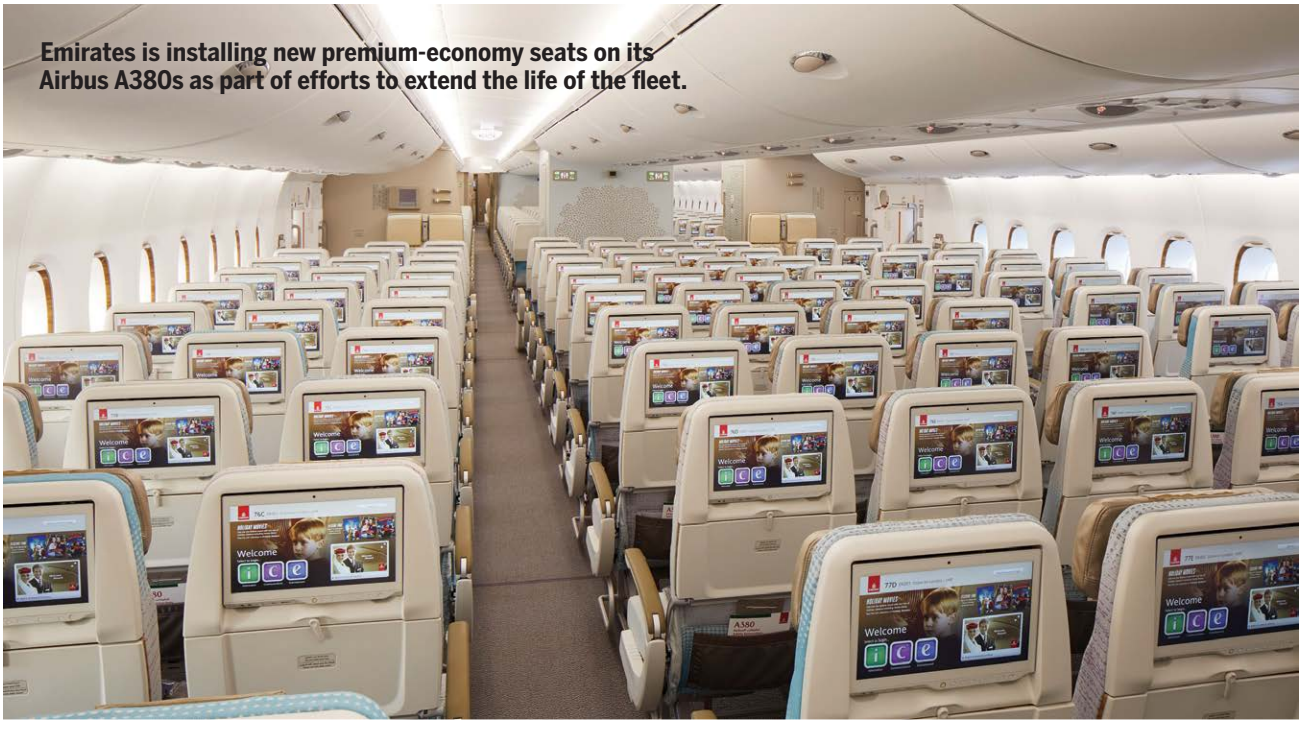


Emirates is installing new premium-economy seats on its Airbus A380s as part of efforts to extend the life of the fleet.

EMIRATES

were introduced in this airframe, these programs will necessitate close collaboration with the original aircraft OEM."

Kate Schaefer, Boeing's vice president for commercial modifications, engineering and specialty products, says: "The strong demand we are seeing for 787 interior modifications reflects a combination of expected cabin upgrades and modifications related to ongoing market recovery and demand. The 787 customer base is diverse, and interior reconfiguration needs vary by customer."

This peak of interest will inherently have knock-on effects for the MRO sector, with hangar space, experienced staff and 787-specific equipment all in high demand. Outside of Boeing's immediate orbit, the airframer faces some criticism around a closed-system design that adds complications.

"Upgrading the 787 aircraft is difficult by design," explains Pierre Michard, director for sales and programs at lighting and safety systems supplier STG Aerospace. "Most system changes require inputs from Boeing, which keeps the market very close. We have had multiple requests from 787 operators, but at the moment we cannot satisfy that demand easily."

Gary Weissel, managing officer at Tronos Aviation Consulting, concurs, highlighting that "the biggest problem here is that for upgrades you're basically forced to go back through Boeing for the engineering and certification due to the data access issue. It is very expensive and limits competition in the market for modifications."

Adding further complexity, OEMs are expanding their own in-house services businesses and are taking an increasingly dim view of industry consolidation and the influence now wielded by larger suppliers such as RTX and Safran.

A related issue, Weissel says, is workload volumes for modifications. "When more of the fleet requires cabin upgrades and Boeing is your only source for engineering and certification, will Boeing have the capacity to handle the workloads? Thus far, the OEMs have been reluctant to license significant data use to third-party firms to engineer and certify major interior reconfiguration work," he says.

Schaefer acknowledges that "as the commercial market continues to recover and grow, capacity to support demand for interior modifications remains a challenge not just for the 787, but industry-wide. We are taking comprehensive actions to strengthen our capabilities to ensure we have sufficient capacity to meet the needs of our customers."

AIRBUS A380 LIFESPAN EXTENSION

Across the Atlantic, a similar yet highly nuanced demand spike is driven by the A380's return to service and lifespan extension work. Airlines including Lufthansa and Etihad Airways are bringing their superjumbos back to meet higher-than-expected demand, creating pressure on the limited capacity of facilities, staff and tooling for A380 retrofits and overhauls.

"It's a small fleet of aircraft that will be upgraded, so no one else wants to make such a huge investment to work on the A380 for small numbers of aircraft," Weissel says. "In the time and effort needed to complete a single A380 upgrade, including taking up valuable hangar slots, an MRO or integrator can do multiple other narrow- and widebody programs."

The double-decker elephant in the proverbial hangar is Emirates' intention to fly its A380 fleet as long as possible. It is well underway with installing new premium-economy seats and performing relatively light upgrades to the rest of its fleet. While Emirates has more than 100 A380s, it has a limited number of configuration subfleets, limiting the number of modifications—and thus the need for investment in staff, skills and facilities—while still requiring a large amount of hangar space.

Fundamentally, Weissel explains, "Airbus is doing whatever it can to keep that platform flying. With no one else jumping in to do the modifications, Airbus must step in to do it."

Tim McVea, Airbus' deputy head of marketing for upgrades and sustainability services, says: "It's important to us that operators can adapt and enhance their Airbus aircraft as their needs change and passenger expectations evolve." Airbus offers service bulletins, supplemental type certificates and support throughout projects. "We are always sending Airbus teams to the chosen MRO to support complex project embodiments," he says.

These teams generally comprise engineers responsible for creating service bulletins, process experts and specialists with type-specific expertise. Operating in many ways as an on-site advisory service, they can answer questions from the operator, owner and MRO around processes and service bulletins, as well as address any issues around documentation and kits that the OEM supplies.

Airbus has "many, many initiatives to work with MROs for all types of projects and considers these organizations a crucial part of the modification ecosystem," says McVea.

ONGOING CHALLENGES

Numerous sub-macro-level challenges, often tightly interwoven, remain at the intersection between fleet upgrades and interiors MRO.

Information flows and data availability, particularly for airframes built since 2000, are a key blocker, explains Tronos' Weissel, because airframers are keen both to expand their modifications and to upgrade their markets. "They have somewhat of a monopoly because they control all the aircraft design data and have been extremely guarded with that data, so if you need to modify your aircraft, you almost have no choice but to go back to the OEM, as they're the only ones that can do the engineering and certification for changes, since no one else has access to any of that data," he says.

Ongoing issues around the supply chain—including Tier 1 suppliers and fundamental component parts, particularly where newer materials like specialized alloys or composites are involved—are also roadblocks.

"Although the supply chain challenges have started to diminish, stability in this area remains essential to guarantee the dependable delivery of interior products and the successful execution of cabin reconfiguration programs," says HAECO's Rasmussen.

Segment-specific issues also remain. "Qualification requirements from one integrator to the next, even on the same platform, are still different," says STG's Michard. "We find the business jet market clearer on that side, as their qualification requirements tend to be DO-160G only. My favorite headache remains data buses. We have Ethernet, CANbus, RS485, CIDS, CSS, GCMS and a few other different flavors. Having a more universal interface would be helpful to speed up technology transfer from one part of the market to another—business jet to commercial, for example," he adds.

Problematic Powder

CHEN XIAO/AIRBUS CHINA

Pratt leans on MRO network to offset PW1100G problems

Sean Broderick Washington

Pratt & Whitney will lean on its growing but saturated engine overhaul network to mitigate the ramifications from years' worth of production-quality mistakes requiring hundreds of PW1100G engines to be pulled from service, and could see 650 Airbus A320neos grounded early next year.

A "fleet management plan" unveiled by Pratt parent RTX, formerly Raytheon Technologies, on Sept. 11 laid out the painful reality for affected A320neo operators. Pratt, with the backing of regulatory mandates, will pull 600-700 engines in the next two years for accelerated shop visits in addition to 500 or so already scheduled for overhauls. Most of the unplanned removals will come by "early 2024," said RTX President and Chief Operating Officer Chris Calio. This includes 137 that must be pulled by the end of September.

The engines will be torn down and high-pressure turbine (HPT) stage 1 and stage 2 disks, or hubs, will be inspected for possible cracks. Pratt is projecting an eye-watering 250-300 days to turn each engine around—a function of an overhaul network already overbooked with PW1000G-series engines that need restorative shop visits to offset long-running durability issues.

Add it up and A320neo operators could see a peak of 650 aircraft on the ground awaiting at least one airworthy engine at the peak of the shop visits, projected to be sometime in the first half of 2024. Pratt is expecting the grounded aircraft count to average 350 aircraft through 2026.

"The impacts to our customers vary," Calio said. "Certain operators are impacted more than others. We're working operator by operator on mitigation and support plans."

The flagged engines are part of a subset of 3,000 made from mid-2015 to mid-2021 that may contain high-pressure turbine (HPT) or high-pressure compressor (HPC) disks containing contaminated powder metal (PM), a common ingredient in engine parts.

Pratt's inspection plan covers 3,000 engines, with about 700 needing shop visits before routine overhauls would normally be due.

Microscopic bits in PM—if they are not detected and wind up incorporated into parts—can lead to cracks. In the case of these parts, Pratt's traditional inspection methods used during production did not detect the contaminants.

"We somehow or other introduced a contaminant into the powder," RTX CEO Gregory Hayes says. "But it wasn't a contaminant that we'd ever seen before."

The problem was discovered during the investigation of a March 2020

engine failure on a Vietnam Airlines Airbus A320ceo. In that case, a contaminated IAE V2500 HPT stage 1 disk failed.

"We made improvements to the powder metal production process, and a new angle ultrasonic inspection was deployed," Calio said. This replaced a long-used linear inspection.

Pratt's analysis flagged a small batch of V2500 parts with contaminated PM. It later broadened its root-cause analysis to look at parts on other engines made during the same time period, which Pratt narrowed down to late 2015 through mid-2021.

That turned up more affected parts, including some on current-generation PW1000G-family engines.

Pratt developed fleet plans, and regulators mandated them. A 2022 FAA airworthiness directive flagged 189 engines on U.S.-registered aircraft and mandated disk inspections during routine, service life-driven shop visits that happen every 7-10 years. It was based on a Pratt service bulletin that lists nearly 2,100 affected PW1100G-series disk serial numbers, which appear to be the entire population of A320neo engines that have contaminated PM.

But Pratt's probe of a December 2022 engine shutdown on a PW1100G-powered A320neo prompted a broader reexamination of the PM problem.

"Investigation of that event caused us to increase our assumptions on the likelihood of a GTF powder metal part having a crack at the time of manufacturing," Calio said.

A closer look at inspection results coming in led to more changes.

"We found cracks that were larger than we had anticipated, which required us to increase our assumption on the rate at which a crack would grow," Calio said.

On an earnings call in July, RTX revealed the anticipated ramifications of Pratt's findings. About 200 engines need accelerated inspections by the end of September 2023, and perhaps 1,000 more will need checks by September 2024, the company said.

The updated fleet management plan cuts the overall number of early removals but also compresses the window in which they will take place.

"Since our call in July, we've now developed a holistic fleet management plan that ensures the continued safe operation of the fleet while balancing the impact to our customers," Calio said.

Pratt's current assumptions call for inspections every 2,800-3,800 cycles, depending on engine thrust ratings. The parts under scrutiny have a new, reduced life limit of 5,000-7,000 cycles.

Aviation Week Tracked Aircraft Utilization data shows the busiest A320neos fly 200-250 cycles per month. At that rate, the highest-thrust engines would need inspections roughly every year. With turnaround times approaching 10 months, affected operators will be clamoring for permanent fixes.

An Aviation Week analysis shows more than 900 Pratt-powered A320neo-family aircraft were rolled out in the time frame that matches when the suspect engines were made and delivered to Airbus. India's IndiGo operates the most by far, with 135. Five other carriers—Air China, Go First, Volaris, Spirit Airlines and Lufthansa—each have at least 40.

Pratt's goal is to replace as many turbine and compressor disks as possible during the overhauls with parts made since the third quarter of 2021, when the PM issue was resolved in production. But it will not be able to make enough disks to send each engine home with new, problem-free parts, leaving some operators exposed to periodic inspections.

The OEM has no plans to divert spare engines from its pool of planned deliveries to Airbus, which is ramping up A320neo production, Calio said. If more spare engines become available, it will be from an overall boost in PW1100G output, he suggested.

Instead, the MRO network's expansion will become a central focus.

"The best thing that we can do to help operators is, yes, continue to produce the spare engines that are in the plan and try to ramp that to the extent that we can, but [also] driving the industrial ramp needed for MRO output," Calio said.

Pratt was adding PW1000 overhaul capacity to help address the engine family's durability issues before the severity of the HPT disk problem became clear. It said in April that it had 12 shops globally that could handle PW1000 work and planned to add seven more by 2025.

"We've had some part constraints and shortages and labor in our MRO network, which has impacted our ability to output MRO to the levels that we and our customers want, which is why we're adding more capacity to that MRO network," Calio said on an April earnings call.

Timelines for opening these new shops are being accelerated where possible to help offset the PM issue's ramifications.

"We are completely focused on ramping up production on HPT and compressor disks driving capacity throughout our MRO network, and reducing the turnaround time in our shops so we can get these assets back to our customers as quickly as possible," Calio said.

The fleet management program will cost Pratt and its PW1000G program's partners $6 billion-$7 billion, RTX estimates. The charges, which will cover labor for inspection and customer compensation, include $3 billion-$3.5 billion for RTX, which plans to take a $3 billion charge this quarter to help reflect the costs. The rest will be shared by the PW1000G's risk-sharing partners.

Customer compensation will account for 80% of the costs, with the rest covering shop-visit labor and materials.

Still to be determined is how the PW1500G-powered Airbus A220 and PW1900G-powered Embraer E-Jet E2 fleets will be affected. Pratt is still analyzing the PM risk and determining potential risk-mitigation strategies. Executives are confident that any disruption to the affected A220 and E2 fleets will be minimal compared to what A320neo operators will face, however.

"We'll have [a plan] in place for the PW1500 and PW1900 soon," Hayes said.

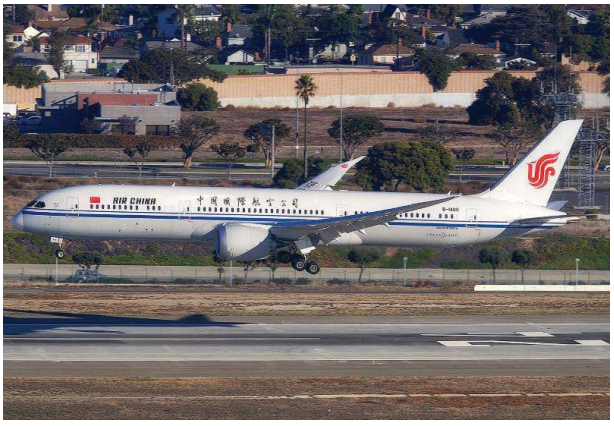
The Aviation Week Network Fleet Discovery database shows about 260 PW1500G-powered A220s and PW1900-powered E2s were built when PM-contaminated disks were produced, along with 450 V2500-powered A320ceo-family aircraft. Executives are confident that after multiple revisions, they now have an effective plan for fixing the PW1100G fleet, and are confident the V2500 inspection regimen is good enough to detect any issues.

Pratt and RTX declined to answer multiple Aviation Week queries.

Groundbreaking

Rolls-Royce, Air China break ground on new engine MRO shop

Chen Chuanren Singapore



JOEPRIESAVIATION.NET

Air China and Rolls-Royce expect their BAESL joint venture to reach full capacity by the mid-2030s.

The Beijing Aero Engine Services Co. Ltd. facility, a 50:50 joint venture established by Rolls-Royce and Air China, is one step closer to being built as the two companies announced Aug. 31 that they have broken ground on the new building.

The MRO facility is being built next to Beijing Capital Airport within the Beijing Capital International Airport Economic Zone. The Beijing Aero Engine Services Co. Ltd. (BAESL) facility will be 80,000 m² (861,000 ft.²) in size and will begin operations in 2026. Estimated to hit full capacity by mid-2030, the facility will support up to 250 shop visits per year, providing MRO services for Trent 700, Trent XWB-84, and Trent 1000 engines.

The Aviation Week Network Fleet Discovery database indicates there are 69 Airbus A350s, 192 A330s and 12 Boeing 787s currently in service powered by these engines in China.

The two companies announced their plans to set up BAESL in September 2022. The groundbreaking ceremony was timed to coincide with UK Foreign Secretary James Cleverly's visit to Beijing to meet his Chinese counterpart.

BAESL is the first Rolls-Royce MRO joint venture in mainland China and the company's fourth globally. The other joint venture sites are HAESL in Hong Kong, SAESL in Singapore, and N3 in Germany.

Doubling Up for Safran

Safran to double Leap engine blade production in China

Chen Chuanren Singapore

SAFRAN

Safran held an opening ceremony for the new facility in Guiyang.

Safran Aircraft Engines says it will double Leap engine blade production in China as it officially opens a new factory at its Guiyang facility.

The French manufacturer says CFM International, Safran's joint venture with GE Aerospace, is preparing for a global manufacturing ramp-up of the high-bypass turbofan engines. Safran welcomed the new capabilities into operation at a ceremony on Sept. 1 at the Shawen Park facility.

In a statement, Safran says that it has invested $30 million into the new facility, which features machinery "dedicated to the manufacturing (lost-wax casting) of the low-pressure turbine blades, vanes and seals for CFM56 and Leap engines."

The existing Guiyang facility, where Safran has been making engines since 2006, reported revenues of $23 million in 2022, the company says. The engine-maker expects the site's turnover to hit $40 million following the opening of the second phase of the new plant.

Eighty new workers have been hired in Guiyang over the past two years, Safran says. There are now 210 staff at the site, and the company plans to have a workforce of 250 there by the end of 2023.

"This important milestone of Safran's development in China also further reflects our confidence and long-term commitment to the country, which is one of the world's most dynamic aviation markets, and to Guiyang, which has gradually formed a development pattern led by the agglomeration of equipment manufacturing industry over the years," Safran CEO Jean-Paul Alary says.

The Aviation Week Network Fleet Discovery database indicates there are 449 Leap-powered airliners currently in service, with 1,079 on order—the majority of which are Airbus A320neo-family aircraft. During the Boeing 737 MAX grounding, Chinese carriers pivoted to Airbus narrowbody equipment, with the "big three" of Air China, China Eastern Airlines and China Southern Airlines placing a massive 292-aircraft order in September 2022, outstripping their MAX orderbook.

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Lift Innovation

Rolls-Royce begins testing its lift motor for electric vertical-takeoff-and-landing aircraft

Rolls-Royce's lift motor for eVTOL aircraft is air-cooled and direct-drive.

Graham Warwick Washington

Rolls-Royce plans to begin ground-testing its lift motor for electric vertical-takeoff-and-landing aircraft this month and is under contract to deliver units to Embraer for Eve Air Mobility's full-scale technology demonstrator.

"We are taking this through a few loops in terms of getting to the final production version," Rolls-Royce Electrical President Olaf Otto told the Vertical Flight Society's Electric Aircraft Symposium in Oshkosh, Wisconsin, in late July. "Our Loop 1A is ready to go on test in August."

Eve plans to begin building its first full-scale prototype in the third quarter and is aiming for a first flight in early 2024. The aircraft will have eight lift propellers for vertical flight and a pusher prop for wing-borne cruise. Production aircraft will use motors developed by an Embraer/Nidec joint venture.

"We are providing strategic support to Embraer in the development of the Eve platform, and this includes the supply of electrical propulsion units for their upcoming proof-of-concept platform," Julia Hetz, head of marketing for Rolls-Royce Electrical, tells Aviation Week.

Rolls is under contract to supply the same lift motor to UK startup Vertical Aerospace for its production VX4 electric vertical-takeoff-and-landing (eVTOL) aircraft. Vertical's full-scale demonstrator is powered with motors by UK company Equipmake. The aircraft crashed Aug. 9 during testing, but a second demonstrator is being built.

ROLLS-ROYCE IMAGES

Rolls-Royce is under contract to provide the lift motor to both Eve Air Mobility and Vertical Aerospace.

Weighing less than 55 kg (121 lb.), Rolls' lift motor produces 150 kW of continuous power and 1,600 newton-meters maximum torque. The motor is air-cooled, with a transverse flux architecture. This is a motor-winding configuration that enables the 3D flow of magnetic flux, increasing low-speed torque.

The eVTOL lift motor is one of three products under development at Rolls-Royce Electrical following its decision to shelve the certification program for an electric propulsion unit (EPU) for small propeller aircraft. "We don't see that the market size and speed are significant enough for us," Otto said.

Rolls is beginning assembly of a high-power, mid-speed EPU for Part 23/CS-23 commuter aircraft. This is planned to be on test by year-end. The power level for the production unit is still under discussion with customers. The starting point is 320-400 kW for a motor that weighs less than 160 kg.

"It seems the upper end of this range is more attractive," he said. "This is a radial flux machine, so scaling up is possible within a certain range. I think this will top out somewhere around 430-435 kW if you still want it to be completely air-cooled."

Rolls' third product in development is a clean-sheet 600-1,200-kW turbogenerator for hybrid-electric propulsion systems. "This is on the test stand in our facility in Berlin and being tested and paired with a generator. And the first runs of the complete system are to take place next year," Otto said.

"There is a completely new gas turbine that is being designed from the ground up for sustainable aviation fuel and to be hydrogen [H_2]-compatible," he said. "We can simply exchange the burners and then burn H_2 in this gas turbine as well." The power-to-weight ratio for the turbogenerator is 4 kW/kg.

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AVIATION WEEK NETWORK

MRO Europe returns to the RAI Amsterdam on October 17-19, 2023 for its landmark 25th anniversary. The combined exhibition and conference is expecting record breaking numbers this year, with 460+ exhibitors, 40+ speakers and 10,000+ expected attendees over the 3 days.

Through the Years

From its launch in Shannon, Ireland in 1991, the event has jumped across the region, landing in 11 cities to date. Since 2010 the event has rotated between key aerospace hubs in London, Amsterdam and Madrid. Attendee and exhibitor numbers have seen huge growth alongside the strength of the industry and the event is firmly set as the place to be for the European aviation aftermarket.

International Exhibition

460+ exhibitors will be ready and waiting to display their latest technology and MRO products and services to buyers during the two-day exhibition, open on October 18-19. Visitors are able to meet suppliers from around the world, as well as take advantage of the complimentary content on offer at the *Go Live! Theater.*

Senior Level Conference

The two-day conference, running October 17-18, takes a strategic look at the regional aftermarket, with some familiar issues remaining at the top of the agenda, such as supply chain struggles, inflation, workforce challenges and capacity shortages. In addition, the industry-led program will address how the emerging India market, the reopening of China and other international trends will affect the European MRO market as well as high level discussions on reducing the lead time on repairs, engine durability and the impact on operators.

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Asia-Pacific Rush to Cargo Conversions

A surge in airfreight demand drives conversion boom, but could overcapacity lie ahead?

Tom Pleasant London

Often referred to as the "factory of the world," the Asia-Pacific region generates approximately one-third of global airfreight each year. Typical exports from the region are lightweight, high-value, time-sensitive or a combination of all three, such as electronics, pharmaceuticals, fresh produce, seafood and luxury goods. Meanwhile, the region's rapid economic growth and urbanization have led to a surging demand for similar imports from the rest of the world, as well as within the region.

Where demand for airfreight leads, demand for cargo capacity follows, be it for aircraft belly space, production freighters or passenger-to-freighter (P2F) conversions.

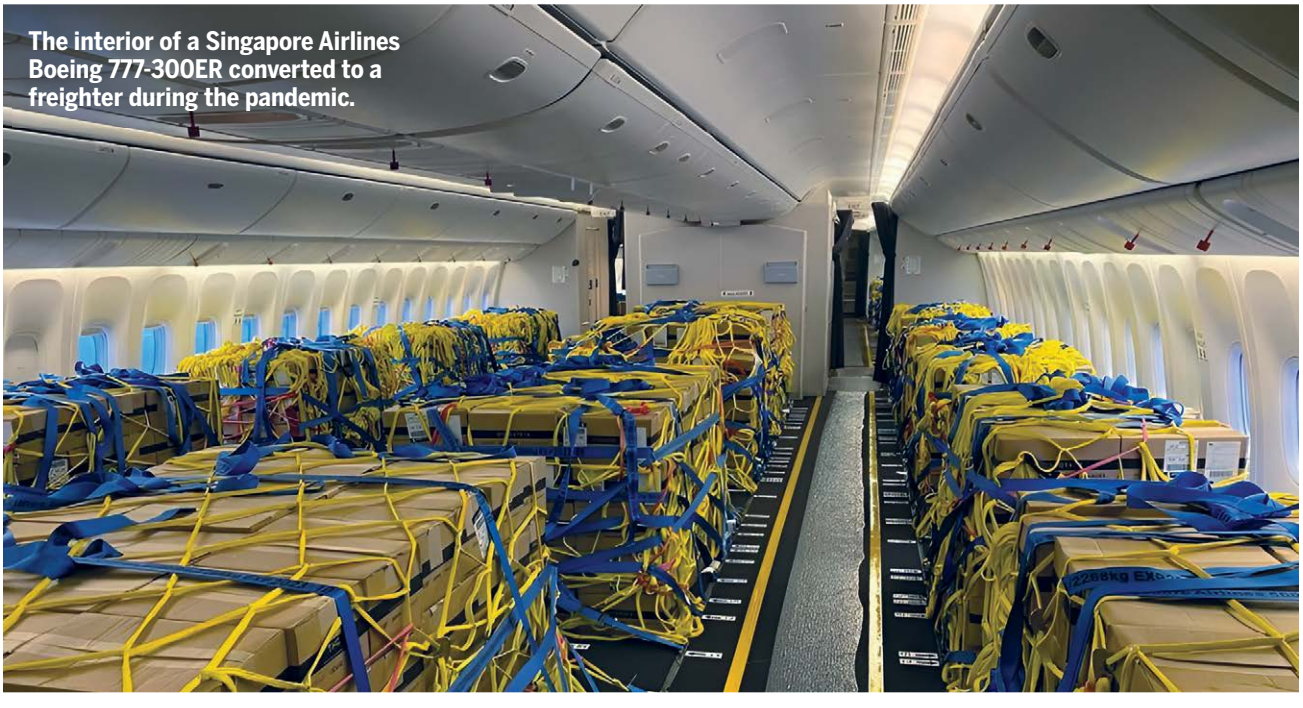
Boeing estimates the global P2F market will reach $5.19 billion by 2029, and forecasts approximately 1,300 P2F deliveries globally over the next two decades—66% of the total demand for freighter conversions. The manufacturer estimates the Asia-Pacific will receive nearly 500 of them, the largest share among all regions. That would make the region's freighter fleet comparable in size to that of North America, indicating a growth rate of more than three times its pre-pandemic fleet.

Airbus forecasts similar figures, predicting the need for 1,590 more conversions from 2023-42, with 600 going to the Asia-Pacific. Both manufacturers have announced plans to increase conversions of their own aircraft to cater to this demand.

Embraer, too, has entered the fray by introducing its E-Jet conversion initiative in March 2022, with the first to be operational in 2024. The aim is to address the demand for freighter capacity between turboprops and narrowbodies, which it believes will be a popular choice in many parts of Asia-Pacific. Embraer's E-Jet conversion program anticipates a need for 700 E-Jet freighters over the next 20 years, with China accounting for 34% of worldwide demand. Presently, 85 E-Jets are operational in China, serving airlines such as Guangxi Beibu Gulf Airlines, Colorful Guizhou Airlines, Hebei Airlines and Tianjin Airlines, so they are already a popular model type.

However, while these forecasts are optimistic, Asia-Pacific's P2F ecosystem is complex and fragmented. Conversion capabilities are constrained, national regulations lack alignment, sustainability rules are evolving and air cargo volatility brings risks. Segment dynamics are also shifting as economies reopen post-pandemic.

Realizing the region's immense potential will require deft navigation of these challenges, including disciplined capacity growth, sustainable profitability, regulatory coordination and balanced investment strategies. If stakeholders collaborate, the Asia-Pacific regions's stature as a preeminent global P2F hub can keep rising.



The interior of a Singapore Airlines Boeing 777-300ER converted to a freighter during the pandemic.

SINGAPORE AIRLINES

DRIVERS OF SURGING DEMAND

But why has the region emerged as a hotbed for aircraft conversions?

The pandemic caused an exponential

rise in e-commerce and online shopping, with Asia-Pacific at the epicenter supplying global demand. Market research firm eMarketer says the region's retail e-commerce sales expanded by a massive 74% in the past two years, far more than in any other region.

This surge fueled air cargo volumes as consumers clamored for faster deliveries, leading to logistics companies tapping air transportation. With the fall in belly capacity (see below), dedicated freighter capacity became essential and P2F models allowed carriers to rapidly add that capacity to their networks.

The decrease in passenger flights due to health and safety restrictions related to the pandemic reduced available belly space for cargo on passenger aircraft. Operators including Singapore Airlines and Cathay Pacific completely reversed the pre-pandemic trend of airlines reducing or even entirely eliminating their freighter fleets, and pivoted capacity by converting idled passenger aircraft into freighters.

ELBE FLUGZEUGWERKE

An A320 P2F converted by Elbe Flugzeugwerke, the joint venture between ST Engineering and Airbus.

While some carriers, such as Air Astana, have swiftly dropped their P2Fs and moved back to the comforting familiarity of all-passenger fleets, others have continued investing in converted freighters even after lockdowns eased, having rediscovered the value of having a versatile fleet mix. IndiGo, India's largest airline, welcomed its first converted freighter, an Airbus A321P2F, in late 2022 and plans continued cargo expansion, both domestically and internationally.


ST ENGINEERING

A drilling robot during a passenger-to-freighter conversion at ST Engineering.

Finally, Asia's manufacturing landscape is progressively shifting production from China to lower-cost countries such as Vietnam, Malaysia and Indonesia. The International Air Transport Association expects this trend could triple Southeast Asia's cargo volumes by 2035 with these production shifts. As manufacturing sees this redistribution, companies reshape their supply chains.

In total, these factors have driven a major increase in demand for P2F conversions. How much they will continue to do so, as passenger travel's recovery post-pandemic brings with it increased belly capacity and fewer grounded aircraft to convert, remains to be seen.

CHALLENGES AND COMPLEXITIES

The region also faces an array of complex challenges—constrained supply, regulations, sustainability, volatility risks and overcapacity concerns—that require nimble navigation.

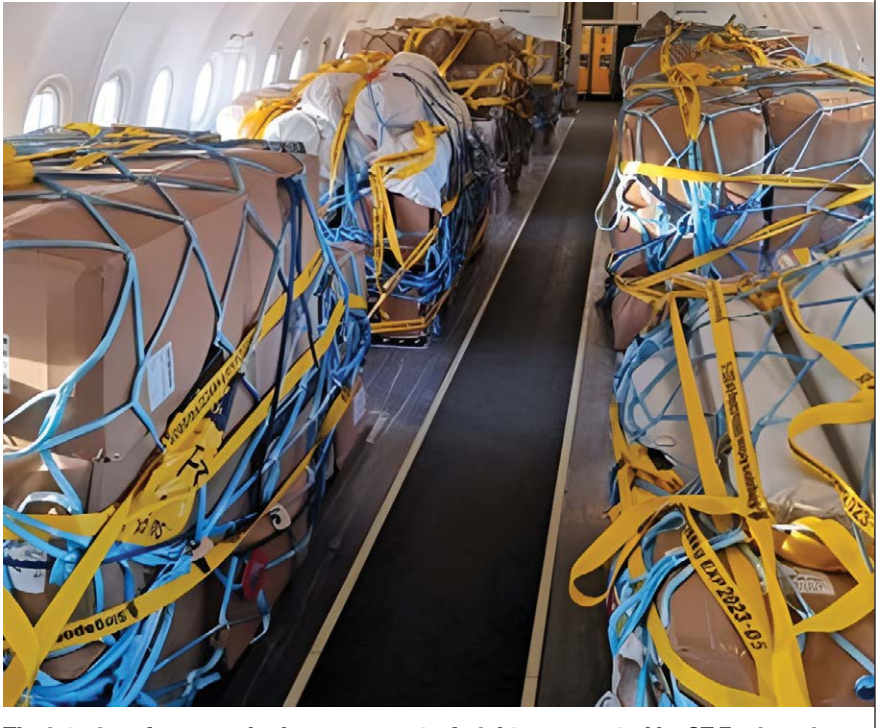
Rising P2F demand is already outstripping Asia's conversion capabilities, causing project delays and backlogs. For example, Singapore's ST Engineering says its conversion slots for Airbus A320/321P2Fs and A330P2Fs are fully booked through 2026. It has announced heavy investment into additional P2F capabilities across China, Singapore and the U.S. to ease the capacity crunch, as are other conversion players

CREATIVE COMMONS

An electronics factory in Shenzhen, China, typical of Asia-Pacific airfreight customers.

operating in the region, including Israel Aerospace Industries and Elbe Flugzeugwerke. New capacity is slow to come online, however, as major new conversion centers take years to complete. The availability of qualified MRO partners to perform conversions is also limited, causing a bottleneck that hampers the pace of expansion.

The Asia-Pacific region's fragmented regulations create another barrier. Each country has distinct processes and directives for certifying aircraft modifications, and these requirements lack harmonization between jurisdictions. Industry group Aircraft Fleet Recycling Association (AFRA) has long campaigned for greater coordination between regulators to align standards and expedite certification to ease the regulatory backlogs delaying P2F projects throughout the region. Earlier this year, Jason Dickstein, president of Washington Aviation Group, which represents AFRA, told Aviation Week about a collaboration between AFRA and the Civil Aviation Administration of China to help global companies navigate China's regulations combatting counterfeit parts. While encouraging, it is only a fraction of the work that needs to be completed to serve current market demands.



ST ENGINEERING

The interior of a narrowbody passenger-to-freighter converted by ST Engineering.

Although "greener" than manufacturing new aircraft, conversions face significant and overlapping environmental regulations due to greater governmental and industry standards regarding emissions. For example, the International Civil Aviation Organization's latest CO_2 standards (Volume 3 to Annex 16 of the Chicago Convention) took effect this year and present hurdles for certain aging Boeing freighters, such as 777Fs and 767-300Fs. While the standards do not directly impact passenger-to-freighter conversion programs, converted aircraft will still face the same operating constraints as other older freighters when the 2028 in-service compliance deadline approaches. Any models not meeting the CO_2 targets by then will face potential usage limits.

P2F converters will need to consider sustainability as a factor when selecting aircraft for conversion in the future. Retiring passenger aircraft with newer engine options that can more easily be adapted to meet emissions regulations is likely to become preferable. Striking the optimal balance between profitability and compliance will be an ongoing challenge.

Changeable market conditions intro-

duce uncertainty as well. For instance, airfreight rates softened in late 2022 after spiking during the pandemic. While they have since stabilized, they teeter on a knife-edge. Talking of the fall in rates, the freight forwarder group Globalia Logistics Network says it does not expect the rates to return to their previous high anytime soon. "It needs to be remembered that the sector is in damage-control mode after the pandemic and a further rise in rates will impact the profitability of this sector," says a company representative. Globalia cited the more conservative spending habits of consumers due to widespread global inflation for the drop. Should inflation increase, dampening consumer confidence, airfreight demand will inevitably decline, affecting demand for conversions.

Fluctuating oil prices also directly impact operating costs, something that has been especially apparent following Russia's invasion of Ukraine. Changing trade policies and currency swings also influence cargo flows and airline routes.

Even though the increase in capacity demand has been recent, overcapacity concerns already loom for some models. More than 200 Boeing 737-800s have been converted to freighters, and 737 fleets may soon surpass converted 757 freighters that took far longer to scale. Consultancy IBA warns this rapid growth signals future oversupply risks, and its data shows 737 values declining recently as the supply increased.

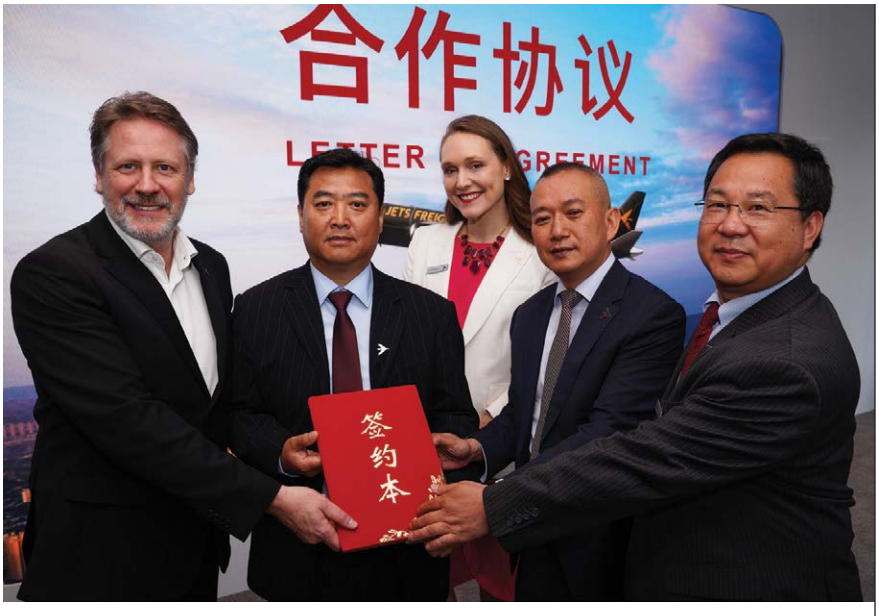
ENABLERS OF COLLABORATION

Asia-Pacific's P2F growth relies on OEMs, MROs, lessors and airlines working collaboratively. Each plays an integral role in this ongoing trend. OEMs, such as Boeing, Airbus and Embraer, provide trusted conversion solutions tailored for the region's carriers. Boeing's 737-800BCF and Airbus' A320/A321P2F models are popular in Asia, and their certification inspires confidence. MROs execute conversion projects by leveraging technical expertise—their experience smooths program implementation across Asia's fragmented landscape. Aircraft lessors also aggregate demand by placing large conversion orders they then lease out as carriers need them. BBAM, Aircastle, Avalon and others have fueled growth by embracing fleet flexibility.

This assembly of stakeholders must align strategies and expertise to address the many challenges looming. Airlines assess market needs, lessors provide capital, OEMs design solutions and MROs deliver them. Partnership between these players enables navigating risks, constraints and complexities more adeptly. Their collaboration is critical to unlock Asia-Pacific's immense potential as a global P2F hub.

FUTURE OUTLOOK

The future of the Asia-Pacific passenger-to-freighter sector looks very positive, but it's important to approach with cautious optimism due to changing market dynamics. Industry experts predict that air cargo will continue to



EMBRAER

grow by about 4% each year for the next 10 years. While this growth rate might be lower than the peak during the pandemic, it is still significant. Ongoing trends in manufacturing and e-commerce remain favorable for air-freight. Surveys also indicate that 91% of shippers plan to use air cargo at least as much as they do now or more over the next five years. This suggests strong demand that can withstand short-term fluctuations.

Embraer signed an agreement in June with Lanzhou Aviation Industry Development Group for 20 E190F and E195F passenger-to-freighter conversions, making Lanzhou the launch customer for Embraer's P2F conversions in China. The companies also intend to establish a conversion capability in Lanzhou.

However, the ability to manage change effectively will determine success in this industry. Leading airlines in Asia have shown their adeptness at switching between passenger and cargo operations using converted aircraft. Their flexibility demonstrates how important it is to be adaptable. While optimism is high now, growth strategies need to be carefully balanced. Long-term plans should consider potential risks, and adjusting capacity according to changing demand is crucial. If aircraft converters, leasing companies and airlines collaborate effectively, the Asia-Pacific P2F sector can flourish despite its complexity.

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On the Move


FL TECHNICS

Zilvinas Lapinskas, *CEO of FL Technics, talked with James Pozzi about the Lithuanian maintenance provider's plans to establish facilities in the Dominican Republic and Indonesia, and how the war in Ukraine has affected its operations.*

What was the thinking behind FL Technics' recent announcement that it would establish an MRO facility in the Dominican Republic? We did this with the whole Americas region in mind: the U.S., Canada, Central America and the Caribbean. We were thinking about the trends, where this maintenance is moving from the high-cost countries to lower-cost countries. We had the same experience when maintenance moved from Western Europe to Eastern Europe, where companies moved to the lower-cost locations for their maintenance.

We've seen some Central American providers who have the benefit of lower-cost maintenance attracting more customers from the U.S. When we started to compare the cost in Central America with the U.S. and the time of ferry flights from the U.S. to the region, we made the decision to set up our hangar somewhere in that region. FL Technics will be able to serve regional demand while being able to do so with a cost advantage. After looking at different locations, we decided on the Dominican Republic and specifically Punta Cana Airport.

Will FL Technics look to build and own the hangar or lease from Punta Cana Airport? The arrangement will see the airport build the hangar for us, and FL Technics will then lease the facility from them. Once it becomes operational in 2025, it will begin with five bays of maintenance, but with the ability to eventually expand by another seven and take the total number of bays to 12.

What is FL Technics anticipating in relation to workforce recruitment in the Americas? Will the Dominican Republic facility look to a domestic or expatriate workforce? It will be a mix. We will be the first base maintenance MRO in the Dominican Republic, as there isn't a lot there apart from a few line maintenance providers. Naturally, that means there will be a shortage of local certified staff. The anticipation is that between 250 and 300 engineers will be needed to work across the five maintenance bays. At the beginning, we will need expatriates while focusing on the training of local people, which we are discussing currently with local universities. There is a two-year window to get the right people in. Building the hangar won't be the problem, but getting the right people inside and creating a reliable production system and guaranteeing a good turnaround time for the customer will be.

Were similar principles applied to the announcement of a new maintenance hangar in Bali, Indonesia? There are similarities but also differences. In Jakarta, FL Technics has operated an MRO hangar since 2015 at Soekarno-Hatta International Airport. There we have three maintenance bays in total, and that is small. That hangar lease runs until 2025, and we expect to extend that. However, given the high volumes of demand from the Asia-Pacific market—especially from leasing customers—we see an opportunity to provide even more services.

Initially we looked at expanding in Jakarta, but for many reasons there wasn't enough capacity at the site for us to grow. Instead we were offered a hangar in Bali, which, like in the Dominican Republic, will be built for us to rent. In Bali, there are two small existing hangars which we will take over shortly and start some operations before the building of four additional bays, eventually taking it to six bays in total.

In Bali, we are specifically targeting the Australia market. Geographically it's not far away, and many Australians holiday in Bali, meaning a high volume of flights, so that means the carrier doesn't have to do their ferry flights and can just arrive with the passengers before replacing their aircraft. The pricing we can offer in Bali compared to Australia is also attractive, as it is cheaper.

Was FL Technics impacted by the outbreak of the nearby Russia-Ukraine war, and how did it readjust its business to deal with this? Before the war started, the largest business we had in Russia and the Commonwealth of Independent States countries was in spare parts trading. When the war started, we stopped all operations immediately and we moved all people dealing with that market to other regions over the course of two months. They instead moved into our Asia-Pacific team and our Dubai office that serves the Middle East, and helped grow our focus on Africa. By the end of April 2022, we were back within budget lines. In the longer term, this move has resulted in greater revenue than we were getting from Russia.

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Cost Considerations

Airlines adapt MRO cost strategies and planning to cope with unprecedented market upheaval

Alex Derber London

Passengers are returning to the skies and airline performance is surging back toward pre-pandemic levels, so one might expect the maintenance market to be resuming its normal rhythms. After all, shops are full, slots are in high demand and the big MRO providers are reporting a healthy uptick in profits and sales.

Scratch the surface, however, and many of the changes wrought by the pandemic endure as airlines continue to prioritize cost savings as they seek to rebuild their businesses and their balance sheets. Furthermore, supply chain challenges and inflationary pressures exacerbated by Russia's war on Ukraine have added extra considerations, especially regarding turnaround times, fleet availability and parts procurement.

"We still see many airlines looking for flexibility—while the majors are reporting great results, there are many more airlines that are thinking short-term as they repay loans and remain short-term cash-focused," says Phil Seymour, president of consultancy IBA Group.

One such airline is Riga, Latvia-based Air Baltic. "Everyone is still affected and trying to fully recover from the consequences of the pandemic and the war in Ukraine," notes Oskars Zalkalns, vice president for engineering at the airline.

NEW-GEN CHALLENGES

Another challenge for Air Baltic and many other airlines: the reliability problems and revised inspection mandate for Pratt & Whitney Geared Turbofan (GTF) engines, which have created considerable uncertainties for their maintenance and fleet planning departments.

Air Baltic operates an all-Airbus A220 fleet, meaning it is also affected by Pratt & Whitney GTF engine problems that have hit aircraft availability for operators around the world and led to new—and usually confidential—maintenance and inspection deals between the operators and OEM.

Speaking to investors in August, V2500 and GTF operator Wizz Air would not be drawn on the details of any compensation arrangements with Pratt & Whitney, but did expect that as the largest airline customer of the OEM, it would receive "treatment according to that status."

Air Baltic has confirmed ongoing supply chain issues with the Pratt & Whitney engines on the airline's A220-300 aircraft.

BENE RIOBO/WIKIMEDIA

However, Wizz Air CEO Jozsef Varadi also noted that it was too early to cost-out a maintenance plan for the latest problems revealed by Pratt—which will require the removal of up to 1,000 engines worldwide—because the OEM had not finalized the inspection program. "Pratt & Whitney is saying that in the best-case scenario they might be able to come up with a designated short program. So it wouldn't affect the current operations of the engine shops, but this is not yet fully confirmed," he said.

There is also uncertainty around the 12 GTF engines that Wizz Air must remove by mid-September under a service bulletin. The airline has budgeted for reduced capacity in the second half of this year due to these removals, but Varadi said it still does not understand exactly what the scope of the inspections will be, how long they will take, or how the work will fit in with Pratt's available shop capacity.

At Air Baltic, Zalkalns confirms that "there are ongoing supply chain issues with the Pratt & Whitney engines on the airline's A220-300 aircraft," but he cannot say when such issues will be resolved.

"The airline is in regular communication with Pratt & Whitney, and the company is actively working on mitigating the issue," he adds.

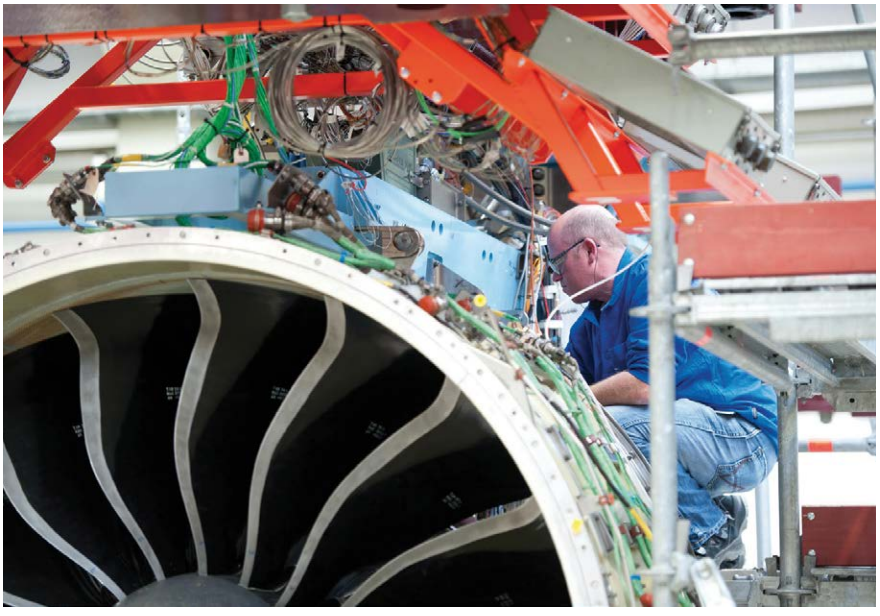
To cut costs at the start of the pandemic, Air Baltic phased out its Boeing 737 and De Havilland Canada Dash 8 fleets while also terminating the associated maintenance contracts. But for airlines transitioning more gradually from older to newer equipment, another wrinkle in their planning has been delivery delays for new aircraft, requiring older aircraft and engines to remain in service longer. Often this requires more use of green-time equipment as well as adjustments to the management of deadlines such as end-of-lease checks.

MANAGING LIFE-CYCLE SAVINGS

To appreciate how airlines have adjusted MRO cost management, it pays to understand the factors driving these changes. Putting aside minimum safety and regulatory requirements, which are nonnegotiable regardless of any cost strategy, normally an operator will seek to minimize the life-cycle cost of aircraft and engine assets by performing additional repair or replacement work in the short term to guard against expensive problems in the long run. Likewise, during engine overhaul events the extra expense of a wider workscope and extensive life-limited part (LLP) replacement helps to protect long-term asset value and ensure simpler maintenance planning for the future.

"Generally, the objective is to con-

One option for airlines to reduce short-term maintenance costs is to lighten workscopes.



MTU

tinuously keep the engine total lifecycle cost front and center and make choices that optimize both cost of ownership and airline value creation, rather than looking only at short-term maintenance costs," says Michael Grootenboer, senior vice president of engine products for AFI KLM E&M.

However, the approach outlined by Grootenboer went out the window for many airlines during the pandemic, when financial constraints forced them to focus on immediate costs rather than a long-term strategy—a shift in emphasis that will take time to unwind.

An easy way to cut costs quickly is to reduce workscopes during shop visits, thereby saving on labor and materials, albeit at the expense of settling for shorter on-wing times—and kicking the can down the road for a more expensive MRO visit in the future.

Many airlines have also opted to change the type of work performed for big-ticket items such as engines, IBA's Seymour explains. "A scheduled full overhaul and LLP stack replacement tended to become a repair with targeted LLP replacement in order to reduce the cash expenditure. But that will result in a premature next shop visit since the build standard will have been reduced. The long-term cost per hour/cycle will have increased, but short-term cash-saving was the priority," he says.

A quicker, cheaper alternative to a full engine overhaul is a module re-

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placement, and there is evidence that these are becoming increasingly popular. Asset manager FTAI Aviation offers these for CFM56 engines and saw revenue in that part of its business rocket 156% in the second quarter of 2023.

"We think that it's a great product if airlines really need to hunker down and focus on cost-cutting," commented FTAI Aviation Chairman and CEO Joseph Adams on an earnings call.

Other adjustments have been applied to engines on long-term maintenance deals even when airlines have operated enough flight hours to initiate an overhaul, since many of these contracts exclude expensive LLPs from the cost-per-flight-hour rates.

"Even though an engine shop visit cost may have been accrued over previous years, it wasn't always put through the full process without consultation between the parties to ensure that an acceptable build standard and turn time was achieved," explains Seymour.

For airframe heavy checks the situation is a bit different, as many of the individual tasks are packaged together and it is not practical to carve them out into intermittent hangar visits.

Even so, airlines must also contend with longer turnaround times for maintenance due to a combination of labor and material shortages in the aftermarket and a rapid uptick in demand for checks from operators around the world. "Turnaround times for heavy maintenance are much longer; roughly they are doubled," comments Air Baltic's Zalkalns.

Wizz Air is uncertain about the time and cost impact of new inspections mandated for the geared turbofan.

WIKIMEDIA/MARVIN MUTZ

Airlines do retain some flexibility to defer certain parts replacements in cases where they can be accomplished in future overnight stops.

PARTS STRATEGY

Across airframe and engine checks, airlines can also pursue savings by opting to install used serviceable material and parts manufacturing approval (PMA) parts and rely on designated engineering representative repairs.

"The result will be some compromise on the time on wing, but again, cash savings are the priority," says Seymour.

Demand for such savings has only increased since the pandemic, as geopolitical events have fed into parts price inflation, which has long been a headache for airlines.

"Unfortunately, A220 component maintenance costs have been increased worldwide by around 15% on average, including the power-by-the-hour contract portion related to components MRO support services," says Zalkalns.

Speaking to *Inside MRO* earlier this year, several PMA manufacturers noted that inflation was driving higher demand for their parts, as well as other factors such as supply chain bottlenecks for OEM equipment and the extended service lives of older aircraft due to new-build delivery delays.

Zalkalns now sees some of these problems easing, at least for Air Baltic. "There are some occasional challenges with parts suppliers that increase engine MRO turnaround times, but overall we see a positive trend for engine turnaround times improving, and it seems that the engine OEM has fixed the spare parts availability problem."

Gearing Up

Aftermarket merger and acquisition activity could be a business growth engine for years

Michael Bruno Washington

The combination of surging commercial passenger numbers, deferred maintenance and slower-than-expected aircraft manufacturing is fueling significantly more merger and acquisition activity in the MRO sector. Experts see this trend running for several years, with the drivers for deal-making expanding beyond just pandemic reactions.

Bullish moves and fresh commentary from strategic players, as well as the growing prevalence of private equity (PE) investors in aerospace and defense, illustrate the intense interest. In July, Apollo Global Management and Air France agreed to a €500 million ($561 million) investment by the PE giant into the airline's engineering and maintenance unit, bringing Apollo's total to €1 billion within a year.

On Aug. 4, Heico closed on its roughly $2.05 billion acquisition of Wencor—the largest deal Heico has ever pursued, and one of the largest ever in MRO.

Veteran aerospace and defense dealmakers such as Stephen Perry, managing director and co-founder of Janes Capital Partners, tell Aviation Week the trend could be just warming up.

"There truly is this desire by people to travel, and you see this in the airports around the country and around the world," Perry said July 19 during a question-and-answer session hosted by the Aerospace and Defense Forum. "As long as that boom continues, you will continue to see elevated MRO. Airlines have older airplanes because they can't get ahold of the new ones they ordered."

Short of a "black swan" event like another pandemic, the trend of heightened MRO deal-making naturally should run a cycle. "It's at least three years, maybe more, maybe five," he said.

Others see it, too. "Aftermarket and MRO M&A [(mergers and acquisitions)] activity has been a bright spot . . . and is expected to continue to be robust given rising fleet size and higher aircraft utilization and MRO spending strength," says Michael Richter, managing director and global head of Lazard's aerospace and defense investment banking group. Global spending on MRO is expected to recover this year to 2019 levels, partly due to robust airline traffic but also because of the need to perform deferred maintenance left over from the COVID-19 era.

Overall aerospace and defense industry M&A activity has regressed since peaking in 2021, but MRO-related M&A appears to be picking up steam. For deal-makers, MRO and support services generally include component repair, fixed-base operations (FBO) and general aviation support, overhaul and test, supply chain management and distribution, and cargo and flight services.

Over the last 13 quarters, MRO and logistics were responsible for 151 known deals, tying for second among almost two dozen aerospace and defense subcategories, according to Janes' data. Only government services and information technology ranked higher. Still, the average deal multiple —measured as total enterprise value divided by pretax earnings—fell to the middle of the pack at 11.3X.

Attention is growing for good reasons, according to deal-makers at Capstone Partners in a midyear M&A report issued for the Paris Air Show. Western MRO specialists such as AAR and Lufthansa Technik saw record operating profits, up around 50% in 2022 and ahead of 2019 levels. MRO revenue drivers are a function of flight hours and fleet age, and the deferred maintenance related to COVID-19, production issues and resurgent passenger traffic are boosting both factors. In addition, part-out activity has been constrained, with fewer aircraft retirements than expected.

"The aftermarket remains as a source of sustainable cash flows that are relatively insulated from cycle timing, since operating results are more heavily dependent on stable fleet sizes as opposed to changing delivery schedules," Lazard's Richter explains.

That means businesses with aftermarket and MRO exposure are valued for that exposure, especially by outside investors hungry to put their capital to work.

Richter points to several recent examples, including Veritas' acquisition of Chromalloy, VSE and Loar Group's acquisition of Desser, ATL's acquisition of Aero Accessories and the Sterling Group's acquisition of West Star Aviation. Overall, more than half the acquirers in MRO deals were PE firms. But as the Heico purchase of Wencor shows, strategic players also are willing to step up more than before.

"There's plenty of value out there," TransDigm Group CEO and President Kevin Stein told financial analysts in May. "Given our ability to generate value, I think we don't turn away when prices go up necessarily as long as we remain convicted with the individual property products.

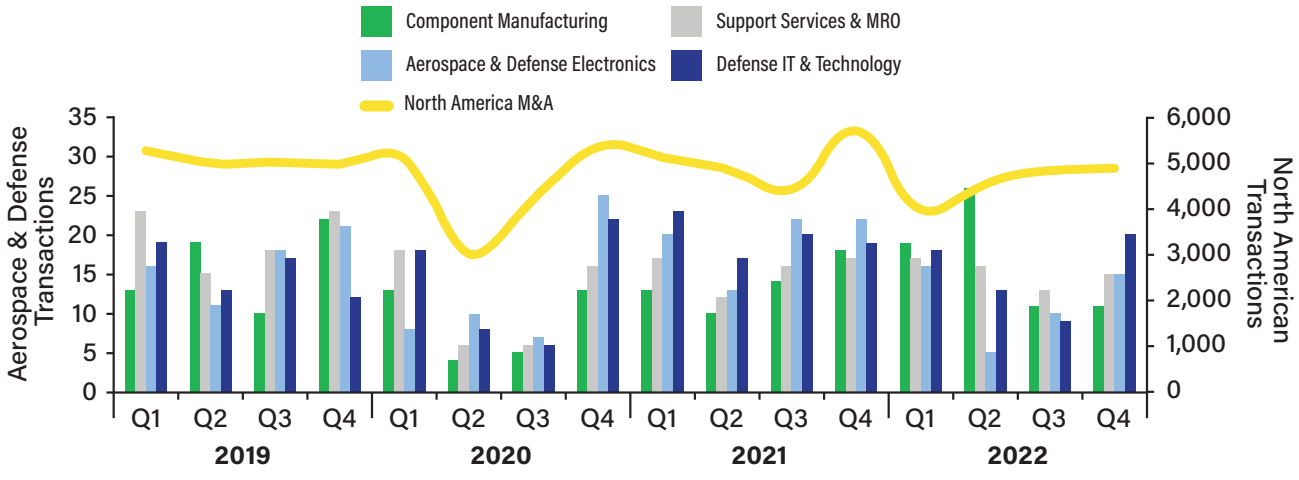
"When you find a business that matches the criteria that we look for in highly engineered products, you're going to have a successful run with those kinds of products over their lifetime," he added.

In recent years through the COVID-19 pandemic, when private aviation and cargo demand spiked, investors focused MRO deal-making more on FBOs and general aviation support services, along with cargo conversions. Initially, deal-making seemed tepid and concentrated in those areas. Transactions in 2022 were 23% below pre-pandemic 2019 levels, according to Capstone Partners. Overall, aerospace and defense transactions dropped 14% in 2022 and were 13% below pre-pandemic 2019 levels, following a similar trend across all industries in North America.

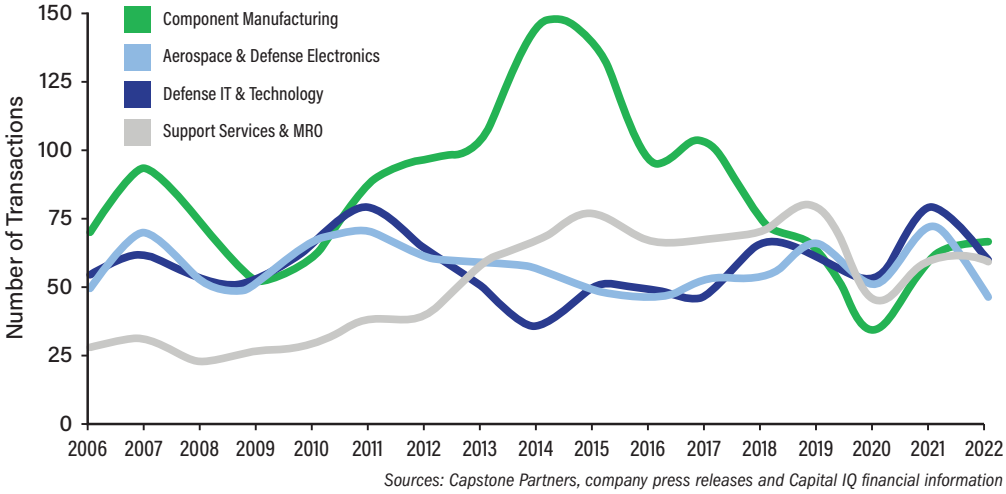
But that has changed, especially in the MRO-related subsector. Stein says TransDigm's deal pipeline over the next 12-18 months is stronger than it has been traditionally, likely because there are more businesses available for sale. TransDigm generally targets small to medium-size en-

Aerospace & Defense Merger and Acquisition Activity

By Quarter



By Subsector



Sources: Capstone Partners, company press releases and Capital IQ financial information

terprises offering proprietary, critical parts.

"Proprietary aftermarket aircraft parts producers continue to be highly attractive acquisition targets not only to traditional acquirers, but also to companies who previously were considered distributors and are seeking to increase their value-add, profitability and importance to customers," according to Capstone Partners.

The investment bank says another theme driving MRO M&A is digitalization: "Western operators' focus has been on employee recruitment and training, following cutbacks during the downturn. They have also been expanding their digital MRO capabilities, with both AAR and Lufthansa Technik making related acquisitions."

AAR acquired MRO and airline fleet maintenance management software, mobile and cloud provider Trax in March 2023 for up to $140 million, including earn-outs. Lufthansa Technik acquired maintenance and engineering software provider Swiss Aviation Software at the end of 2022, and it is combining the unit with its data analytics, digital records and asset management operations.

Lazard's Richter also sees engine MRO generating investor interest. "Engine MRO is expected to exceed 2019 levels in 2023, driven by air travel demand and utilization," he says. "Newer-generation engines, such as the [CFM] Leap and [RTX] Geared Turbofan, are larger than current-generation engines and made with more expensive materials, which in turn drives high maintenance growth over the long-term."

Whether Richter is right remains to be seen. Regardless, the motivations driving MRO deal-making now include far more than just a pandemic surge in private flying. Final 2023 M&A results will not be known until January, but as a whole, aerospace and defense activity is expected to fare better than many other industries—and within that sector, MRO will do better than many other subcategories.

"For the commercial aerospace subsector, we expect the landscape to continue at a consistent level, with activity heavily tilted toward MRO and supply chain transactions," PwC consultants said in their 2023 M&A outlook for the Paris Air Show.

Looking Inward

VietJet boosts its in-house maintenance capabilities

Chen Chuanren Singapore

VietJet Air is among Southeast Asia's fastest growing airlines. Together with its affiliate Thai VietJet, the group has more than 100 aircraft in service and an additional 260 on order, including roughly 110 Airbus A320neos and over 150 Boeing 737 MAX aircraft. To prepare itself for the impending ramp-up in operations, the low-cost carrier is in the process of establishing its own aircraft maintenance organization.

The airline's maintenance arm, unofficially named VietJet MRO, provides technical services for a range of aircraft up to code F, including those currently registered in Vietnam such as the Boeing 777, 787, Airbus A330 and A350. However, the maintenance branch of the Thai carrier will initially focus on narrowbody aircraft such as the A320, A321, 737 MAX and 737-800 to cater to its own fleet. It will have both FAA and European Union Aviation Safety Agency certification on top of the local Civil Aviation Authority of Vietnam certification.

VietJet plans to establish an aircraft maintenance organization to support its rapidly growing fleet.

AIRBUS/CHRISTIAN BRINKMANN

"VietJet plans to establish an [aircraft maintenance organization] to meet the high demand for maintenance services that a fleet of more than 100 aircraft requires and provide us the flexibility and cost controls that are difficult to achieve when outsourcing," says VietJet Chief Operating Officer Michael Hickey.

"VietJet's long-term investment strategy—combined with the support from the local authorities, OEMs and potential partners in the region and globally—is expected to pave the way for the investment and operation of our MRO facility in the coming time," Hickey adds.

The airline has several third-party MRO partnerships in the Southeast Asian region to support its operations, including SIA Engineering, Lufthansa Technik, GMF AeroAsia, Asia Aero Technic and ST Engineering Aerospace. Its recent MRO collaborations include a deal with ST Engineering through which the Singaporean company provided maintenance-by-the-hour for VietJet's entire fleet.

"While we have been happy with the service levels we have experienced, we feel that there is a lack of capacity in this region," Hickey says. "And that, combined with our aircraft orders and fleet growth plans, is more than sufficient to justify our exciting new plans."

A significant shift in the carrier's operations and fleet is the introduction of the A330-300 widebody aircraft, serving new markets such as Australia and Kazakhstan. Vietjet currently has seven A330s.

"From a technical perspective, the plan included: working with the OEMs to review their reliability recommendations; working with previous and existing operators to understand reliability areas that we need to focus on; the renovation and upgrade of our maintenance infrastructure; the establishment of new workshops and hangars; and the improvement of our supply chain," Hickey says.

VietJet has also opted for Rolls-Royce's TotalCare service to support the A330's Trent 700 engines.

The airline has recruited A330 technical experts while simultaneously providing comprehensive training to upskill its existing engineers and mechanics. It has also expanded the capability of its Maintenance Operations Center (MOC) as a central hub to address recurring issues and facilitate quick recovery in case of an AOG situation. Hickey says the revised and improved MOC will play a crucial role in coordinating maintenance activities and ensuring efficient troubleshooting.

As far as technology is concerned, VietJet is further expanding its use of the Swiss-AS AMOS mobile application and introducing electronic tech logs for efficient and streamlined digital maintenance processes. VietJet also plans to establish an AMOS Competence Center to ensure optimal utilization of the system.

VietJet will be hiring a range of personnel to ensure sufficient capacity to its growth, but upskilling current staff is a primary focus to guarantee a stable talent pipeline.

"Upskilling existing staff and providing a pathway into the industry for new entrants will be a priority," Hickey says. "With such a large operation, we will be focusing on providing high-quality training to many new entrants to the industry that we will employ to ensure we have sufficient skilled staff available as we expand our business."

Future-Proofing FADEC

New engine technologies require advances to full-authority digital engine control systems

Paul Seidenman and **David Spanovich** San Francisco

COLLINS AEROSPACE

FADEC systems monitor engine parameters to make discrete adjustments to the control system and optimize engine performance.

As the digital world keeps pushing the electronics technology envelope, engine OEMs are seizing the opportunities to incorporate more capable full-authority digital engine control systems into their products, resulting in greater operational and maintenance efficiencies.

P.J. Titone, vice president of engine control systems at Collins Aerospace explains that full-authority digital engine control (FADEC) systems are essentially the "brains" of an engine, converting pilot inputs, such as throttle position, into the direction to control effectors such as the engine's valves or actuators. "They in turn meter fuel or establish engine vane position," he notes.

The FADEC, Titone points out, operates in a closed loop, which means that while providing direction to control effectors, it is monitoring other engine parameters, such as pressure and temperature, in order to make discrete adjustments to the control system and optimize engine performance. "FADEC also protects the engine from undesired events such as overspeed and overtemperature, and takes actions to mitigate them," he says, adding that as engine control systems continue to become more complex, they will directly contribute to improved engine performance and fuel efficiency.

"This also requires additional advanced signal processing coupled with operation in increasingly challenging environments," Titone says. "Collins has made significant investments and improvements to its FADEC portfolio that include increased use of microelectronics, advanced manufacturing techniques and sophisticated packaging solutions that accommodate demanding thermal and vibratory environments."

A typical FADEC system is comprised of a single, line-replaceable unit (LRU), explains Brent Ostermann, vice president of engineering at StandardAero. However, he says many inputs to the FADEC come directly from multiple LRUs, such as the main fuel control, starter control valve, operability bleed valves, ignitor boxes, ignition leads, exhaust gas temperature harnesses and thermocouples, pressure valves, the fuel flow meter and speed alternators.

Ostermann says these types of LRUs provide important information to the FADEC that the engine requires for thrust management, including compressor discharge pressure, exhaust gas temperature and ambient pressure. Other inputs include fuel flow, variable guide vane positioning, fan speed, core speed, high-pressure turbine cooling temperature and low-pressure turbine cooling temperature.

He adds that as engine technology has evolved, more inputs are coming into the FADEC, which means an increase in parts count. "For example, an engine with newer technology, such as the CFM Leap 1A and Leap 1B [powering the Airbus A320neo and Boeing 737 MAX, respectively], have incorporated a second FADEC to measure and record additional parameters for engine management," he explains. "There are many more inputs from LRUs and engine monitoring equipment used on these engines today."

That is the direction in which FADEC is going. "With advancements in electronics in general, we've been able to build much higher computing capability into our FADECs," says Dave Milne, senior director of engine controls at Honeywell Aerospace. "This enables ultrafast and precise control, which equates to higher engine performance

SAFRAN

CFM Leap engines incorporate FADEC 4 systems, which have 10 times the computing power of previous-generation FADEC 3 systems.

and improved thrust-specific fuel consumption (TSFC), diagnostics/prognostics and high-speed data communication with other aircraft systems—all with robust cybersecurity protection."

Milne adds that improvements in FADEC engineering have focused on hardware as well as software. "The improved computing hardware allows us to run more sophisticated software," he says. "With multicore processing, we're able to partition across different functions or design-assurance levels. There have also been dramatic improvements in tools and processes."

To achieve that, Milne says, Honeywell has employed advanced model-based development and simulation environments that enable the OEM to rapidly optimize the engine control. "Integrated tools automatically generate software code, test cases and procedures and documentation—taking humans out of the loop to reduce development time, cost and errors," he says.

Milne says Honeywell began incorporating engine condition trend monitoring to support diagnostics/prognostics in its digital electronic engine controller (DEEC) and FADEC products in the early 1990s. DEEC, he explains, was a limited-authority, single-channel system that preceded FADECs.

"Since then, the focus has been on capturing more data and incorporating more advanced analytics to reduce maintenance cost and downtime," Milne says. "We have implemented real-time data logging and are now capable of implementing 'digital twins' in the FADEC."

The digital twin is a high-fidelity, real-time model of the specific engine the FADEC is bolted onto. It degrades as the engine does, affording deep understanding of the engine's condition, and has the ability to accurately forecast needed maintenance actions, providing an effective arbiter if redundant input signals do not agree.

"This continued advancement in diagnostic/prognostic capability is one of the reasons our HTF7000-series engines achieve 99.996% dispatch reliability," Milne says. The HTF7000 family powers the Challenger 350, Learjet 40, 45, 70 and 75, as well as the Gulfstream G280.

Milne predicts that as engine manufacturers develop new-generation turbine engines and continue to push the limits of higher TSFC, lower weight and better reliability, the control system—and hence the FADEC—will become more complex. "[That] means more variable geometry, sophisticated surge/bleed control, active tip clearance and complex thermal management," he says.

"Managing FADEC size, weight, reliability and affordability will continue to be a challenge," Milne cautions. "We are also entering an era where FADECs share volumes of data with a variety of aircraft and ground systems. This presents a substantial cybersecurity challenge."

Claire-Marie Letourneur, FADEC programs director within the avionics division of Safran Electronics & Defense, says the capacity needs of FADECs are continuing to accelerate. Safran's FADEC family, she says, includes multiple products designed to work with an engine thrust range of 30,000 lb. for CFM56-powered single-aisle aircraft up to 115,000 lb. for the GE 90-115B on the Boeing 777 family.

Safran's latest-generation family member, FADEC 4, is a product of FADEC Alliance, a joint venture of GE Aviation and FADEC International—itself a joint venture of BAE Systems and Sagem/Safran Electronics. As Letourneur explains, FADEC 4 works with the Leap engines powering the Airbus A320neo, 737 MAX and Comac C919, as well as with the GE Passport engine used on the Bombardier Global 7000, 7500 and 8000. The FADEC Alliance is also developing the GE9X FADEC, which will be used on the Boeing 777X.

According to information published by Safran, FADEC 4 has 10 times the computing power of the previous generation, FADEC 3. "The next generation of engine, [Revolutionary Innovation for Sustainable Engines (RISE)], will require five times more computing power than FADEC 4," Letourneur says.

She says FADEC 4 also contributes to engine performance by decreasing fuel consumption by 15%. "Safran Electronics & Defense has delivered more than 12,000 FADEC 4 units since 2016," she says. "This is the fastest commercial engine control production ramp-up in our history, and now we are facing a second ramp-up following the COVID crisis."

Letourneur adds that diagnostic/prognostic features for the FADEC and the engine "have significantly increased" on the Leap engines—both qualitatively and quantitatively.

The retrieval of the data, she explains, is mainly performed on the ground, either wired or wirelessly. "Data transmitted during flight through the [Aircraft Communication Addressing and Reporting System (ACARS)] system are usually limited to those parts needing maintenance action at the next stop," she says.

Letourneur says one of the biggest engineering challenges for FADEC development has been the integration into a single box of 50% more functions with various criticality levels, such as engine control and engine protection functions, as well as engine health monitoring. "This increased functional scope had to be achieved while maintaining the box size and reliability to the same level as for the previous generation," she says. "This led to the introduction of several new technologies, including

multicore processors, distributed architecture, active thermal control and advanced vibration processing."

To address the technical challenges of the new engines, a technical engineering team has been established within FADEC Alliance to work on the definition and design of future FADEC systems and FAR 33-associated electronics to reduce fuel consumption and emissions. Letourneur says the team's main goals include: enabling new engine architecture such as open rotor and hybridization; minimizing the system's weight and footprint; ensuring compatibility with product cybersecurity constraints; managing new engine interfaces; better distribution so that electronics can be placed closer to their function and are easier to integrate, and providing innovative architecture for obsolescence management.

HONEYWELL AEROSPACE

Honeywell is building much higher computing capability into its FADEC systems. One is pictured here as a black box installed on the fan case of an HTF 7000 engine.

The team also hopes to achieve 100% compliance with the European Union's registration, evaluation, authorization and restriction of chemicals (REACH) regulation to improve protection of human health and the environment from the risks that can be posed by chemicals.

"In order to mature these technologies and get a good readiness level for a production program, Safran Electronics & Defense will integrate these new functions on the RISE demo program," Letourneur says. RISE is an open-rotor engine program of CFM International.

Innovating Interiors

Lindsay Bjerregaard Chicago

1. OEM Support

Company: Airbus Services
Product: Airbus Services offers a catalog of cabin products designed for line-fit and retrofit on its aircraft, as well as support services for interior modification projects. Through its Hamburg-based center for cabin customization and its worldwide supplier network and engineering centers, it produces documentation and kits required to modify Airbus aircraft. In May, it introduced its new Airspace L bins, which are upgraded overhead bins available for retrofit on A320-family aircraft. Airbus says the bins provide a 60% increase in baggage capacity and can be installed in 3-5 days. In January, Delta Air Lines chose Airbus to retrofit and upgrade nine A350s entering its fleet, which will include new seats, monuments and overhead bins. In June, Airbus signed a cabin retrofit agreement with ITA Airways for six A350-900s that will include installation of a new premium-economy class section.
https://marketplace.aviationweek.com/company/airbus

2. Connected Cabin

Company: Collins Aerospace
Product: Collins Aerospace designs, develops, manufactures and services cabin interior products for commercial, business and military aviation from more than 20 global facilities. Its interior products include aircraft seating, lighting, oxygen systems, galley inserts, monuments and lavatory systems. In January, Starlux Airlines launched Collins' Elements premium business-class suite on its Airbus A350s. Etihad Airways will be the first airline to fly the suite on the Boeing 787-9. In June it debuted Aurora, its first fully lie-flat business-class suite for narrowbodies, as well as wireless connected galley inserts. The galley inserts can be installed onboard to quickly identify and communicate faults to aircraft maintenance teams, which Collins says can help airlines better schedule repair and replacement during regularly scheduled maintenance.
https://marketplace.aviationweek.com/company/collins-aerospace

AIRBUS/H. GOUSSE/MASTER FILMS

COLLINS AEROSPACE

DIEHL AVIATION

SOISA AIRCRAFT INTERIORS

3. Unique Cabin Concepts

Company: Diehl Aviation
Product: Diehl Aviation is an aircraft interior product OEM that also provides aftermarket upgrade solutions and services to major aircraft manufacturers such as Airbus, Boeing and Embraer. Its cabin products, the majority of which are available for retrofits, include lavatories, monuments, lighting, electronics, and systems for water supply, fire protection and air conditioning. Diehl was recently commissioned by Airbus to develop new overhead bins for the A220 that will provide 20% more stowage capacity. The Airspace XL Bins are scheduled to start production in early 2024. In June, Diehl unveiled a new premium cabin concept in partnership with HAECO Cabin Solutions that features new cabin lighting, lightweight partitions, enlarged overhead stowage bins and staggered seats in a unique four- or five-abreast configuration. The seats give passengers more shoulder room and are enclosed at the rear by a fixed backrest, so reclining passengers do not occupy the space of those seated behind them. The cabin concept will be available through a standard modification kit offered by Diehl and HAECO.
https://marketplace.aviationweek.com/company/diehl-aviation

4. Sustainable Cabin Upholstery

Company: Soisa Aircraft Interiors
Product: Headquartered in Mexico, Soisa Aircraft Interiors designs, engineers, manufactures and services upholstered products for aircraft cabins. Its portfolio includes laminated dress covers, cushions, curtains and ottomans, as well as insulation, acoustic and sidewall panels. Soisa's customers include major aircraft seat OEMs, airlines and MROs. It recently expanded dress cover operations to Dubai to support customers such as Emirates, Etihad and Flydubai. The company has also increased its capabilities to assemble composite panels to make consoles for business-class seats. Soisa recently launched a unique sustainability program in which it donates production scrap materials to a local ethnic group in Chihuahua, Mexico, and trains its people in upholstery-making so they can generate income from artisan products. It is developing a similar program focused on prison reform, where at least 50% of income generated from the products created will go to prisoners' families.
https://marketplace.aviationweek.com/company/soisa-aircraft-interiors

*Go to **marketplace.aviationweek.com** for more information.*

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AEROPROFESSIONAL

By SAM SPRULES

Sam Sprules, managing director of AeroProfessional, leads a team of specialists to deliver recruitment solutions for airlines and aircraft operators.

Workforce Investment

Solving MRO's workforce crisis will require significant investment in recruitment and training strategies

The shortage of aviation professionals has been widely documented over the past decade, with discussions of demand outstripping supply at the center of the conversation. Even prior to that, 2009 saw the International Civil Aviation Organization establish the Next Generation of Aviation Professionals task force in a bid to address the anticipated shortage.

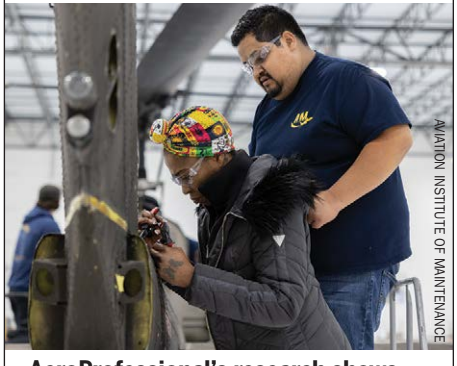
Fast forward to 2023 and—even in the wake of a global pandemic that caused extensive disruption and resulted in mass redundancies across the sector—the conversation remains unchanged.

The pilot shortage is, of course, a key topic, but the shortfall of engineers is creating a quieter storm behind the scenes as those who maintain aircraft face their own workforce challenges.

The shortage flies in the face of growing demand for air travel. Airbus estimates that passenger traffic will double by 2041, requiring 2 million new personnel, of which 34% will be engineers, while Boeing suggests that more than 600,000 new engineers will be needed in the next 20 years. Both OEMs forecast engineering demand to be higher than pilot demand.

AeroProfessional provides recruitment services for segments such as flight crew, cabin crew and engineers, along with more niche skills such as Continuing Airworthiness Management Organization services, management and operations, leasing, brokerage and executive search. Despite this wide range of roles, our delivery has nearly always been dominated by demand for pilots and cabin crew. However, we have recently seen a shift in this trend. In 2022 technical- and engineering-based roles accounted for 37% of our total vacancies, which is in sharp contrast to 2019, when they accounted for just 18% of total client requirements.

We are already seeing demand growing at pace with employers struggling to fulfill their needs. The situation is exacerbated by the pandemic, which resulted in attrition at record rates as many took early retirement or found work in alternative sectors. Additionally, aircraft engineering is an aging workforce, with as many as one-third of workers approaching retirement and nowhere near enough new talent—mostly due to a 2-3-year pause in training due to the pandemic. This is without taking into consideration the impact of Brexit on the UK labor market.


AVIATION INSTITUTE OF MAINTENANCE

AeroProfessional's research shows candidates prioritize careers with a stable and progressive future.

Aircraft engineering is a rewarding industry, but the younger generation does not know enough about it. We need to invest in talent attraction from an earlier age, helping students gain an understanding of the occupation through energized learning, role models, site visits and internships. Better coordination with educational institutions and governments will raise awareness for STEM-focused careers like aerospace engineering.

Additionally, as we are seeing large numbers of engineers defecting from the industry, retaining the existing workforce should be an absolute priority. While shortages are driving up salaries, pay is only one factor that increases retention. Our research indicates that candidates value careers with a stable and progressive future. It is therefore vital for the industry to provide clear routes for continued growth through additional training, mentoring, management and leadership programs.

We know there is a need to create a strong pipeline of future engineers, but what happens when that pipeline is realized and training capacity becomes another issue?

This is where the collective industry could step in to support future talent and ease bottlenecks. Some airlines, OEMs and MROs already offer apprenticeships, but there are not enough supporting this route to handle the capacity needed. If more organizations adopted this and worked with industry and governments to place a spotlight on them for the next generation, we could see holdups easing.

Equally, as the next generation of aircraft start taking to the skies, the training required to maintain them must also evolve. It is vital to seek out ways of improving the process, supporting new cutting-edge training mechanisms and championing different learning styles to see a steady pipeline of talent ready to fulfill those expanded apprenticeship slots.

It will take a concerted effort from all stakeholders to attract talent and future-proof the engineer pipeline. This will require significant planning and investment in all forms—time, money and resources.

The bottom line is the industry needs to get back to investing in talent attraction at grass roots, integrating an ongoing selection process and then streamlining training to avoid watching its aircraft sit empty on the tarmac.

The decreasing popularity must be addressed to mitigate the problem for the long term. Change must happen now to protect aviation's future and keep aircraft in the skies. Future demand necessitates it.

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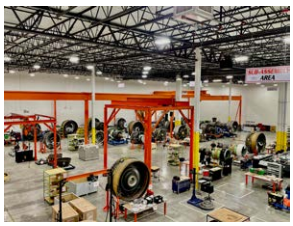

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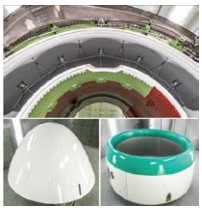

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viding and sustaining the world's finest military flight training systems," says Tom Webster, vice president for Textron Aviation defense global sales and strategy.

Textron's offer is the latest in its Navy training history through Beechcraft, following aircraft such as the T-34 Mentor, T-44 Pegasus, T-6 Texan II and the T-54A, which was recently selected for the Navy's Multiengine Training System. The new agreement comes just three months after Leonardo announced a similar deal with Airbus to offer the M-346 in Europe in preparation for the European Future Combat Air System. The M-346 is already in service with several nations, including Greece, Israel, Italy, Poland, Qatar and Singapore, along with the International Flight Training School.

Meanwhile, Lockheed Martin displayed the TF-50N, its newest version of the T-50, partnering with Korean Aerospace Industries for the program. Current operators of the T-50 include Indonesia, Iraq, Malaysia, the Philippines, Poland, South Korea and Thailand.

Greg Moseley, Lockheed Martin's director of domestic business development for its integrated fighter group, says the baseline T-50 is a proven platform—it has been used to train more than 2,500 student pilots and logged more than 300,000 flight hours. As part of a new agreement with Korean Aerospace Industries, Lockheed Martin has worked closely with South Korean pilots to assess their transition from flying T-50s to F-35s to guide the TF-50N offering.

Lockheed's engineers have been reviewing the Navy's latest RFI to determine what added work the aircraft would need. Though the requirements for unflared landings and glideslope would put stress on a trainer's airframe over its lifespan, the company is confident it will meet the Navy's requirements.

"The Navy is harder on their platforms, and rightfully so," Moseley says. "Their sole fighter platforms are recovering to carriers, and so it does take and it will take a much longer and harder look at engineering and fuselage strain on platforms. But as our engineers continue to focus on it, I really believe we'll be in a strong position as we come out of the research we're doing."

Lockheed Martin is not yet ready to specify the exact capabilities of the TF-50N, which will depend on the company's response to the RFI. Still, Moseley asserts, "We're going to be very competitive going forward."

At the symposium, Boeing displayed a Navy white-and-orange version of its T-7A Red Hawk—the winner of the Air Force's T-X program, with at least 351 of the aircraft expected for the service. Like its competitors, Boeing says it will refine its aircraft to meet FCLP requirements.

"We plan to work with the U.S. Navy to modify the T-7 to meet the requirements for their Undergraduate Jet Training System," says Donn Yates, Boeing's executive director for fighters and trainers business development. "We see this as an opportunity to help define and develop future training needs for the Navy's next generation of naval aviators."

Other prospective competitors include the Sierra Nevada Corp.'s Freedom, an aircraft it originally partnered with Turkish Aerospace Industries on for the T-X program. The company teased the competition ahead on social media of Tailhook with a photo of the aircraft in the Navy's signature orange and white.

The increased emphasis on the carrier landing profile and repeated unflared landings is new in the August RFI, compared to previous versions released as early as 2018. Specifically, the document calls for an aircraft that can maintain a fixed angle-of-attack approach targeting a 3-deg. glideslope while maintaining field of view during an unflared landing. The aircraft needs to be capable of 6-10 unflared landings per training event, as well as conducting unflared landings throughout its service life.

To further replicate carrier operations, the aircraft must be able to maintain control and come to a stop on a minimum 6,000-ft.-long X 100-ft.-wide runway. In performance, the aircraft needs to be capable of Mach 0.9, a 7.33g sustained load factor and a ceiling of 41,000 ft.

Driving home the importance of FCLP operations, the Navy is inviting industry to a training base in Texas in October to monitor T-45 touch-and-goes in the flight profile "to enhance industry's understanding of the unique Navy landings."

In addition to the UJTS, the Navy has expressed interest in a Tactical Surrogate Aircraft to further improve pilot training. A fleet of about 64 aircraft would provide advanced instruction following the undergraduate program. Though discussed, the program has seen no movement since an October 2021 request for information.

Trainer Engine Troubles Worsen U.S. Air Force, Navy Pilot Shortages

> USAF WANTS TO PRODUCE J-85 PARTS ITSELF

> NAVY LOOKS TO DECREASE CARRIER REQUIREMENTS

Brian Everstine Sparks, Nevada, and Washington

Both the U.S. Air Force and U.S. Navy have been plagued by a stubborn shortage of pilots despite several efforts to increase their ranks, and both services have faced the same specific issue blocking progress.

In short, old engines on aged training aircraft have forced a cutback in training flights, in turn worsening the shortages.

The Air Force relies on the aging T-38C Talon II jet trainer, which is powered by a GE Aerospace J85 turbojet that dates back to the early 1950s. Recently, J85 problems have decreased the T-38C's readiness rates into the low 50% range, disrupting the Air Force's training plans.

"The entire system is struggling right now because there are not many people in the world that are flying J-85 engines," says Maj. Gen. Clark Quinn, commander of the 19th Air Force.

For the Navy, the news is not much better for its old T-45 Goshawk fleet. Following a series of hypoxia-like events in 2016 that caused a large de-

SENIOR AIRMAN JAMES R. CROW/U.S. AIR FORCE

Engine issues on the T-38C have slowed the Air Force's output of student pilots.

crease in mission capability, the fleet had started to improve. However, three "black swan" events involving the Rolls-Royce Adour engine have placed limits on the aircraft's flight hours. In October 2022, for example, a compressor blade shot through an engine at NAS Kingsville, Texas, and the service grounded the fleet for 4.5 months.

For both services, the engine issues highlight the need to move beyond the old T-38s and T-45s as soon as possible. The Air Force is looking forward to fielding the Boeing T-7A Red Hawk with initial operational capability expected in 2027. The Navy is starting its Undergraduate Jet Training System acquisition plan, with a request for information released in August (see page 34).

Quinn, who took command of the 19th Air Force in May 2023, says the U.S. Air Force's total pilot shortage is at about 2,000 pilots. That number is approximately the same as it was in 2019, a year after the service first stood up a task force to target the issue in 2018. Along with a series of syllabus changes, such as increasing simulator use including virtual reality in early training, the service planned to address the shortage by moving student pilots through training more quickly.

In early 2022, the service had planned to train about 1,500 students per year. However, the T-38's engine problems made that goal impossible. That, combined with a shortage of instructors, has limited Air Education and Training Command's (AETC) ability to chip away at the shortage.

After dialing back flying hours as engine issues first emerged on the T-38 in 2022, the problem has not specifically gotten worse, but it has not gotten better, Quinn says. The service relies on StandardAero under a 2020 contract to overhaul the J-85 engines, but because the GE powerplant is no longer in production and parts are in short supply, the Air Force itself is looking to get involved in more maintenance.

"We, the government, is looking at perhaps doing some in-house . . . parts production to try and help facilitate getting the engine back healthy," Quinn says.

The idea, which is in its infancy, would focus on the government putting together parts that are most needed to be fed into depot maintenance instead of looking to contract out more production, he says.

Beyond just the engine, the Air Force has recently stood up a broader T-38 effort called the Talon Repair Inspection and Maintenance (TRIM) program. This effort focuses on inspecting and repairing critical structure areas on T-38s—not just aircraft used in AETC, but also those used by Air Combat Command, Air Force Global Strike Command and the Navy. TRIM replaces nearly 200 primary structure components, including longerons, bulkheads, skins and many others. The program also handles inspections of more than 150 other components, AETC said in a statement.

In the meantime, the Air Force faces a backlog of more than 900 prospective pilots who are awaiting training. AETC says that about 25% of these pilots have a wait of more than nine months, with most waiting between three and nine months to start training. During this time, lieutenants do required initial flight training and survival training, and some are assigned to operational or staff organizations.

The number of pilots awaiting U.S.

Navy training is about the same. There's good news on the initial T-6 and rotary wing training, both of which are at about 105% of the overall goal, according to a briefing at the annual Tailhook Symposium on Aug. 25. However, T-45 training is at about 80% following the grounding.

This comes after years of underproduction at the Naval Air Training Command, which fell about 10% below its goal last year. This caused a backlog of about 1,000 pilots. At one point, students were waiting 14 months to start training. Like the Air Force, the Navy has stood up new efforts to ensure that this time is not wasted, including certification programs and a Student Naval Aviation Junior Officer course for preflight instruction.

Coupled with T-45 issues, the Navy has seen a lingering issue with a strike-fighter pilot shortage.

For example, the Navy's main strike fighter—the Boeing F/A-18—has not been receiving enough pilots in recent years, according to the briefing at the Tailhook conference. In 2016, the T-45 trained 113% of the required F/A-18 pilots, until engine issues hit the fleet. That caused the percentage to drop to just 43% by fiscal 2018, before starting to rise. In 2023, the percentage of pilots trained for T-45s reached 71%.

With regard to the "black swan" events that the Navy has seen, an inspection found the engine compressor blade was manufactured out of tolerance. The fleet has since been fixed to return to flight after the grounding, Naval Air Systems Command says.

In an attempt to accelerate pilot training, the Navy in 2022 started a program called the Carrier Qualification Pilot Project (CQPP). Under this program, students will not actually land on an aircraft carrier before going to fleet replacement squadrons (FRS)—a paradigm shift for traditional naval aviation. The service says early indications show that these pilots are nearly indistinguishable from those who go through the original syllabus.

At the time of the August briefing, 32 pilots had gone through CQPP. When they got to the FRS for their first carrier landing, 30 made it on the first try. The remaining two came around and landed "just fine" the second time, says Rear Adm. Richard Brophy, chief of Naval Air Training.

Poland Presses Forward With Air Defense Umbrella Plans

- PROCUREMENT PLANS CALL FOR EIGHT PATRIOT BATTERIES
- CAMM MISSILE FAMILY WILL GROW WITH UK-POLISH MEDIUM-RANGE WORK

Tony Osborne London

Germany may have taken on the role of advocate for strengthening Europe's ground-based air defense through its European Sky Shield Initiative, but it is next door in Poland where the real activity is taking place.

Poland signed contracts worth $15 billion on air defense systems at the MSPO defense exhibition in Kielce on Sept. 5. The agreements included six batteries of RTX's Patriot air-and-missile defense system—adding to the two previously purchased—as part of

PRZEMYSLAW KELER/OFFICE OF THE PRESIDENT OF POLAND

Poland's President Andrzej Duda said that no expense should be spared in expanding the country's defense capability, and promised that 4% of GDP would be spent on national defense in 2024.

Along with Warsaw's already enormous investments in new main battle tanks, helicopters and rocket and conventional artillery (*AW&ST* Sept. 4-17, p. 20), the Polish military is plowing billions of zlotys into a multilayer air defense umbrella—soon to be arguably one of the most comprehensive anywhere in the Western world.

Spurred on by concerns about Russia's extensive use of ballistic and cruise missiles in Ukraine, as well as thousands of Iranian-sourced one-way attack uncrewed aircraft systems, the country is rapidly expanding the scale of its point defense as well as short- and medium-range ground-based air defense (GBAD) systems.

The scale of the plans became more apparent when Warsaw signed the second phase of the country's Wisla (Vistula) medium-range air defense requirement.

Poland's Patriots will not be the standard Foreign Military Sales fare—they include 12 examples of the 360-deg.-coverage Lower-Tier Air and Missile Defense Sensors, making the country the first export customer for the radar and reflecting concerns that Russian threats could come from more than one direction.

The second phase of Wisla calls for continuing involvement in the Patriot program by Polish industry, including production and deliveries of M903 launchers and components for the PAC-3 missiles.

Warsaw also formally launched its Narew short-range program with

the Polish Armaments Group (PGZ), under which it plans to purchase 22 Narew batteries equipped with European missile manufacturer MBDA's Common Anti-Air Modular Missile-Extended Range (CAMM-ER). Poland is buying more than 1,000 of the missiles, most of which are to be produced in-country through a complex technology transfer mechanism that would have Polish industry building the components and assembling the complete missile. Once finalized in the coming weeks, the CAMM-ER purchase and technology transfer agreement would become MBDA's largest-ever export commitment.

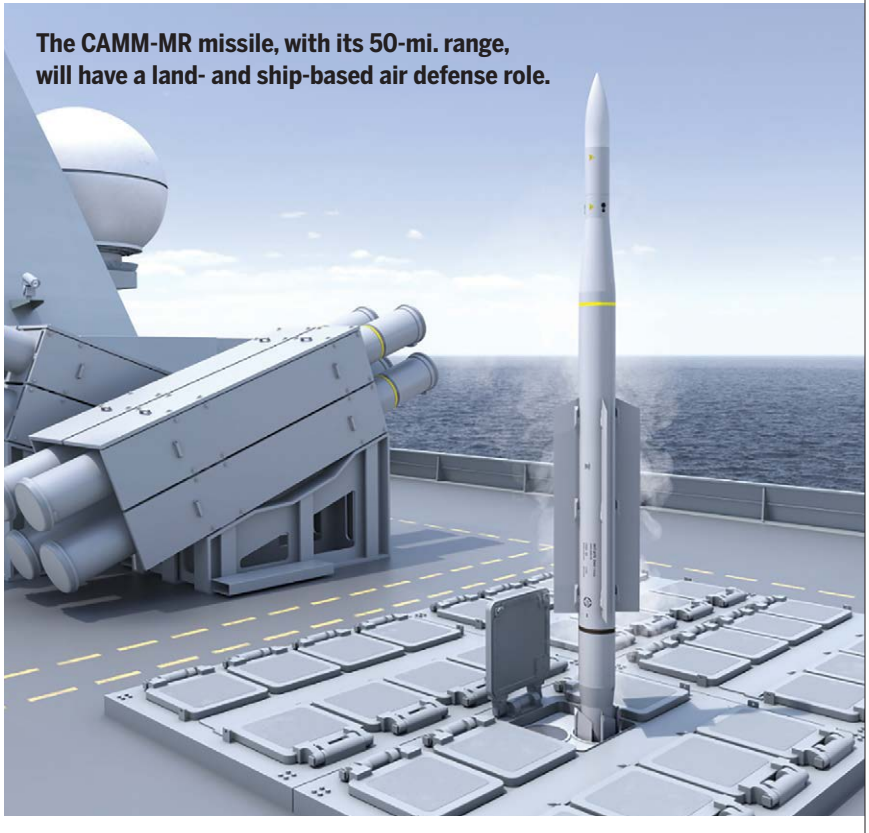
Both the Narew and Wisla agreements are in addition to the signing of a contract for the Pilica+ point defense system in April, which is planned to feature the standard CAMM missile, Poland's Piorun man-portable surface-to-air missile and a locally developed autocannon.

Industry officials say Poland is in "1938 mode," referring to when the country watched the growing threat from Nazi Germany.

Today it carefully watches its northern border with Russia's Kaliningrad Oblast and to the east with Belarus, a nation essentially militarily subservient to Moscow. Poland has recently raised concerns about Belarusian provocations after Minsk flew helicopters across the frontier with Poland and provided sanctuary to Russia's Wagner mercenaries.

"When we see the emerging danger beyond our eastern border, when we see the rebirth of imperialism, which we also faced in 1939 and for decades later . . . there is no price that is not worth paying for Poland to be free, sovereign, independent and for Poles to live safely," Polish President Andrzej Duda said at MSPO's opening ceremony. "State authorities very quickly [have] come to the conclusion that no savings can be made here [in defense] and all resources must be spent to defend themselves as effectively as possible." He also admitted that Poland's rearmament efforts had looked "chaotic at first," but said that it was now delivering the intended effects (*AW&ST* Sept. 26-Oct. 9, 2022, p. 20).

To pay for all this new equipment, the country is raising its defense spending as a proportion of GDP to 4%, the highest rate in NATO, with plans to spend 137 billion zloty ($32 billion) in 2024, Duda said.



The CAMM-MR missile, with its 50-mi. range, will have a land- and ship-based air defense role.

MBDA

And this is far from the end of the air defense growth effort. Poland and the UK are advancing a joint effort to develop an even longer-range version of the CAMM to provide Warsaw with a lower-cost alternative to the Patriot PAC-3 Missile Segment Enhancement (MSE) missile that is equipping the Wisla batteries.

The so-called CAMM-MR (Medium-Range), also known as the Future Common Missile, is a proposed enlarged version of CAMM-ER but with a range of up to 80 km (50 mi.).

The initiative to develop a joint missile was born out of a joint agreement signed by the countries last October and is a component of a UK-Poland 2030 strategic partnership formed in July. The program is advancing into further studies through a letter of intent between MBDA and PGZ agreed to on the sidelines of MSPO.

MBDA has been contracted by the Polish defense ministry to study the nation's requirement and propose several concepts that might satisfy it. One of the designs on display at MSPO showed a single-stage weapon with a broader and longer body than the CAMM-ER, to accommodate a larger rocket motor. One of the criteria is the ability to fit two of the missiles into a Mk. 41 Vertical Launching System that will equip Miecznik-class frigates.

The hope is that if fully developed, the CAMM-MR would share significant commonality with other members of the CAMM family, allowing Polish industry to produce the weapon in-country. However, the UK level of interest in such a weapon remains unclear. The UK is considering acquiring a medium-range capability but with the CAMM-ER, after underinvesting in ground-based air defense capability—like many European countries—for decades.

As well as the air defense systems, Poland signed contracts at MSPO for deliveries of additional coastal missile defense batteries from Norwegian defense firm Kongsberg. The land-based systems, which are planned to be used to protect Poland's Baltic ports, use the Kongsberg Naval Strike Missile.

While far behind in quantity, Europe is waking up to the need for additional ground-based air defenses, with Slovakia the latest to join a growing list of European nations with plans to acquire an Israeli-developed GBAD to replace its Soviet-era systems.

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REVAMPING THE

> DARPA REVERSES TREND OF CANCELED PROJECTS

> SHEPARD SCHEDULED TO BEGIN FLIGHT TESTS

> LIBERTY LIFTER MIGHT BE RE-BASELINED

Steve Trimble Washington

For six different experimental aircraft being developed by DARPA, the first "breakthrough" achievement would be to get built—and then flown.

From fiscal 2003-16, the Defense Advanced Research Projects Agency launched 19 unclassified X-plane development projects, with each seeking a different aeronautical breakthrough, an Aviation Week analysis of agency budget documents shows. However, only two X-planes made it off the drawing board and into manufacturing. Only one—the seven-year-old Gremlins program—achieved a first flight.

Program Series Hybrid-Electric Propulsion Aircraft Demonstrator (Shepard)
Status Built*

*Status based on assessment of program schedule.

Program X-65 Control of Revolutionary Aircraft with Novel Effectors (CRANE)
Status Finalizing design

Ken Plaks, the newly appointed director of DARPA's Tactical Technology Office, inherits a diverse portfolio that includes six X-plane projects (see table). Unlike most of their predecessors, all six appear on track to break the two-decade-old trend. Two have been built or are in manufacturing, another is in design finalization, and the last three are involved in competitions to select a manufacturer.

A new strategy that DARPA embraced in 2020 is responsible for ushering X-plane programs beyond the design phase, Plaks says.

"The older way of doing things . . . we would kind of build a bridge to nowhere. We would design the plane, but then look for partner funding to help build it. And if we didn't get partner funding, we wouldn't build it," he says. "And that's very unsatisfying for a couple reasons. We're engineers and we like to build stuff. But you're [also] not really answering the question."

In many cases, DARPA has reversed the process of soliciting the armed services for financial support for a new project. Instead of asking for tens or hundreds of millions of dollars up front from one or more of the armed services, the agency's program managers are now trying to self-fund projects at a smaller level to demonstrate whether the essential breakthrough technology works.

"If I were to go to the Navy or the Air Force and say, 'I need $100 million for your share to build this airplane [and] we don't even know if it's going to work,' that's a hard thing to do," Plaks says. "But if I can build a smaller airplane and demonstrate that we've slain the dragon and actually solved the technical issue . . . it increases our likelihood of getting partners to join us on a follow-on phase."

Since 2020, DARPA has advanced two programs to the agency's Phase 3, the start of manufacturing. The Series Hybrid-Electric Propulsion Aircraft Demonstrator (Shepard)—a stealthy follow-on to the Northrop Grumman XRQ-72 Great Horned Owl—is scheduled to enter flight testing by year-end. In July, DARPA awarded a $94 million contract to General Atomics Aeronautical Systems Inc. (GA-ASI) to start building the LongShot X-plane, an air-launched uncrewed aircraft system (UAS) designed to fire multiple air-to-air missiles and extend the striking power of fourth-generation fighters.

Meanwhile, Boeing and Aurora Flight Sciences have entered Phase 2 of the Control of Revolutionary Aircraft with Novel Effectors (CRANE) program, which will finalize the design of the X-65 UAS with fluidic flight controls. The development strategy of CRANE is typical of the new model for DARPA's X-Plane projects.

Program LongShot
Status In manufacturing

"The airplane that we're building is very much a technology demonstrator," Plaks says. "It's never going to be an operational airplane or even close to one. It is all about testing out the aerodynamics and building the design tools that would allow you to build a real operational airplane."

The new philosophy has prompted

Fact Box Data: DARPA and Aviation Week

X-PLANE

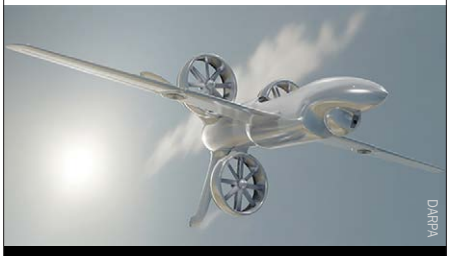
Program Liberty Lifter
Status Concept definition

an internal review of the Liberty Lifter program, which entered the concept definition phase last year with awards to GA-ASI and Aurora Flight Sciences.

The program was conceived in 2021 with two breakthrough goals: applying the shipbuilding industry's cheaper structural materials to a transport aircraft and mastering the autonomous algorithms required to safely fly a wing-in-ground-effect vessel slightly above rolling seas with waves up to 18 ft. high. But the original program also called for other advanced features, including a distributed, hybrid-electric propulsion system and C-17-size cargo volume.

"Could we build a slightly smaller airplane with the money that we've set aside and actually solve [those] problems?" Plaks asks. "So we're actually looking at the Liberty Lifter in particular to re-baseline that program."

A vertical-takeoff-and-landing (VTOL) X-plane funded by the Advanced Aircraft Infrastructure-Less Launch and Recovery (Ancillary) program also is in the concept definition stage, with multiple companies competing to design a MQ-9-size UAS that can operate from a destroyer-size ship. Finally, the Speed and Runway Independent Technologies (Sprint) project will seek to push the boundaries of high-speed VTOL beyond the 300-kt. speed of the Bell V-280, with a goal of achieving 400 kt.



Program Advanced Aircraft Infrastructure-Less Launch and Recovery (Ancillary)
Status Concept definition

Program Speed and Runway Independent Technologies (Sprint)
Status Concept definition

Watch *Aviation Week's webinar: "Explaining the Blended Wing Body":* **AviationWeek.com/webinars**

DARPA X-Planes That Never Flew

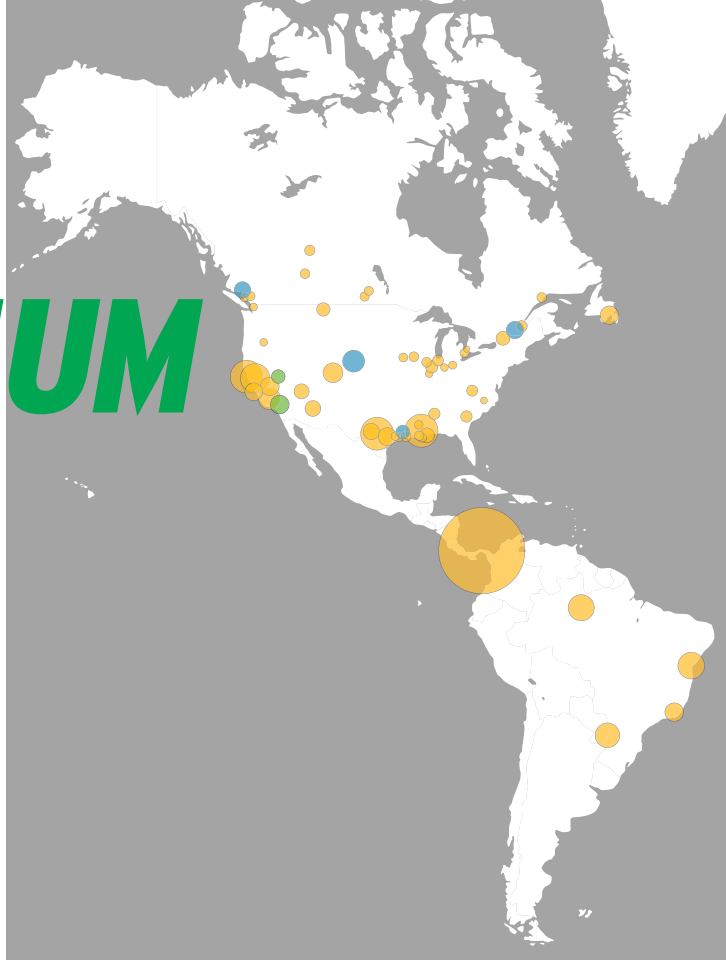
Name	Mission	Launched (fiscal year)
Unmanned Combat Armed Rotorcraft	Autonomous VTOL strike	2003
Peregrine UAV Killer	A high-speed UAV to intercept small UAS	2005
Walrus	Airship capable of C-130-size cargo transport	2005
Cormorant UAV	Sea-based UAV to provide close air support for frigates and submarines	2005
Oblique Flying Wing	Demonstrate oblique wing with laminar flow and articulated propulsion	2006
Heliplane	A VTOL aircraft with 350-kt. speed	2006
Heavy Lift	Optionally piloted VTOL airlifter capable of lifting C-130-size load	2007
Close Air Support Technology for Loitering Engagement	Loitering close air support aircraft	2007
Integrated Sensor Is Structure	High-altitude, lighter-than-air surveillance balloon	2007
Disc-Rotor Compound Helicopter	High-speed VTOL aircraft	2008
Rapid Eye	Rocket-launched, long endurance UAS	2008
Very-High Altitude, Ultraendurance, Loitering Theater Unmanned Reconnaissance Element	High-altitude pseudo-satellite	2008
Adaptive Morphing Super-Maneuver Aircraft	Aircraft featuring morphing control surfaces	2009
Transformer (TX)/Aerial Reconfigurable Embedded System (ARES)*	Launched as a flying car under TX, the concept evolved into ARES and an electric-powered VTOL airlift UAS	2010
XV-24A LightningStrike	Hybrid-electric VTOL UAS featuring distributed electric propulsion	2013
Tactically Exploited Reconnaissance Node	Sea-based UAS to support frigates and destroyers	2013
Petrel	Aerodynamic concepts to deliver brigade combat teams anywhere in the world within seven days	2014
XS-1	Reusable experimental hypersonic spaceplane	2015

*Lockheed Martin built an ARES aircraft, but the program was canceled before it flew.

Source: AW&ST Research

SUSTAINABILITY > Eliminating contrails **p. 44**

FUELING MOMENTUM



- > EU FINALLY ADOPTS SAF MANDATES
- > ETHANOL PRODUCERS CHALLENGE U.S. SAF CREDIT RULES
- > MORE FEEDSTOCK-TO-FUEL PATHWAYS ARE IN THE PIPELINE

Graham Warwick Washington

FUELED BY GOVERNMENT carrots and sticks, a wave of announcements promises to dramatically increase the availability of sustainable aviation fuel by 2030. Significant challenges still lie ahead—from raising the billions of dollars in financing these projects require to the likely cost of the fuel they will produce—but momentum is finally growing.

The principal drivers of that momentum have been government policies to incentivize the production and consumption of sustainable aviation fuel (SAF). On Sept. 13, the European Parliament finally voted to adopt the ReFuelEU regulation that establishes a blending mandate for SAF. Fuel suppliers must ensure that 2% of fuel made available at EU airports is SAF in 2025, increasing to 6% by 2030 and 70% in 2050. From 2030, 1.2% of fuel must be made using captured CO_2, rising to 35% by 2050.

In the U.S., the Biden administration's Inflation Reduction Act established a SAF blenders' tax credit of $1.25-1.75 per gallon. To qualify, the SAF must reduce life-cycle greenhouse gas emissions by a minimum of 50%. How this is calculated has sparked controversy. Instead of the model used by the International Civil Aviation Organization, the U.S. agriculture industry is lobbying for an Energy Department model that imposes a lower penalty on ethanol for changes in land use. A decision is expected in December.

Dozens of SAF production projects have been launched in anticipation of these incentives. Most plan to use well-established feedstock-to-fuel pathways including HEFA (hydroprocessed esters and fatty acids) from fats, oils and greases and alcohol-to-jet from waste CO_2. But eight production pathways have been approved so far by standards developer ASTM International, and many more are in the pipeline.

Air Company is developing a power-to-liquid pathway to produce SAF from captured CO_2 and green hydrogen in a single CO_2 hydrogenation step, avoiding the cost and complexity of conventional multistep Fischer-Tropsch (F-T) conversion. The CO_2-to-SAF efficiency is greater than 50%, compared with 20-30% for F-T, and the life-cycle CO_2 reduction is up to 100%, Air says.

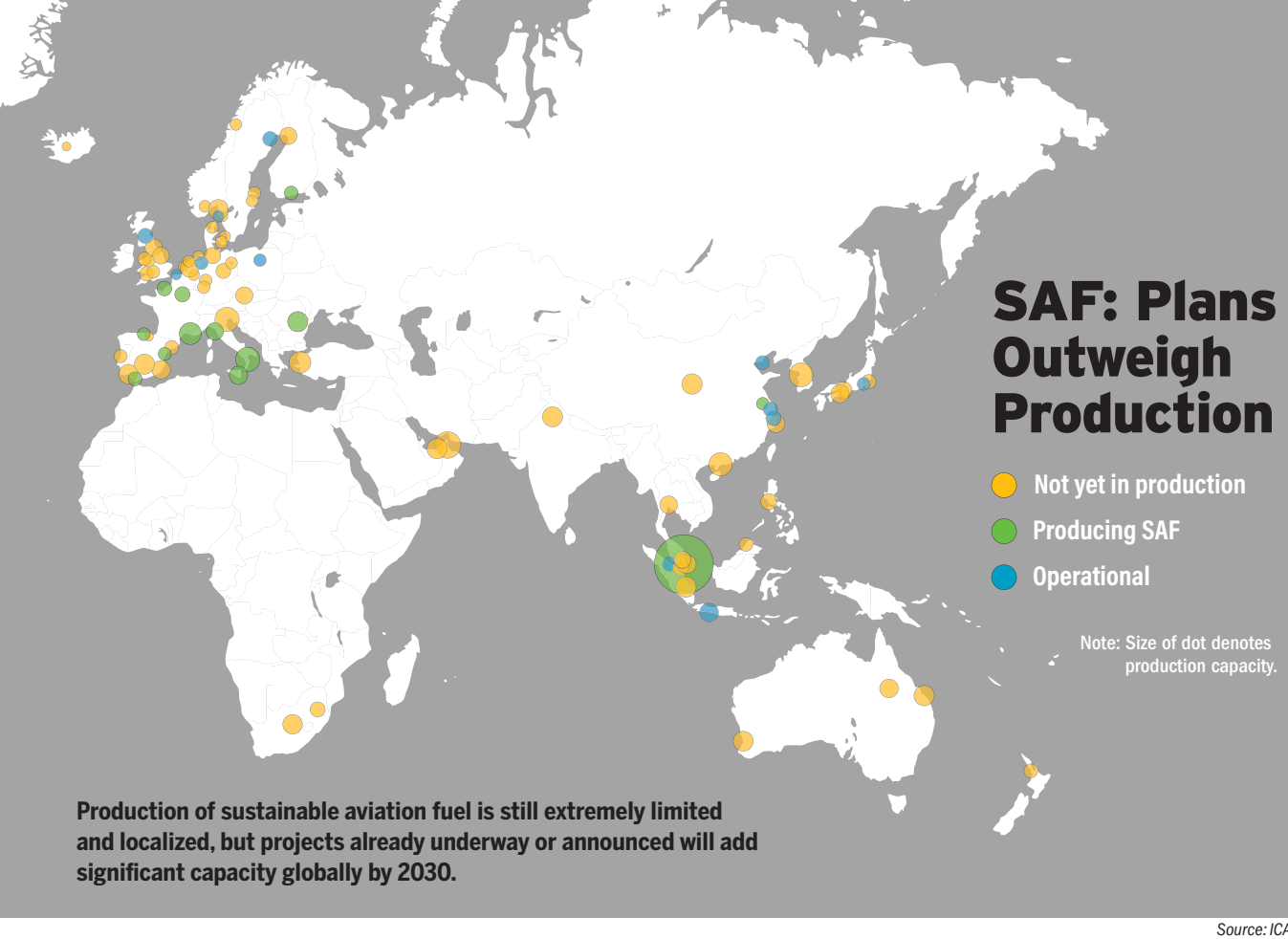
The CO_2 is sourced from industrial plants, cooled, pressurized and delivered as a liquid. The CO_2 and green hydrogen from water electrolysis are fed into Air's modular carbon conversion reactor, where a catalyst facilitates a chemical reaction producing a liquid that includes ethanol and methanol. The alcohols are then upgraded to liquid fuels. Air is operating a pilot-scale reactor and has produced a 100% SAF that was flight-tested by the U.S. Air Force in an uncrewed aircraft.

Alder Renewables plans to convert nonfood feedstocks including woody biomass, agricultural residues and purpose-grown energy crops such as miscanthus into a renewable crude that can displace fossil-based oil in the existing refinery infrastructure. Biomass is preprocessed, converted to fast pyrolysis oil and shipped to Alder for conversion to a low-to-negative-carbon biocrude that can be supplied to refineries.

Demonstration-scale production of Alder Renewable Crude (ARC) began in July at the National Renewable Energy Laboratory (NREL) in Colorado. The pilot-production unit, or skid, integrates all the operations required to produce renewable crude into a continuous process generating 1 barrel per day. Alder is pursuing ASTM approval and has demonstrated the viability of producing a 100% SAF using ARC.

Denbury is a U.S. enhanced oil recovery company that is proposing an ultra-low-carbon aviation fuel (LCAF) produced from "blue oil" extracted from depleted oil wells.

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



Production of sustainable aviation fuel is still extremely limited and localized, but projects already underway or announced will add significant capacity globally by 2030.

Source: ICAO

CO_2 captured from industrial sources is injected as a pressurized liquid into the well, where it scrubs the remaining oil off the rock. Brought to the surface, the CO_2 is separated from the oil and reinjected underground.

Ultimately 99% of the CO_2 brought to the field stays stored underground. The oil can be processed into conventional fossil aviation fuel, but the CO_2 sequestration during its recovery offsets the emissions. It takes 0.75 tons of CO_2 to recover a barrel of blue oil and total life-cycle emissions, including burning the fuel, is about 0.5 tons, Denbury says, so the net process is close to carbon-negative. The company is conducting a full life-cycle analysis in a bid to establish blue oil as a low-carbon fuel.

Process developer Honeywell UOP led development and certification of the HEFA pathway to produce SAF from waste fats, oils and greases. HEFA was the first SAF to enter commercial production in 2012 and remains the dominant pathway globally. Honeywell UOP has now introduced two more processes: ethanol-to-jet to produce SAF from ethanol sourced from corn, grains and sugar cane, and a methanol-to-jet process that converts methanol produced from CO_2 and green hydrogen into a sustainable electrofuel, or eSAF.

Oil-and-gas giant ExxonMobil also is developing a methanol-to-jet process and working with ASTM to gain approval for the LCAF pathway. The process uses methanol derived from the gasification of biomass and waste, as well as from lower-carbon hydrogen and captured CO_2. ExxonMobil says methanol is a stable energy carrier that can be stored in ambient conditions and, like crude oil, can be aggregated and shipped from small production sites to a large facility to produce the finished fuel.

India's Council of Scientific and Industrial Research—Indian Institute of Petroleum (CSIR-IIP) is developing a process to produce HEFA SAF, but in a single reactor with a single catalyst. Where today HEFA is purely paraffinic and must be blended, the fuel produced by the new process includes almost 8% aromatic hydrocarbons, making it a viable route to produce 100% SAF, says CSIR-IIP, which is working to gain ASTM fast-track approval for the pathway.

Under the Drop-In Liquid Sustainable Aviation and Automotive Fuel project, CSIR-IIP has operated a pilot-scale plant since early 2018, producing fuel from oils such as jatropha, pongamia and sapium. The fuel has been flight-tested in a 10% blend in an Indian Air Force Antonov An-32 and a 25% blend in a SpiceJet Bombardier Q400. India plans to have a demonstration-scale plant operational by 2025, with used cooking oils and rotation crops such as carinata as feedstocks.

The Massachusetts Institute of Technology (MIT) is developing a process to sustainably produce the aromatic fraction required for a 100% SAF from lignin, the nonreactive material that gives plants structural support and is left behind as waste when biomass is converted into ethanol. MIT has developed catalysts first to remove lignin from biomass to produce lignin oil and then to remove the oxygen to produce the aromatic hydrocarbons required in SAF to ensure fuel seals work properly.

MIT has demonstrated its process using biomass from poplar trees, viewed as a promising energy crop because they grow fast with little fertilizer. The resulting fuel has been tested by Washington State University, and MIT is working with the NREL to scale up the process. The next steps include testing to gain ASTM approval and exploration of other types of biomass, including pine, switchgrass and corn stover, the leaves, stalks and cobs left behind after harvesting.

CLEARING

> PRE-TRAILS PROGRAM WANTS TO PREVENT CONTRAIL CIRRUS

Graham Warwick Washington

Aviation's contribution to global CO_2 emissions from human activities is estimated to be about 2.1%. Non-CO_2 contributions such as contrails and aircraft-induced cirrus clouds are estimated to be higher, albeit with greater uncertainty.

But the impacts of non-CO_2 effects such as contrail cirrus on radiative forcing, the driver of the Earth's energy balance, are short-lived compared with direct CO_2 emissions. If contrails could be mitigated or eliminated, aviation could achieve a rapid and visible reduction of its climate impact.

The U.S. Energy Department has launched a program to demonstrate the ability to predict when aircraft contrails could form and persist to create climate-impacting cirrus clouds. The goal is to enable flight crews to avoid atmospheric conditions where persistent contrails can form.

A total of $10 million in funding is planned to be awarded to five teams under the Advanced Research Projects Agency–Energy's (ARPA-E) Pre-Trails exploratory program (for Predictive Real-time Emissions Technologies Reducing Aircraft-Induced Lines in the Sky).

ARPA-E is also making $30 million in funding available to spur development of energy storage systems with at least four times the energy density of lithium-ion batteries, sufficient to power a 100-seat, 700-nm-range all-electric regional aircraft with zero in-flight emissions and no contrails.

Under Pre-Trails, teams led by Boeing, GE Research, Northrop Grumman Systems, RTX Technologies Research Center and the Universities Space Research Association will develop diagnostic and predictive tools to enable mitigation of contrail-related climate forcing.

Condensation trails—contrails—occur when water vapor in the aircraft engine exhaust mixes with cold, humid air at high altitude. Most contrails dissipate in less than 10 min. and are not a concern, but in certain atmospheric conditions they can persist and produce clouds known as aircraft-induced cirrus (AIC) that can last for hours and spread over a wide area.

Persistent cirrus clouds can have a cooling or a warming effect, respectively reflecting sunlight back into space or trapping heat radiating from the Earth's surface that would otherwise escape to space. The dominant forcing effect is considered to be warming, and contrail cirrus is thought to contribute more than half of aviation's warming effect on climate.

Persistent contrails can form when an aircraft passes through an ice-supersaturated region of the atmosphere, triggering the formation of ice crystals that can grow and spread to create cirrus. "Pre-Trails is focused on increasing the accuracy of predicting whether a contrail will form, will persist and will form a cirrus cloud," says Peter de Bock, ARPA-E program director.

"I feel it's lower-hanging fruit that we can solve. By accurately predicting where the ice-supersaturated regions are and making sure we don't produce contrails, we will potentially be able to eliminate the global warming effects from contrails completely," he says. "And if it is equivalent to all CO_2 emissions, that must be about 2% of global warming, which will be incredible."

Pre-Trails has three areas of technical interest. The first is sensors on the aircraft "so that we can understand the humidity, pressure and any other conditions such that we can predict locally, but also ahead of the aircraft," he says. This is because the Schmidt-Appleman criterion describes specific temperature, pressure and humidity conditions where contrails can form.

The second area is data fusion "because there has to be a predictive element to this, as the cloud might form 5-10 hr. later," de Bock says. "We have to keep track of that data and keep observing that space" so the formation of cirrus cloud can be correlated with the generation of contrails. The third area is observation of the atmosphere to train and to validate predictive models.

Taken together, the target for Pre-Trails—what is called the F1 score—is an accuracy of prediction of 80% or greater. "Current estimates from other research seem to indicate we're incorrect 90% of the time," de Bock says. "So you can't really act on anything, because flight path deviations will increase CO_2 emissions, and you're not really sure you're doing it for the right reasons.

"We want to increase the accuracy of predicting whether we are going to produce cirrus clouds to where it can be acted upon in the future," he says. At the end of the Pre-Trails program, teams are required to demonstrate this accuracy of at least 80% for a period of 5-12 hr. after the passage of the aircraft.

Teams are also required to demonstrate a minimum of five positive predictions of persistent AIC for relevant flights at cruise altitude while satisfying the F1-score criterion. "So teams have to either monitor active flights

THE SKIES

> PROPEL-1K PROJECT AIMS TO ELECTRIFY REGIONAL AIRCRAFT

ARPA-E-funded research projects target the avoidance of persistent contrails that spread to form climate-impacting cirrus clouds.

UK MET OFFICE

or fly their own aircraft to demonstrate that 80% accuracy," he says. "We felt we needed that to ensure it's not an academic effort and will lead to a real demonstration."

The five teams selected to negotiate contracts for the single-phase, 18-month Pre-Trails program are:

- Boeing ($2.5 million), to develop a comprehensive approach that leverages satellite observations, deep learning, an onboard humidity sensor and a numerical weather prediction model and that can be used during flight planning to mitigate aircraft-induced cirrus.
- GE Research ($1.5 million) with Southwest Airlines, to develop a real-time inflight prediction system that combines engine operational data, a hybrid physics and machine-learning model, on-aircraft data and real-time satellite observations to predict AIC that lasts more than 5 hr.
- Northrop Grumman ($2.5 million), to develop a contrail avoidance system to scout optimal altitudes. This includes a new airborne radiometric temperature and humidity sensor to measure environmental conditions above, below and in front of the aircraft and enable crews to avoid regions conducive to long-lived cirrus formation minutes before entering the area.
- RTX ($2.5 million), to develop a platform able to provide a physics-informed forecast of AIC potential 100 km (54 nm) ahead of the aircraft by up to 10 min. using an onboard lidar sensor for water vapor. This could be installed on a small fraction of the aircraft in a fleet to furnish data and predictions for the entire fleet.
- Universities Space Research Association ($1 million), to improve an existing contrail computer model with a novel machine-learning approach to develop a real-time, cloud-based prediction and observation system that would produce forecasts of persistent contrail-forming regions and provide new atmospheric data services.

ARPA-E's Propel-1K program (for Pioneering Railroad, Oceanic and Plane Electrification with 1K Energy Storage Systems) meanwhile aims to develop technologies with energy densities of at least 1,000 Wh/kg and 1,000 Wh/liter at end of life.

Typical values for lithium-ion batteries in electric vehicles and initial electric aircraft are 285 Wh/kg and 650 Wh/liter at the cell level, says ARPA-E, noting these figures are for beginning of life and assume the full state of charge of the battery is used.

Other program objectives for Propel-1K include a turnaround time of 30 min. or less, discharge energy efficiency of at least 70%, target storage system size of 1-100 megawatt hours, emissions from system manufacture of no more than 100 kg CO_2/kWh and zero emissions of CO_2, nitrogen oxides or sulfur oxides during operation.

Specific objectives for aircraft systems include a peak power of at least 1.5 kW/kg for 3 min., continuous power of at least 0.5 kW/kg, energy storage cost of not more than $0.30/kWh and a system voltage of 1,000 volts or higher.

Pack-level energy density for lithium-ion energy storage systems (ESS) can be up to 25% less than for the individual cells because of the need for structural enclosure, crash protection, thermal runaway containment and battery management.

Propel-1K dismisses package constraints "and instead considers the extent to which removing the restrictions imposed by conventional materials and practices for energy storage packaging permits approaching the theoretical energy densities of a chemical or electrochemical system," ARPA-E says. "As the constraints of classical energy storage thinking are reconsidered, operating temperature, fuels versus oxidizers, energy versus power and the physical boundaries of the ESS are all subject to being redefined," the agency says, noting the possibility of integrating the ESS into the vehicle's structure.

Technical areas of interest to ARPA-E include batteries and fuel cells, rapidly swappable batteries or energy boxes, mechanically rechargeable solutions such as replaceable anodes, platforms that separate energy and power, pumpable electroactive slurries and systems that use external catholytes such as air.

The Propel-1K program is planned to have two phases. In the first phase lasting 18 months, performers are required to experimentally show that at least 1,000 Wh/kg and 1,000 Wh/liter can be achieved at the chemistry level.

In the second phase also lasting 18 months, selected performers from Phase 1 are required to construct an experimental unit of at least 1 kWh energy storage capacity and confirm at least 1,000 Wh/kg and 1,000 Wh/liter at the packaged unit level.

This unit is required to demonstrate 100 recharge cycles, reuses or refills with no more than 5% performance loss between the first and 100th cycles. Peak power capability must be shown for 50% of the required duty cycle or 90 sec. for an aircraft system.

NASA Sets Off on a Voyage To Explore a Metal World

- METAL BODY COULD BE THE REMNANT CORE OF AN EARLY PLANET
- DEEP-SPACE OPTICAL COMMUNICATIONS TEST IS PLANNED

Irene Klotz Cape Canaveral and **Mark Carreau** Houston

Lindy Elkins-Tanton, the principal investigator for NASA's upcoming mission to the asteroid Psyche, sheepishly confesses that the $10-quadrillion estimate of the value of iron, nickel and gold contained in the asteroid—a figure cited in *Forbes*, Reuters and other financial news outlets—came from her.

Elkins-Tanton, a planetary scientist at Arizona State University in Tucson, calculated the value based on the selling price of metals today and the estimated mass and composition of Psyche, one of nine known metal bodies in the main asteroid belt between Mars and Jupiter.

"It was a fun intellectual exercise," Elkins-Tanton told reporters during a prelaunch press conference on Sept. 6. "We have zero technology to bring Psyche back to Earth. And if we did, it would likely be a catastrophic mistake . . . because we would flood the metals market, and it literally would be worth nothing.

"We are not going there to mine an asteroid," she added. "There are other metal objects in the Solar System for humans to think about in the future, but that's not our mission."

The driving force behind the mission, also named Psyche, is purely scientific discovery. "We have never seen a body with a largely metal surface, [which] is what we think Psyche is," she said. "That's one of the things that make it such an important primary exploration destination and so exciting—because we don't know what we are going to see."

Distant observations suggest the asteroid has an extremely dense composition of iron, nickel, silicon and oxygen all compressed into a potato-shaped object that is 144 mi. long and 173 mi. wide.

Though Psyche orbits between Mars and Jupiter, it is not clear whether the object formed in the distant Solar System during the planet-forming era or if it evolved close to the Sun and then migrated outward. Scientists suspect Psyche could be a partially formed planet or the remnant of a fully formed planet whose outer layers were shattered away by multiple collisions with other protoplanetary objects when the Solar System was just 10-20 million years old.

The mission will attempt to resolve Psyche's mysterious origins and provide data to better understand how planets and rocky bodies, including Earth, separated into core, mantle and crust. The information also could help answer if the chemical building blocks for life are indigenous to planets, rather than delivered later by impacting comets and asteroids.

If Psyche is not the core of a dead planet, the metal ball might be something even more bizarre: a body that came together in a part of the inner Solar System so rich in primordial metals that it had little rock from the beginning, creating a body that never melted. "That is chemically and physically plausible, but we have no samples of such an object, no evidence that such an object would exist," Elkins-Tanton said in an earlier interview. "My secret hope is that we get there and it turns out that's what it is and not a core, because that would be just mind-blowing."

Following launch, the spacecraft and its science instruments are to undergo a 100-day checkout as it begins a 2.2-billion-mi. journey to Psyche. The outbound segment is to include a Mars flyby in May 2026, where the probe is to receive a gravitational boost to set up the spacecraft's arrival at Psyche in August 2029 to begin a 26-month primary mission.

BEN SMEGELSKY/NASA

NASA's Psyche spacecraft, pictured at the Astrotech Space Operations Facility near the Kennedy Space Center, during preparations for an October launch.

Scientists plan to lower the spacecraft's orbital altitude in stages to 40 mi. from 440 mi. to provide increased scientific insight into the asteroid's core.

With an array of imagers, a magnetometer and a spectrometer to detect gamma rays and neutrons emitted from the asteroid's surface, the probe aims to collect data to help scientists learn if Psyche is a core or primordial object, whether it froze from the inside out or outside in, whether it ever had a magnetic field and if any patches of rock on its surface are the splattered remains from the destroyed parent body or due to later impacts.

NASA had hoped to launch the spacecraft in August 2022 but postponed the mission to resolve issues with verifying the flight software, among other problems. The delays increased mission costs almost 20% to an estimated $1.2 billion.

Earlier this year, a 16-member independent review board assembled by NASA attributed delays in the mission's flight software development and in testing of flight equipment to staffing shortages, a lack of personnel with sufficient experience at all organization levels in the development effort, poor communications, hybrid work schedules, operational readiness and shortcomings in programmatic metrics. The organizational response to the COVID-19 pandemic was a factor as well.

With the shift in launch dates and a new trajectory, two secondary science missions that were to ride with Psyche were removed from the manifest. A third experiment remains onboard: the Deep Space Optical Communications, a technology demonstration to test the viability of future deep-space exploration missions that use lasers for high-speed communications with mission support teams on Earth.

Psyche's 20-day launch window opens at 10:38 a.m. EDT on Oct. 20. The spacecraft is due to fly onboard a SpaceX Falcon Heavy rocket launching from Kennedy Space Center. "One month out, we are in great shape," says Laurie Leshin, director of NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, which is overseeing the mission.

"We are counting the days," added Henry Stone, a JPL project manager.

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AVIATION WEEK NETWORK

Amid Capacity Gap, Europe Advances Ariane 6 Launcher Project

> VULCAIN AND VINCI ENGINES PASS MAJOR TESTS

> EUROPE RESORTS TO SPACEX FOR SCIENCE MISSIONS

Thierry Dubois Lyon

Recent successes in the development of Ariane 6 are good news for the medium- to heavy-lift launcher program, meaning innovative ideas are materializing. However, the inaugural launch will happen about four years late. The wait has contributed to a serious predicament in access to space for Europe, where the sector and its institutional customers have yet to find solutions.

As delays built up, Soyuz was designated to replace Ariane 6 for some launches. Soyuz was part of Arianespace's portfolio under a Euro-Russian agreement, and its payload capacity was suitable. Just like the medium-size Ariane 62 variant, Soyuz could have accommodated spacecraft for European institutions such as national governments and the European Commission. Then in February 2022, Russia invaded Ukraine, and the accord was terminated.

Meanwhile, Vega-C, the upgraded version of the existing Vega, was facing serious teething troubles. After a launch failure in 2022 came an anomaly during a test of the Zefiro 40 engine last June, and plans for return to flight have yet to be issued. Vega-C could have been a candidate for some institutional payloads.

As for the light Vega, only two examples remain to be launched before Vega-C takes over. The final Ariane 5 was launched in July.

The Vulcain 2.1 engine successfully ran for 4 sec. on the launchpad in Kourou, French Guiana.

CNES/ESA/ARIANEGROUP/ARIANESPACE/OPTIQUE VIDEO DU CSG-S. MARTIN

Europe now finds itself with virtually no sovereign access to space. Strategic autonomy is still a long-term goal, but in a vexing short-term resolution, archrival SpaceX is reaping the fruits of Europe's launcher crisis.

Two science missions, Euclid and EarthCare, have been or will be launched on a Falcon 9, officials in Europe's space launcher industry said during a joint press conference Sept. 4. For the French government, a military observation satellite, CSO-3, may be launched on Ariane 6, but that plan is still tentative. For the Galileo positioning constellation, several satellites are waiting for a launcher.

Major tests of Ariane 6 have taken place recently, and more are to come in the next few weeks. As the development program enters the final stretch, the results of the trials will enable officials to announce a launch period in 2024. The inaugural launch with an Ariane 62 is still part of the development phase, and the first commercial launch will come about six months after. The first commercial customer has yet to be determined, said Stephane Israel, CEO of launch service provider Arianespace.

The Ariane 6 Launcher Task Force, which held the press conference, has been working on the program's plight and has regularly met at the top management level, European Space Agency (ESA) Director General Josef Aschbacher said. Represented on the task force are ESA, the overall Ariane 6 procuring entity and launch system architect; French space agency CNES, the launch base prime contractor; ArianeGroup, the launcher system prime contractor; and Arianespace.

The Vulcain 2.1, the main stage's engine, successfully ran for 4 sec. of stabilized operation on Sept. 5. On the launchpad in Kourou, French Guiana, the test capped a thorough trial with the so-called combined test model of Ariane 6. The 26-hr. exercise represented a launch sequence and also included removal of the mobile gantry, as well as filling the launcher's upper and core stage tanks with liquid hydrogen and liquid oxygen.

In addition to checking prelaunch procedures and ignition, the tests showed that the system can be kept safe in the event of a launch abort, ESA said. A 470-sec. hot-fire test of the Vulcain 2.1 is scheduled for Oct. 3. It will cover the entire flight phase of the main stage.

At German aerospace center DLR's test facility in Lampoldshausen, Germany, the inaugural flight was simulated for the upper stage. Known as Hot Firing Test 3, the Sept. 1 trial involved 680 sec. of operation of the Vinci engine. In parallel, the auxiliary power unit (APU) was operated for a cumulative 30 min. The APU, a part of the upper stage, supports the engine's ability to reignite and deliver payloads on different orbits, among other roles.

Later this fall in Lampoldshausen, Hot Firing Test 4 will include degraded modes for the upper stage.

The tests in Kourou and Lampoldshausen—and ensuing data analysis—are expected to provide answers for the remaining uncertainties in the development.

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AVIATION WEEK NETWORK

ORBITAL OUTPOSTS

- PRIVATE SPACE STATIONS PREPARE FOR LEO OPERATIONS
- SPACEX PITCHES FREE-FLYING STARSHIP STATION
- NANORACKS AND AXIOM CITE ISS EXPERIENCE

Irene Klotz Cape Canaveral

More than 50 years ago, the world's first space station reached low Earth orbit. Salyut 1 set the stage for a series of outposts culminating in the International Space Station, a project of 15 nations—and a growing cadre of companies selling research, manufacturing, educational, tourism, transportation and other services in space.

For the next 50 years—and beyond—NASA is counting on buying low Earth orbit (LEO) services, including housing for astronauts, from this nascent and promising industry. "It's an extraordinarily exciting time," says Jeffrey Manber, co-founder of Nanoracks, the first company to set up shop on the International Space Station (ISS), where it offers payload hosting, cubesat launching and other services to NASA and various customers.

"We will be successful this time in something that we have been very bad at in the past—a seamless transition from an existing program to ensure continuity in low Earth orbit," he tells Aviation Week.

"We were very bad with Skylab, we were bad with the space shuttle, and we were bad with the human crew," he notes, referring to gaps after every U.S. human spaceflight program following the foundational 1961-72 Mercury-Gemini-Apollo missions.

NASA does not plan to own or operate a station in LEO again. Instead, before the ISS is decommissioned, targeted for 2030, the agency wants to buy services from commercial outposts in LEO. Its mantra and mission: to be one of many customers.

"I applaud Congress and several administrations for having the foresight to begin to implement the transition from the government-owned-and-operated ISS to a new chapter, where there will be multiple, private space station operators in LEO," says Manber, who now serves as president of international and space stations at Voyager Space, which acquired Nanoracks in 2021.

Toward that goal, NASA has made direct investments in four proposed private space stations and agreed to work on two more planned outposts through unfunded Space Act Agreements under the agency's Collaborations for Commercial Space Capabilities technology development program.

Voyager Space is teamed with Lockheed Martin and, most recently, Airbus on a private space station known as Starlab, which is targeted to launch in 2028-29. With a 26-ft.-dia. module, the multilevel Starlab is designed to launch onboard a Blue Origin New Glenn or SpaceX Starship, both of which can accommodate higher-diameter payloads than current and other planned launch vehicles. The ISS laboratory modules, for example, are 14-15 ft. in diameter.

Starlab, which is designed to house a crew of four, is expected to reach initial operational capability with just one launch. For reference, assembly of the ISS took more than 40 flights. "We're doing everything we can to make Starlab efficient and useful," Manber says.

That includes positioning Starlab at a lower-inclination orbit than the ISS, which circles Earth 51.6 deg. north and south of the equator. The ISS' orbital inclination was chosen to accommodate launches by partner Russia from the Baikonur Cosmodrome in Kazakhstan, located at 45.6 deg. N. Lat.

The intertwining of the U.S. and Russian human spaceflight programs began in 1994 with the Shuttle-Mir astronaut-cosmonaut exchange program. Post-ISS, Russia intends to build a new space station on its own, while NASA and the remaining ISS partners Europe, Japan and Canada—and possibly some newcomers—plan to collaborate in LEO with commercial operators. China also operates a station in LEO.

"We want to be in a more commercially efficient orbit, one that is of greater use to partners," Manber says, referring to Starlab's planned 38-42 deg. inclination.

AXIOM SPACE

Thales Alenia Space is building the first two pressurized modules for the Axiom Space Station.

"It puts us in [reach from] India, Japan, Europe—all the places that have launches or are expecting to," he adds. "It's probably not as good for polar and some higher-inclination launches, but that's a very minor point."

Voyager Space in July signed an agreement to explore using India's upcoming Gaganyaan crewed transportation system to service Starlab, which would be reachable from the Satish Dhawan Space Center in Sriharikota, located at 13.7 deg. N. Lat. The Indian Space Research Organization is preparing for the first of two uncrewed Gaganyaan flight tests, which are expected to be followed by the first crewed launch from India, possibly in late 2024.

Voyager Space's Nanoracks won the largest of three NASA Commercial LEO Destinations (CLD) awards in December 2021, the first phase of a planned two-phase program intended to provide NASA with options for continuing microgravity research, technology testing and astronaut training in LEO before the end of ISS operations.

In addition to Voyager Space's $160-million Space Act Agreement, NASA signed with Blue Origin for $130 million and with Northrop Grumman for $125.6 million for early design work on two more stations. The contracts followed NASA's February 2020 firm, fixed-price, indefinite-delivery, indefinite-quantity award to Axiom Space, worth up to $140 million, for development of at least one commercial module to be attached to the ISS. Axiom plans an initial four-module station that would detach to become a free-flyer before the ISS is removed from orbit.

NASA also is working with startup Vast Space and with SpaceX on two more private space station projects, the latter of which proposes to use a variant of the Starship to become a free-flying outpost in LEO. NASA already is dependent on the Starship program to provide a lunar landing system for astronauts to use during the first crewed mission to the Moon under the Artemis program, targeted for late 2025.

All the aspiring station operators would be eligible to compete for Phase 2 of the CLD program, expected around 2025, when NASA intends to select two or more companies for additional development funds and flight service contracts.

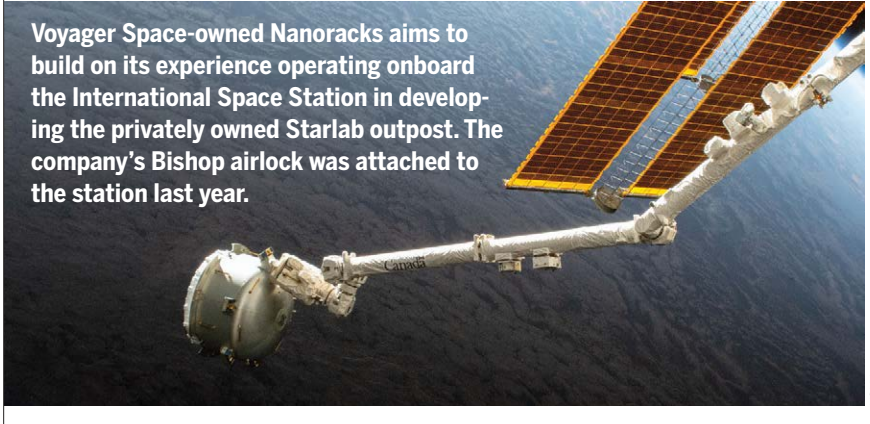
"A phased approach allows NASA to explore designs that are mutually beneficial to NASA and industry. It also helps to reduce risk by enabling industry to mature concepts and NASA to mature future requirements prior to the commitment of a services contract," the agency noted in a letter to the independent NASA Advisory Council's Human Exploration and Operations Committee.

The committee has urged NASA—the anchor tenant for the CLDs—to specify its demand for LEO services as soon as possible. "A firm commitment by NASA will be essential in enabling the CLDs to attract additional customers and close the business case," the panel said in a 2022 recommendation to NASA.

Phase 1, which is expected to run through 2025, is considered a period of "formulation and design by private industry, in coordination with NASA, of CLD capabilities determined to be most suitable for potential government and private sector customer needs," NASA noted.

CLD Phase 2, which is slated to in-

Voyager Space-owned Nanoracks aims to build on its experience operating onboard the International Space Station in developing the privately owned Starlab outpost. The company's Bishop airlock was attached to the station last year.

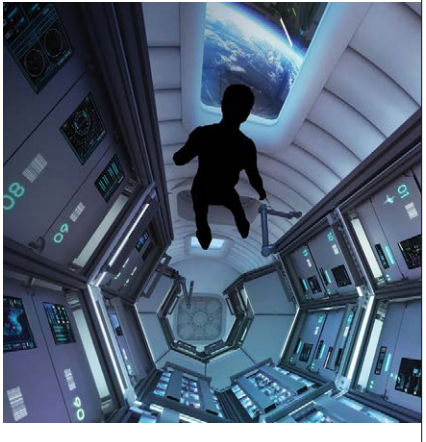


NASA

SpaceX has an unfunded Space Act Agreement with NASA to study using its Starship spacecraft as a free-flying station in low Earth orbit.

SPACEX

clude NASA certification, is planned to be a competitive procurement for LEO services that include transportation and accommodation of NASA crews and payloads to and from Earth, as well as trash disposal. Initially, the agency is looking to fly at least two NASA crewmembers on-orbit continuously and perform about 200 research experiments. The goal is to have one or more CLDs providing services by 2028, which should provide a two-year overlap with the ISS.



BLUE ORIGIN

Blue Origin and Sierra Space lead the Orbital Reef program, which intends to build and operate a large, multipurpose space station that can house up to 10 people at a time.

"We know that this strategy is a major paradigm shake from what we've done before and we know it's going to take different ways of doing business to be successful," Angela Hart, program manager for the Commercial LEO Development Program Office at NASA's Johnson Space Center, said at the ISS Research and Development Conference in Seattle in August.

"Building safe, reliable and cost-effective space stations is going to be hard. We have a lot of experience, we know we can meet the technical challenges, but operating these CLDs and sustaining them in a profitable, business-making enterprise may even be harder . . . than what we've done on the ISS.

"Understanding the challenges that businesses have to make this a reality is going take a big change in how we look at things and how we work with our partners," she added.

Nanoracks, which has flown about 1,400 experiments to the ISS for a variety of customers, estimates costs could be reduced 30-40% by operating on a private station such as Starlab. "We're very conservative," Manber says. "We don't put into our numbers how quickly the cost of space transportation is probably going to drop. And transportation, ballpark, is half our cost.

"If transportation [cost] does indeed come down, then these platforms probably become far more sustainable, but we don't assume that in our calculations," he adds.

Like Nanoracks, Axiom has already begun commercial operations onboard the ISS. The Houston-based company, run by former NASA ISS program manager Michael Suffredini, is flying private astronaut and research missions, with transportation and training provided by partner SpaceX. "We're starting to see some really interesting results from some experiments and capability that we've been flying as part of these private astronaut missions," Axiom's Chief Technology Officer Matt Ondler tells Aviation Week.

"There's great technical advantage to build a space station off an existing one," he adds. "It's kind of like going camping and you have running water and electricity. We don't have to have every system matured on the first flight, so it allows us to upgrade over time."

The companies' initial funding from NASA is a small fraction of the capital investment needed to develop and fly the station. For now, the government's buy-in adds credibility as the companies build customer and supplier bases. Having a sound business plan will be key for winning a CLD Phase 2 award.

"Early on, it's hard to support more than one or two space stations," Ondler says. "Long term we believe the market and the opportunities are huge. The things we're going to manufacture and build in space are going to change the world, so there is room for lots of space stations."

Northrop Grumman plans to parlay its Cygnus cargo craft and other systems into free-flying platforms in low Earth orbit. Northrop's latest Cygnus capsule reached the International Space Station on Aug. 4.

NASA

Debris Collision Highlights Danger of Tiny Objects in Orbit

- 100 MILLION PIECES OF DEBRIS ABOUT 1 MM OR LARGER IN DIAMETER ORBIT EARTH
- EVEN PAINT FLECKS CAN CAUSE SERIOUS DAMAGE

Garrett Reim Seattle

In a perfect advertisement for its services, ClearSpace, a Swiss startup focused on space debris removal, says a fast-moving small piece of junk hit a leftover payload adapter floating in Earth's orbit—one it had planned to remove.

Observing two pieces of space junk collide is rare.

"The frequency at which something observable happens like this event is pretty low," says Greg Henning, project leader with The Aerospace Corp.'s Center for Orbital and Reentry Debris Studies. "We really only see something like this once every year or every couple years or so."

According to NASA, more than 23,000 pieces of space debris larger than a softball orbit Earth. There are approximately 500,000 pieces of debris at least 1 cm in diameter and an estimated 100 million pieces measuring at least 1 mm.

The object that hit ClearSpace's target payload adapter was likely small.

"We're talking, like, millimeter size—less than a centimeter—really, really small stuff," Henning says.

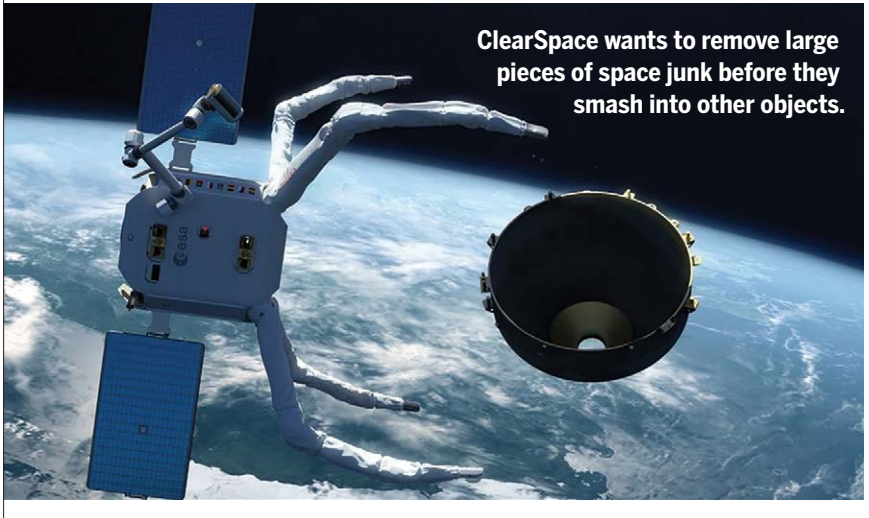
Even small paint flecks—traveling at speeds up to 17,500 mph—can cause damage, NASA says. The space agency notes that multiple space shuttle windows had to be replaced after being hit by tiny paint chips.

ClearSpace says an early analysis of the debris created by the collision with the payload adapter appears to show "extremely low" risks for other missions but adds that "a full analysis will last for several weeks."

ClearSpace plans on its first mission to use a spacecraft with four robotic arms to remove the 112-kg (247-lb.) Vega secondary payload adapter (VESPA) left in a 664-801-km (413-498-mi.) orbit after an Arianespace Vega launch in 2013. That upcoming mission, commissioned by the European Space Agency (ESA) and dubbed ClearSpace-1, is scheduled to launch in 2026.

ClearSpace says it first heard of the impact on its VESPA target from the ESA's Debris Office, which learned of it on Aug. 10 from the U.S. Space Force's 18th Space Defense Sqdn., which had detected new objects near the payload adapter.

The 18th Space Defense Sqdn. operates the U.S. Space Surveillance Network (SSN), a worldwide group of ground- and space-based sensors created to track all human-made objects in Earth's orbit. The SSN tracks objects as small as 5 cm in low Earth orbit, but new methods are needed to spot smaller debris.



ClearSpace wants to remove large pieces of space junk before they smash into other objects.

CLEARSPACE

Of the more than 100 million objects greater than 1 mm orbiting the Earth—debris that can cause mission-ending damage—less than 1% is currently tracked, says the Intelligence Advanced Research Projects Activity (IARPA), the research and development arm of the Office of the Director of National Intelligence.

IARPA aims to track the smallest of space junk. On Aug. 29, it said it had granted a new Space Debris Identification and Tracking (Sintra) contract to Colorado-based tech company Advanced Space to use machine learning to find and identify space debris 1-10 cm in size.

Advanced Space says it plans to detect debris using data from the ExoAnalytic Global Telescope Network, ground-based radar, space-based ionospheric measurements and ground-based ionospheric measurements, with a machine-learning program to help make sense of the differing data.

"Machine-learning methods allow us to extract information from weak signals, decreasing the minimum signal-to-noise ratio needed for useful observations," says Nathan Re, Advanced Space principal investigator for the Sintra program.

Debris removal companies like ClearSpace and Japan's Astroscale—as well as the space agencies behind them—hope chucking larger pieces of floating garbage into the atmosphere for incineration can delay the dreaded Kessler Syndrome: "a point in which there's enough debris on orbit that future collisions would occur at a rate faster and generate debris at a rate faster than the atmosphere could burn them up and remove them from orbit," Henning says. "There's already evidence that that's the case," he says. "Now, the timeframe of [making space unusable], we're talking many decades or hundreds of years."

Yet with mega-constellation companies such as SpaceX, Amazon and China SatNet projected to collectively launch tens of thousands of satellites over the next 10 years, minding debris and finding ways to clean it up is becoming even more important.

"Taking this VESPA object out of orbit doesn't work a miracle on cleaning up space, but it gets you that one step closer to be able to do the bigger stuff," Henning says. "It's a really important step."

Megawatt-Class Electric Motor Shown Safe at High Voltage, Altitude

> OPERATED AT SIMULATED 50,000 FT. WITHOUT PARTIAL DISCHARGE

> DEMONSTRATED HIGH-SPEED AND HIGH-CURRENT CAPABILITY

Graham Warwick Washington

A multiuniversity U.S. team has demonstrated a megawatt-class electric motor at simulated high altitude in a NASA test facility, showing the ability to protect against insulation breakdown at high voltage and low air pressure—a key concern for high-power electrics in commercial aircraft.

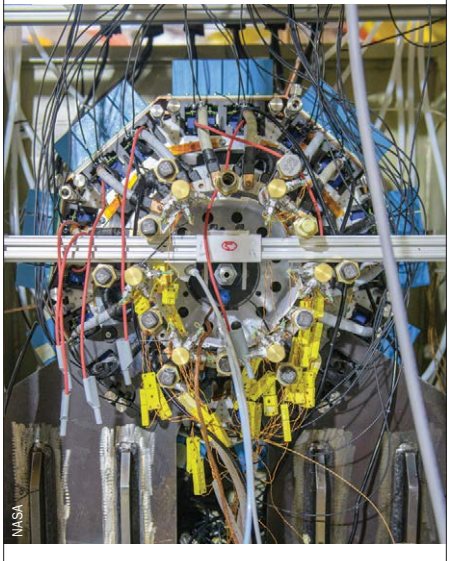
The Integrated Modular Motor Drive (IMMD) was developed under a NASA-funded University Leadership Initiative (ULI) project led by Ohio State University (OSU). A 2-kilovolt, 1-megawatt motor drive operating at 20,000 rpm, the complete system has an "unprecedented" power density of 9 kW/kg including 40-kHz silicon-carbide inverters and polyalphaolefin liquid cooling, the team says.

For several reasons, the university-built IMMD prototype did not achieve the intended 1 megawatt of power in the NASA Electric Aircraft Testbed (NEAT) in Ohio. But the machine ran at full speed and at a simulated 50,000 ft. altitude without partial discharge, which were major outcomes, says Jin Wang, professor of electrical and computer engineering at OSU and leader of the five-year ULI project.

Megawatt-scale motors are viewed as a building block in the electrification of aircraft propulsion, being large enough to power electric regional aircraft and enable the hybridization of commercial aircraft. They are also a steppingstone toward the higher power levels needed for electric airliners—from 22 megawatts for a 150-seater to 60 megawatts for 300 seats.

In developing and testing the IMMD, the ULI also studied partial-discharge mechanisms for high-voltage systems. "We made a lot of discoveries and identified measures to detect and prevent partial discharge at altitude," Wang says. The researchers are working with U.S. power electronics manufacturers and system integrators to improve their designs with the knowledge gained.

At high altitude, where ambient pressure is low, the breakdown voltage of air decreases significantly and partial discharge, or localized insulation breakdown, can occur on parts of the drive that are exposed to air, such as connectors, busbars, printed circuit boards (PCB) and cables. Partial discharge can damage insulation, cause strong electromagnetic interference and create hot spots.



Access issues following installation of the 1-megawatt motor in the NEAT caused test challenges.

Partial discharge is a result of electric field (e-field) stress. "The breakdown at normal air pressure is 30 kilovolts/cm . . . and the breakdown at the altitude we were testing at is one-third of that voltage," Wang says. "Our design showed that at all our critical points, e-field stress was less than 10 kilovolts/cm."

The ULI pursued multiple approaches to reduce e-field stress on insulation materials. One is the modular architecture. The IMMD has three stages connected in series. Each stage has two three-phase motor drive units connected in parallel. With the 2 kilovolt rating, each stage has an input voltage of 667 volts. This reduces voltage stress and provides redundancy. One stage can still drive the motor with reduced power.

The team also developed partial-discharge-free designs. "We built generic models and used them for simulation and hardware validation. Then eventually, once the generic models gave us good results not only in simulation but also in testing, we finalized our design with the real busbars, PCBs, etc.," he said.

The models identified locations with the highest possibility of induced partial discharge. These were capacitor pins, busbar edges and input connectors. The insulation design for these weak points was then optimized in terms of thickness, surface creepage distance and arc gap distance.

The team also developed a system to detect partial discharge. "First we used coupons to generate real partial discharge and showed we could detect it," Wang says. "The reason we did that is NEAT is a large facility. With the machine and other supporting equipment running at the same time, whether we could detect partial discharges effectively or not was something we had to validate. By using the test coupon we validated our system can work properly in a very noisy environment. Then we performed the test on the IMMD, and the system did not detect any partial discharges."

In tests, the IMMD did not achieve full power, reaching only 250 kW. One reason was its installation in the NEAT, which prevented access to submodules that failed after the motor was mounted on its support plate. This was combined with a control software problem that caused the current to oscillate and peak at 600 amps when only 200 amps were commanded, and an alignment issue between the dynometer and machine that caused jittering of the shaft. NASA will address the latter when it relocates the NEAT.

"Everything was designed and fabricated by university teams. As a first prototype from a university, it's difficult to realize the final power rating, but we had very safe operation all the time. Even though we had failed modules, we were still able to push this to full speed and significant current," says Wang. "This shows the integrated motor drive approach is very promising for aircraft. It also shows the modular structure provides redundancy and fail-safe capability, and it enables us to upgrade the motor."

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MACIEJ HATTA

AVIATION WEEK NETWORK

UNDER PRESSURE

- HIGH-SPEED ROLES PUSH ROTATING DETONATION DEVELOPMENT
- RDEs STUDIED FOR COMPACT HIGH-MACH MISSILES
- CONCEPT YET TO SHOW MEASURABLE PRESSURE GAIN

Guy Norris Colorado Springs

As part of the never-ending drive for better propulsion performance, improving combustion efficiency remains an aspiration for developers of air-breathing engines and rockets.

One approach, which addresses the fundamental physics at the heart of the combustion process, continues to gain traction. Although they have yet to demonstrate their full thermodynamic potential, rotating detonation engines (RDEs) are undergoing tests for initial propulsion roles ranging from compact, high-speed missiles to improved upper-stage rocket engines.

Theorized for decades, pressure-gain combustion devices like RDEs offer the prospect of significantly improved efficiency by detonating the fuel mixture instead of conventionally burning it in a slower thermal radiation and diffusion process called deflagration. The detonation forms a shockwave, effectively containing the expanding reactant gases at a near-constant volume and thereby increasing its pressure.

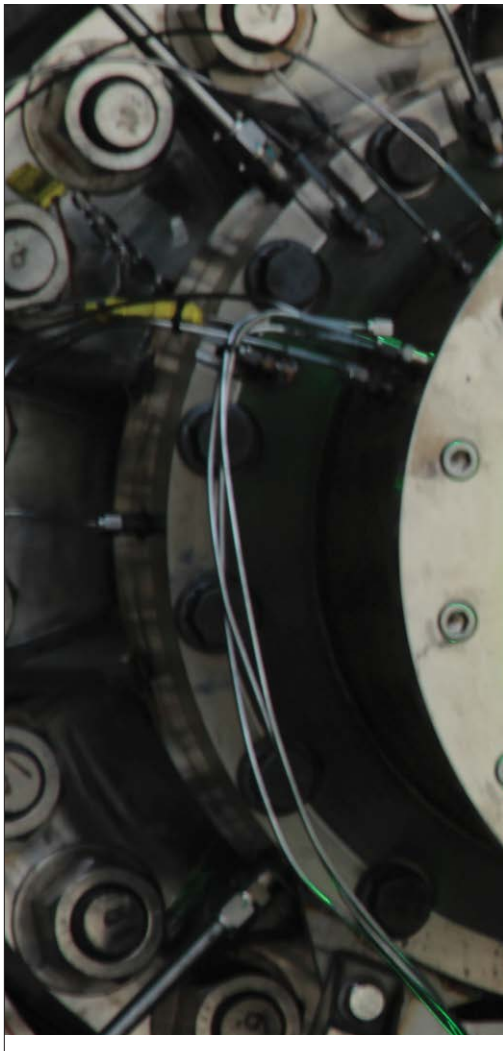
In today's deflagration-based gas turbine and rocket engines, the flame front moves at a slow 10 m/sec. (22 mph), allowing reactants time to disperse and resulting in incomplete fuel combustion. The shockwave in a detonation-based engine moves supersonically at up to 2,000 m/sec., leaving little time for expansion. Compression forces from the shock cause rapid heating and combustion of a higher portion of the mixture, improving overall fuel efficiency.

Though researchers have explored several approaches to pressure-gain combustion, such as internal combustion wave rotors, detonation-based devices remain the most promising. These follow two main paths: RDEs and pulse detonation engines (PDEs). The latter consists of a single or multiple detonation chambers filled with a fuel/oxidizer mixture. Detonation propels the exhaust from the chamber and generates thrust. Fresh reactants are then fed into the chamber and re-detonated to repeat the cycle.

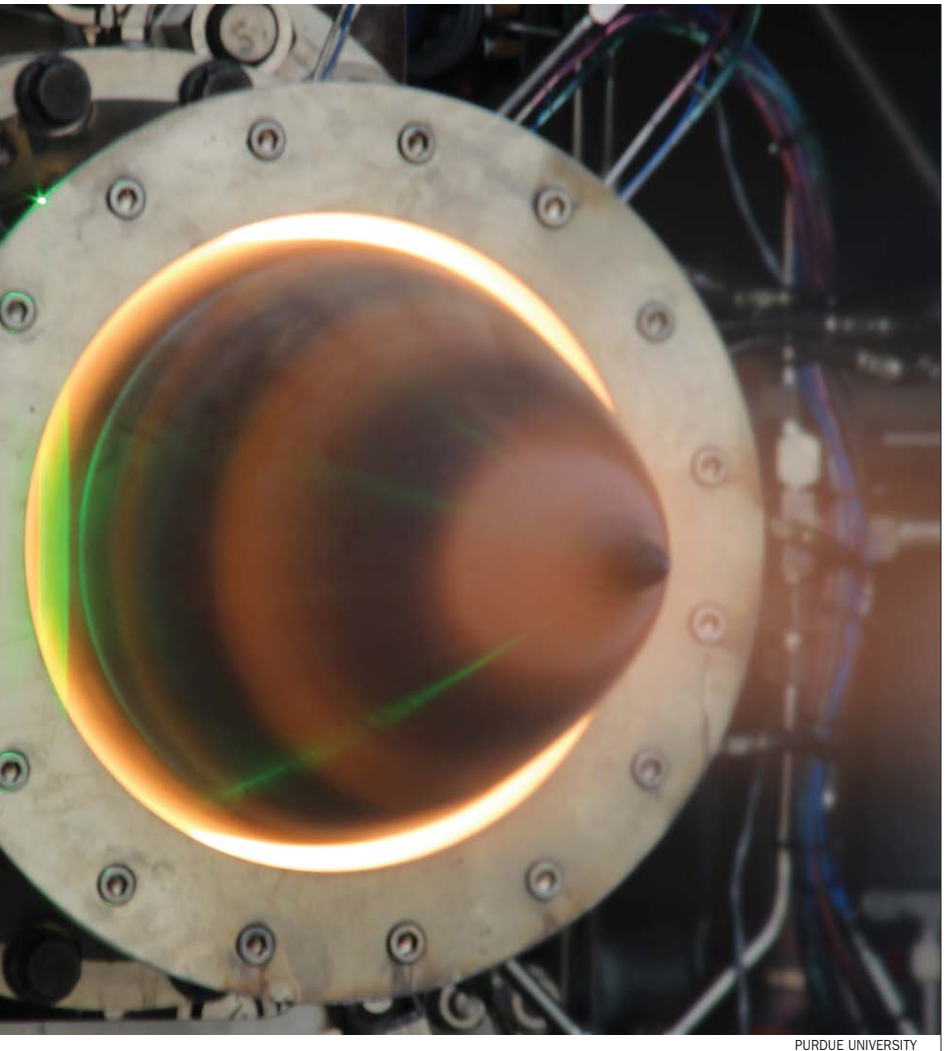
Testing over the past two decades in Europe and the U.S. has shown PDE combustors for gas turbines are feasible, but results have been disappointing in most cases, with efficiency levels little or no better than conventional engines.

The focus for most detonation-based advanced propulsion work has since shifted to RDEs, in which detonation waves continuously rotate around an open-ended annular combustion chamber. Feeding the fuel mixture is a series of injection ports at the compressor inlet, or ram diffuser end of the chamber. In the case of a rotating detonation rocket engine (RDRE), fuel is fed from the turbopump end of the chamber. To start the process, a high-speed flame ignites the mixture, setting off a detonation shockwave.

As the wave travels around the chamber, it consumes the fuel, generating a high-pressure area in its wake. That area, constrained by the wave front and geometry of the RDE, ultimately expands and exits the chamber, generating thrust. Fresh fuel is injected behind the wave, priming that section of the chamber to sustain the wave. This process produces quasi-continuous thrust through high-



Academic facilities like Purdue University's Zucrow Labs are helping pioneer pressure-gain developments like this RDE aerospike nozzle concept.



PURDUE UNIVERSITY

frequency rotations, and with a steady fuel supply, becomes self-sustaining.

As RDEs are also relatively simple mechanically, with no moving parts, they are one of the most promising technological routes toward achieving pressure-gain combustion. Experimental rig tests conducted around the U.S. since the 2000s—at locations such as the Air Force Research Laboratory (AFRL), the Office of Naval Research Laboratory, the Energy Department's National Energy Technology Laboratory, GE Research and RTX—have shown their potential for increasing thermodynamic efficiency.

What about the practical aspects of developing rotating detonation-based combustors for air-breathing engines, rockets or the propulsive core of ramjet-powered missiles and combined-cycle engines? Can this promising technology successfully vault the developmental "valley of death" that all too frequently prevents experimental concepts from becoming real-world applications?

RDE technology is making this leap to an extent, but not necessarily because of pressure gain. Even as researchers continue to optimize designs in hopes of detecting a pressure rise, an increasing number of U.S. defense projects are underway to integrate these devices into missiles and advanced, high-Mach combined-cycle propulsion systems.

Even without the thermodynamic advantage of a pressure rise, an RDE benefits from being more compact, says Daniel Paxson, an aerospace research engineer and RDE specialist at NASA's Glenn Research Center in Ohio.

"In a conventional ramjet, the amount of length you need to get that combustion process over is quite long because it's not particularly efficient," Paxson explains. "But if you have a detonation, then it's like, 'I'm not giving you a pressure gain, but I'm done here, and I burned all the fuel, by the way.' Then there's something there."

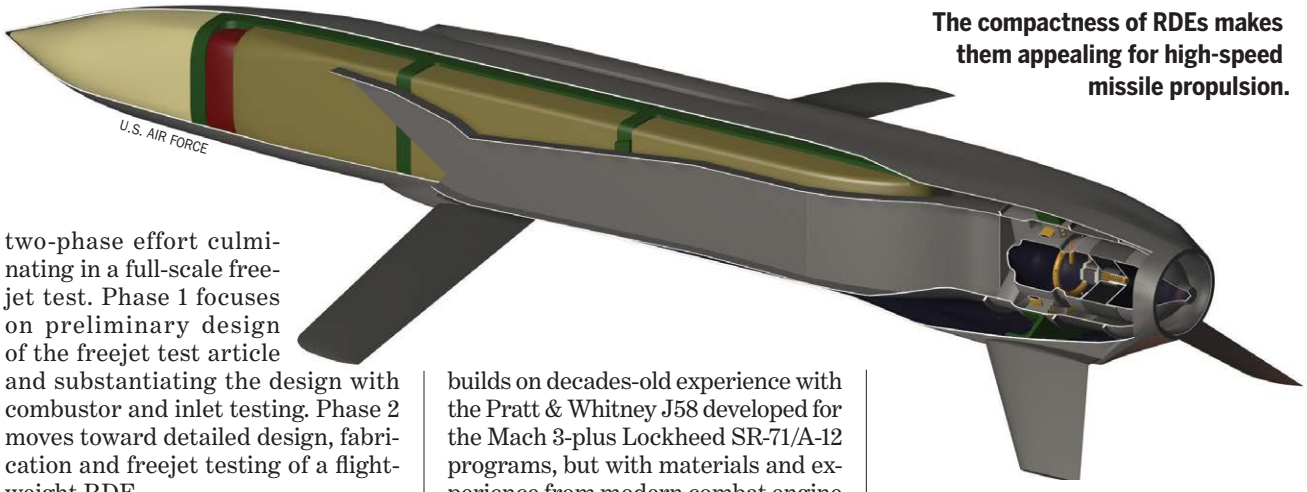
Additionally, when it comes to combined cycles in which a ramjet takes over from a turbine to accelerate a vehicle—potentially toward a supersonic combustion ramjet (scramjet) velocity—the RDE may offer additional benefits. Paxson notes, "You may have the possibility—depending on your system, if you're talking about a pure ramjet system—of something that can kick in at a much lower Mach number than a conventional ram system."

"The value is the power density piece," says Chris Hugill, senior director of Pratt & Whitney's GatorWorks rapid prototyping unit, where RDE development has been underway for several years. "When you look at producing power in a way that's both compact and lightweight, it has a lot of advantages for a range of applications and future systems that we're looking at."

Pratt & Whitney is one of several key players aiming to take advantage of the compactness of RDEs through a flurry of test and demonstration work that has accelerated across the U.S. since the mid-to-late 2010s. Initial test work has also been undertaken by Aerojet Rocketdyne (now part of L3Harris) and GE Aerospace as well as by units of Pratt's parent company, RTX. Contracted initially under the AFRL's Advanced Turbine Technology for Affordable Mission pressure-gain propulsion program in the late 2010s, these early projects have led to follow-on technology maturation developments targeting high-speed propulsion roles for RDEs.

These initiatives include a 2022 fast-track effort by Pratt to run an RDE ground-test demonstrator jointly with parent company partners Raytheon Missiles & Defense and Raytheon Technologies Research Center. This project continues today, building on the initial concept development work by Pratt's GatorWorks. RTX is working in parallel under a DARPA initiative aimed at development of a ramjet-RDE-powered long-range strike missile for fourth-generation fighters called Gambit.

Gambit is designed to pave the way for future prototype weapons development and is intended to demonstrate RDE technology in a



The compactness of RDEs makes them appealing for high-speed missile propulsion.

two-phase effort culminating in a full-scale freejet test. Phase 1 focuses on preliminary design of the freejet test article and substantiating the design with combustor and inlet testing. Phase 2 moves toward detailed design, fabrication and freejet testing of a flight-weight RDE.

"My intention is to be an early adopter of some of these technologies and see if they really work," says Ken Plaks, director of DARPA's Tactical Technology Office, which oversees the office in charge of Gambit. "And if they don't, that's a learning point, too. It tells me where I need to go for the next program." The launch of Gambit reflects both the increasing pace of research into the propulsion concept as well as the promise of the technology. "There is certainly a lot of energy in that area. They offer a lot of attractive things—if we can get it to work," Plaks adds.

Pressure-gain technology also is emerging as a potential contributor to propulsion systems for reusable high-speed vehicles. At the Paris Air Show in June, GE revealed ongoing work to develop a DARPA-funded demonstrator for a turbine-based combined-cycle propulsion system to power a reusable hypersonic vehicle, with the high-speed turbine element incorporating a rotating detonation combustor.

Meanwhile, Pratt & Whitney is developing the Metacomet, an air-breathing propulsion system for high-Mach speed weapons and reusable vehicles. It is also considering applying pressure-gain combustion to the advanced engine concept. Both the GE and Pratt combined-cycle systems will be considered for further development by the AFRL's High-Speed Systems Division, which recently issued a request for information from industry on the state of reusable hypersonic air vehicle technologies.

Launched in 2018 to focus on low-cost alternatives to ramjet and scramjet propulsion for high-speed flight, Metacomet is believed to be an advanced turboramjet. The program builds on decades-old experience with the Pratt & Whitney J58 developed for the Mach 3-plus Lockheed SR-71/A-12 programs, but with materials and experience from modern combat engine programs as well as potential innovations like rotating detonation.

"Advanced concepts like Metacomet obviously first were not envisioned to take advantage of RDE technology, but today we are looking at how perhaps it could," Hugill says.

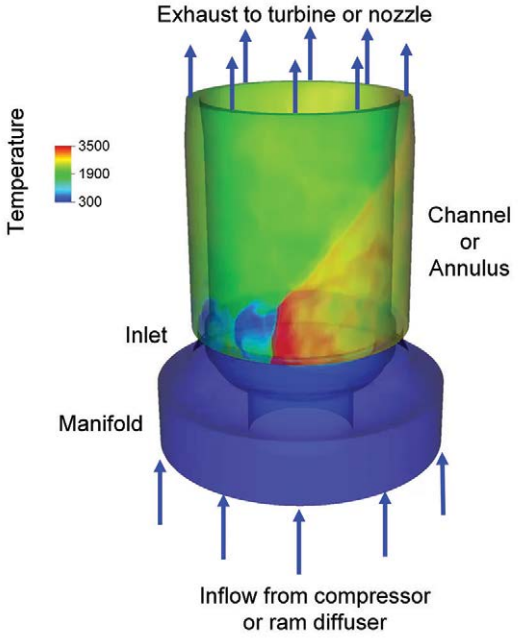
Referencing the RDE ground-test demonstrator, Hugill adds, "The thrust of our effort today is really working to validate our advanced modeling concepts that integrate all the speed, pressures, flows and temperatures of that unique cycle. Our current goals near-term are to validate that our models are predicting those correctly as we transition into even more product-like testing and environments."

Although Hugill says there have been no showstoppers with the program to date, the technology remains immature and has plenty of development work ahead. "Our vision is for future phases of development that will move even more toward product relevance. I think that's about all I can say today," he adds.

The company's RDE is still "years away from flight test," Hugill says. The timing of a full-up flight test effort "will be dependent upon probably a government customer and a weapon system prime launching a program of record or a full flight demonstrator program that we would then seek to support and integrate with."

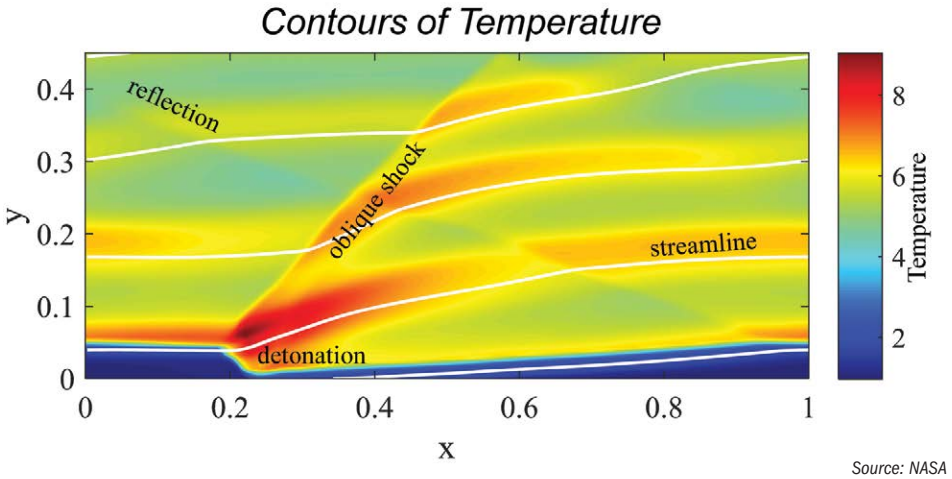
Although the near-term applications are focused on maximizing the power density of the RDE's compact configuration, developers still face the complexities of integrating the unsteady device into the conventional steady flow path regime of a ramjet or the core of a high-pressure turbine.

"Rotating detonation combustion, as it supports an RDE, relies on that supersonic combustion and the ability to produce and control that detonation wave to provide the thrust,"



Source: NASA

Computational modeling aids NASA analysis and refinement of RDE concepts.



Source: NASA

Temperature contours indicate the detonation and its shockwave as it moves from right to left in this unrolled representation of a single cycle.

Hugill says. "How we do that and validate that we're getting the results we predicted is the technical challenge. It is challenging in testing and instrumentation, as well as adapting design features to the desired outcome."

The challenges are particularly intense for researchers like those at NASA who want to maximize the RDE's thermodynamic efficiency.

"We're getting closer, but we have yet to achieve a measurable pressure gain across one of these things," Paxson says. "One of the frustrating things about almost all pressure-gain combustion systems is that they are mechanically simple, but they are fluidically unbelievably complicated, and so they end up being really hard to analyze and optimize.

"One of the big technology challenges that we've only started to delve into—although we've known about this for years—is that as a rule, turbines do not like unsteadiness," Paxson continues. Flow nonuniformity poses structural and aerodynamic issues. "You've got this fundamentally unsteady process going on, and it may give you tons of pressure gain, but if it's all thrown away by the inefficiencies that you cause to the turbine, then where have you gotten?" Paxson asks.

Researchers are studying various options, including redesigning turbines to be more tolerant to the unsteady flow or—as Paxson sees as more likely in the near term—conditioning—the flow as it exits the RDE. Flow conditioning can be especially challenging in an air-breathing gas turbine, where length is the enemy of efficiency.

"In general, detonation is an unbelievably compact way of getting the combustion job done," he says. "But then if you need this big, long duct to condition the flow, then you're right back to where you started."

Thermal management is also a key challenge for RDEs and RDREs. "Obviously these things burn pretty hot," Paxson says.

Although the average temperatures are the same as any other combustion device, he notes, "You've got this combination of high velocity and high pressures and high temperatures, and so there's a lot of heat transfer."

Controlling the fundamental operation of the detonation process is also problematic and requires innovative solutions, Paxson says. "You have a device with no moving parts, you are trying to introduce fuel and air, and you want it all flowing axially and into the device without any losses. Then along comes this detonation, which, of course, is also trying to drive the flow right back in the other direction."

As no mechanical valve can cope with the typical RDE operating frequency of around 10 KHz, the only option is a fluidic device to prevent pulses of pressure from traveling upstream to the compressor—or turbopumps, in the case of the RDRE. "So you're trying to create fluidic diodes, which are a very tall order," Paxson says. "In that process of trying to create a fluid diode you also have to have your fuel and your oxidizer mix super quickly—both in a very short distance and in a very short time."

Designing the inlet geometries for low resistance in one direction and very high resistance in the opposite direction is therefore considered the secret key to a successful RDE. For fuel injection, some RDE developers are studying diodes based on Tesla valves—passive fluidic devices first patented by Nikola Tesla in 1916 that incorporate a series of flow obstacles. The shape of the obstacles promotes laminar flow and lower resistance in the preferred direction and strong turbulence in the opposite direction.

Another challenge is to maximize the amount of fuel and air detonated while minimizing the area in which the slower deflagration process consumes fuel, as sometimes occurs behind each detonation wave. Known as parasitic deflagration, this "doesn't buy you anything," Paxson says. "The easiest way to prevent deflagration is to not mix things well. But of course, if you don't mix things well, you're not going to get a detonation! So you have a very small device with no moving parts and you're trying to do all that in the inlet—and that is one of the fundamental challenges of these devices."

The complexity of pressure-gain combustion means "that this is a technology that you are not going to optimize by the seat of your pants or by just testing through build-and-burn, build-and-burn," Paxson says. "It's really going to depend on computational models that you can parametrically change and use to say, 'Well, I can't separate things in the lab, but I can try this in a computational environment.'"

Better models will help NASA toward achieving long-sought efficiency goals with RDEs. "We really need that pressure gain," Paxson says. "The applications that I think are most important for NASA are those that represent efficiency increases, and you just can't get that without a pressure gain. In the era that we're living in where we really need to be shooting out less carbon, efficiency is what it's all about. Gas turbines are not going away anytime soon, so anything we can do to make them more efficient is a good thing."

—With Steve Trimble in Washington

Rotating Detonation Factors in GE High-Speed Engine Tests

> RDE TESTED IN TBCC DEMONSTRATOR

> SHORT COMBUSTOR OUTLINED IN HIGH-SPEED PATENT

Guy Norris Colorado Springs

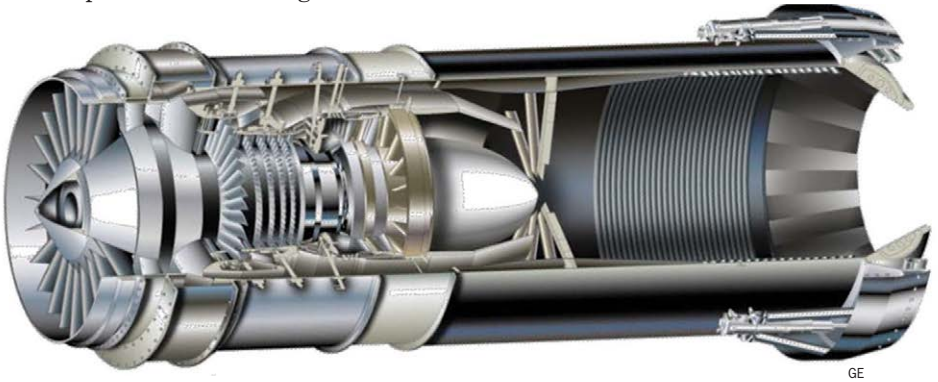
Rotating detonation technology is a growing element of GE Aerospace's accelerating push to play a key role in propulsion systems for future high-speed missiles, reusable hypersonic vehicles and other uncrewed applications.

Based on more than two decades of pressure-gain combustion research at its GE Research (formerly GE Global Research) facility in Niskayuna, New York, the company's focus switched from pulse detonation engines to rotating detonation engines (RDE) in the 2010s as a result of work under the U.S. Air Force Research Laboratory's Advanced Turbine Technologies for Affordable Mission-Capability pressure-gain propulsion program.

In June, GE revealed it was testing RDE technology within a turbine-based combined cycle (TBCC) propulsion system demonstrator for high-Mach applications as part of efforts supported by DARPA, AFRL and the Missile Defense Agency. GE is currently focused on testing the transition mode at high-supersonic speed from an RDE-equipped turbine to a dual-mode ramjet/scramjet, says Amy Gowder, CEO of GE Aerospace Military Systems.

Other than acknowledging the advantage of the RDE's compactness for reducing the overall length of the propulsion system, GE has offered few specifics about the device or its place within the TBCC configuration in general. Some clues may be gained, however, from a broad-ranging 2020 company patent for high-speed aircraft flight technologies that outlines, among other features, the use of an RDE in an afterburner.

Rather than using the RDE in place of the primary core combustor downstream of the high-pressure compressor, the GE concept outlines using the device to boost the pressure, temperature and speed of a secondary inlet airflow ducted into the afterburner via a bypass system. Other advanced features show a major focus on thermal management using an inlet pre-cooler, bypass intercoolers, porous flowpath liner walls to interact with cooling fluids, fuel-air heat exchangers and fluid-based cooling concepts for fan blades.



GE

GE's TBCC work builds on experience gained on earlier hypersonic designs such as the GE57.

Some architectural elements of the hypersonic concept also appear to be based on the variable-cycle GE57 engine design, also known as the Revolutionary Turbine Accelerator (RTA), developed by the company in the early 2000s for a proposed Mach 4 TBCC ground demonstration. Intended as part of NASA's Next-Generation Launch Technology Program at the time, the RTA was to demonstrate mode transition from an augmented turbofan to a ramjet, as well as the Mach 4 thrust level required to accelerate an X-vehicle—specifically the X-43B, a proposed follow-on to the subscale X-43A Waverider—to scramjet takeover speed.

Leveraging adaptive bypass injector features from GE's YF120, a variable-cycle engine developed for the Advanced Tactical Fighter contest of the 1980-1990s, the key new feature of the J58 was the augmentor design that was dubbed the hyperburner. Although acting as a conventional afterburner to transition from takeoff to supersonic flight, the device was designed to kick in at higher Mach numbers and transition to a ramjet to accelerate the vehicle to Mach 4.

It is possible that—in combination with more advanced adaptive features developed over recent decades for the F136 and XA100, respectively—GE is therefore considering RDEs as part of an updated hyperburner design within a new TBCC demonstrator, as well as a future alternative to the conventional combustor at the heart of the high-pressure core.

GE's acknowledgment of its TBCC progress comes as work continues under a 2021 NASA Hypersonic Technology Project (HTP) contract to support materials technology development for high-speed aircraft structures as well as air-breathing engine technologies.

The materials research involves the development of high-temperature-resistant, lightweight ceramic composites made from silicon carbide/silicon carbide (Sic/Sic) and carbon/silicon carbide (C/Sic). The Sic/Sic material is targeted at advanced turbines for high-speed environments, while the C/Sic is aimed primarily at thermally resistant structures for high-speed hypersonic and space access vehicles.

Under the same effort, GE has been assessing the viability of a modified F101 Mach 2-plus turbine engine to operate in a TBCC propulsion system for a hypersonic concept vehicle dubbed Aether, which has been developed under NASA's HTP effort. The F101 is the only powerplant of its type with a fan bypass ratio of 2-to-1, which would allow most of the flow to bypass the core when it is throttled down to avoid exceeding the temperature limits of the core's compressor and turbine.

NASA Steps Up Rotating Detonation Rocket Power Tests

> RDRE COULD DOUBLE SPECIFIC IMPULSE OVER CURRENT ROCKETS

> SHORTER COMBUSTOR DRIVES INTEREST IN LANDER PROJECTS

Guy Norris Colorado Springs

NASA is taking rotating detonation rocket engine technology to the next level, with development underway on reusable 10,000-lb.-thrust-class demonstration engines for potential use in future human landers and interplanetary vehicles.

Based on the same unsteady-flow pressure-gain combustion principle as an air-breathing rotating detonation engine (RDE), the rotating detonation rocket engine (RDRE) derives its increased efficiency from generating thrust using a supersonic combustion phenomenon known as detonation.

The high speed of this detonation process, compared with the slower deflagration combustion used in current chemical rocket engines, adds heat and pressure to the reactant gases in a confined area. As a result, RDREs can potentially increase specific impulse by at least 10% and enable reduction in combustor length by around 50%—with associated mass savings.

Following research work started within NASA and several universities in 2019, developers at Marshall Space Flight Center (MSFC) in Huntsville, Alabama, and Indiana-based primary partner IN Space produced additively manufactured RDREs that were successfully tested over June-August 2022. The tests, which were conducted on two regeneratively cooled engines and involved liquid oxygen (LOx)/methane and LOx/liquid hydrogen, amassed more than 600 sec. of runtime with 17 starts.

Although the RDREs demonstrated good performance with a single full-throttle test—producing more than 4,000 lb. of thrust for 15 sec. with the mean pressure of 620 lb./in.^{2} at a single point on the injector face—the prime focus was the durability of the NASA-developed copper-alloy GRCop-42 material used in their manufacture. The alloy was selected to withstand the heat and duration of successive detonative events; up to five co-rotating detonations were seen during most tests, with a single test showing 2-3 waves.

Following these tests NASA has partnered with Texas-based Venus Aerospace on the design and testing of a higher-pressure design capable of 10,000 lb. of thrust.

"That seems to be around the sweet spot of what most industry in the U.S. is looking for doing Commercial Lunar Payload Services lander missions, for example," Thomas Teasley, liquid propulsion systems development and test engineer at NASA's MSFC, said during a June 7 podcast on advanced rocket engines.

Shock diamonds emanate from an additively made aerospike nozzle during initial NASA RDRE tests in 2022.

NASA

Teasley, who was commenting on the program in NASA's "Houston, We Have a Podcast" series, said the larger engines will also be regeneratively cooled. "We have to demonstrate that we can successfully cool the hardware with just the propellants that we're taking with us into space," he said. "And because the heat loads are being shown to be so high, we have to use both fuel and oxidizer in this new combustor."

Speaking on the same podcast, Steve Heister, co-owner of IN Space and professor of engineering and technology integration at Purdue University, said sounding rocket flights could help transition RDREs to real-world use by testing performance in a vacuum. "We've done very little—almost no work—as a community verifying how well these systems work in the vacuum of space," Heister said.

Outside the U.S., some initial flight tests of small-scale RDREs were conducted two years ago. In July 2021, the Japan Aerospace Exploration Agency worked with three Japanese universities to successfully deploy a gaseous methane/gaseous oxygen RDRE from the upper stage of an S-520-31 sounding rocket and to demonstrate ignition in space. The group was also able to measure a small torque believed to have resulted from viscous interactions of the detonation fronts with chamber walls.

Additionally, in September 2021, a team from the Lukasiewicz Research Network at the Institute of Aviation in Poland launched a small propane/nitrous oxide RDRE sounding rocket at the testing ground of the Military Institute of Armament Technology in Zielonka, near Warsaw. The RDRE operated for 3.2 sec., accelerating the rocket to a speed of about 90 m/s (200 mph) and an altitude of 450 m (1,480 ft.).

Beyond its work with NASA, Venus Aerospace received additional backing from the Airbus Ventures capital investment company and is also developing RDREs to power a proposed family of Mach 9 hypersonic Stargazer transports and uncrewed air vehicles. The company conducted the first run of its liquid-propelled RDRE rocket at its Houston test site in September 2022 and is focusing on longer-duration operating tests in the buildup to initial flight tests on a Mach 3 proof-of-concept test vehicle.

TECH TAKE

By **Graham Warwick**

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Clean Aviation Adds Electric Projects

Technologies for hybrid-electric and hydrogen-powered aircraft are among eight projects awarded €380 million ($408 million) in funding following a second call for proposals by Europe's Clean Aviation public-private aeronautics research program.

CLEAN AVIATION

The Hybrid-Electric Regional Aircraft is one of Clean Aviation's key thrusts.

The announcement adds to 20 projects awarded more than €700 million in funding in September 2022 following the first call for proposals. The eight new projects selected will receive €152 million in EU funding, with the rest coming from industry.

Of the EU funding, €86 million is dedicated to hydrogen-powered aircraft, €33 million to hybrid-electric regional aircraft and €33 million to ultraefficient short/medium-range commercial aircraft—the three key thrusts of the Clean Aviation program, which was launched in 2022 with a budget of €4.1 billion, including €1.7 billion in EU funding.

A further €750,000 is dedicated to monitoring the impact of EU aviation research and innovation. The projects' official launch is still subject to completion of grant preparation, which is targeted for year-end, Clean Aviation says.

Under hydrogen-powered aircraft, Clean Aviation will fund: the Safran-led Trophy project to research hydrogen propulsion technology; the Airbus-led FAME project to develop a fuel-cell system for megawatt-scale aircraft engines; and the Herops project led by MTU Aero Engines to develop a zero-emission, hydrogen-electric propulsion system.

Under hybrid-electric regional aircraft, Leonardo will lead the Herfuse project to develop fuselage and empennage technologies while German aerospace center DLR will develop an open digital environment for developing aircraft architectures. The first call funded projects covering megawatt-class hybrid-electric propulsion systems, thermal management, kilovolt-level electric distribution and wing design for distributed electric propulsion.

Airbus will lead the Companion project to develop a common platform and advanced instrumentation for ultraefficient propulsion on short/medium-range aircraft, while French aerospace research agency ONERA will mature and integrate advanced wing technologies under the Awatar project.

The 28 first- and second-call projects are being funded under Phase 1 of Clean Aviation, which runs to 2025 and is intended to mature technologies to readiness level (TRL) 4 through ground test. Under Phase 2, planned to begin in 2026, selected technologies will be matured to TRL 6—ready for use in product development—by 2028 through integrated demonstrations.

Startup Promises Cheaper e-Fuel SAF

Electrofuels generated from carbon dioxide and green hydrogen using renewable electricity are widely regarded as the long-term solution for producing enough sustainable aviation fuel (SAF) to decarbonize commercial air transport. But the energy costs of producing such power-to-liquid e-fuels are high.

U.S. startup Lydian Labs has raised $12 million in seed funding to build a pilot plant to begin generating fuel using a high-temperature electric reactor that the company says will dramatically reduce the cost of producing e-fuel SAF using CO_2 captured from the atmosphere or industrial plants.

The technology can be used to produce a range of low-carbon liquid fuels and carbon-negative chemicals, but "aviation is the killer app for e-fuels," says Lydian CEO Joe Rodden. "We believe fuels produced with our technology will consume less energy per gallon than any other e-fuel."

Lydian's electrothermal reactor technology applies to the first of two key steps in producing an e-fuel: reducing captured CO_2 to carbon monoxide (CO),

LYDIAN LABS

Chief Technology Officer Branko Zugic (right) with CEO Joe Rodden.

which is then combined with green hydrogen generated by the electrolysis of water to produce synthesis gas or syngas. In the second step, the well-established Fischer-Tropsch process is used to convert the syngas into the hydrocarbons that make up jet fuel.

The startup's reactor is a highly efficient electric reformer that reaches temperatures exceeding 1,000C (1,830F) to drive a catalytic reaction that reduces CO_2 to CO, Rodden says. The technology can achieve a total energy consumption approaching 2 kWh/kg for the reduction of CO_2, which will be 30-50% lower than competing first-step processes such as low-temperature CO_2 electrolysis, Lydian says.

The system also has a physical footprint up to 100 times smaller than traditional reactor technology, the startup says, adding that its reactor is modular, scalable and manufacturable while using no precious metals.

Lydian's electric reactor has a yield 2-3 times that of competing technologies, converting 80-95% of CO_2 on a single pass, and a CO_2-to-SAF conversion efficiency of upward of 90% is feasible, including recycled carbon, Rodden says. The energy efficiency of CO_2 reduction is up to 95%—twice that for CO_2 electrolysis, Lydian says.

Founded in 2021, Lydian raised an initial $3 million in June 2022 and has run a "fairly large" bench-scale reactor with a throughput of 10-20 kg/hr. of CO_2, Rodden says. The $12 million in seed funding will be used to bring a pilot plant online in 2024. Including an integrated Fischer-Tropsch reactor, this Boston-area plant is planned to be capable of producing more than 5,000 gal. of SAF per year.

"We are now exploring a demonstration plant beyond that," Rodden says. Lydian plans to have its first commercial-scale plant operational by 2026. The first plants could be built by Lydian itself or jointly developed with partners, he says, but the startup's business model is to license its technology and manufacture and sell reactors to fuel producers.

UK Rejoins EU's Horizon Research

More than three years after it exited the European Union, the UK has rejoined the EU's Horizon research and innovation program, much to the delight of the UK aerospace industry.

Reentry into the €95 billion Horizon initiative sees the UK rejoining the Copernicus Earth observation program as well as enabling UK industry to regain access to efforts such as the EU's Clean Aviation civil aeronautics research program.

The UK had retained associate membership in the Horizon program despite its departure from the EU in January 2020, but it had been excluded by the EU from the scheme over disagreements between London and Brussels about the Northern Ireland Protocol. The issues have been partly resolved through negotiations that resulted in the signing of the Windsor Framework by both sides in February.

UK Prime Minister Rishi Sunak said the country had secured a bespoke deal to reenter the Horizon program with improved financial conditions. "With a wealth of expertise and experience to bring to the global stage, we have delivered a deal that enables UK scientists to confidently take part in the world's largest research collaboration program," he said.

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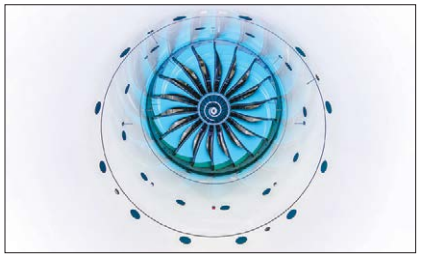

Rolls-Royce's UltraFan program has been a beneficiary of EU funding.

UK aerospace trade body ADS Group welcomed the UK rejoining Horizon, with CEO Kevin Craven stating that membership in the scheme was essential to develop the next generation of aerospace technologies and to address a wide range of societal challenges.

"The UK aerospace, defense, security and space sectors had been leading participants and recipients of funding in [Horizon's] predecessor, and this will provide a welcome boost to scientific and industrial collaboration in our sectors," Craven said.

Rolls-Royce Chief Technology Officer Grazia Vittadini said the Horizon initiative already had a "significant impact on aerospace technologies," and that the company was looking forward to "going further and doing more" through the new arrangement.

As well as access to Copernicus, for which UK industry built many of the satellites, the UK will also have access to EU Space Surveillance and Tracking services, a joint statement from the UK government and the European Commission states.

—Tony Osborne in London

Autonomy Proving Ground Takes Flight

The U.S. Air Force has conducted the first test flights at its Autonomy Prime proving ground at Eglin AFB, Florida. The flights demonstrated an uncrewed aircraft testbed that allows software developers to conduct rapid testing of their algorithms.

The Autonomy Prime Environment for Experimentation (APEX) is part of the Autonomy, Data and Artificial Intelligence Experimentation (ADAx) proving ground at Elgin, a joint venture between the Defense Department's Chief Digital and Artificial Office and the Air Force's AFWerx innovation arm.

Autonomy Prime was established to engage nontraditional players in the development of autonomous capabilities for Air Force platforms, and APEX is intended as an open-door, purpose-built place for industry to partner with the service on iterative autonomy development.

The first autonomous test flights in July involved an Unmanned Aerial Research Osprey Mk III uncrewed aircraft. Ground operators launched the aircraft, then switched control to the onboard autonomy. The five flights totaling 2.7 hr. tested APEX's autonomy watchdog feature.

This feature is part of the Test of Autonomy in Complex Environments (TACE) system developed by Johns Hopkins University's Applied Physics Laboratory. TACE is middleware located between the autonomy engine and the platform interface to the autopilot. The system is designed to guarantee that nothing commanded by the autonomy can circumvent TACE and command the platform directly.

Sitting between a vehicle's safety-critical control system and its autonomy and mission systems, TACE monitors commands sent from the autonomy to the autopilot and passes information such as the vehicle's position, speed and orientation, sensor and mission environment data back to the autonomy.

U.S. AIR FORCE

Tests demonstrated a watchdog system to safeguard autonomous flights.

If the autonomy commands the platform to do something that will violate a safety-of-flight parameter, TACE's runtime assurance function will unilaterally stop the commands from the autonomy and send a remediation command to the platform instead.

In the July test flights, the onboard autonomy was purposely programmed to fly the Osprey outside the user-defined geospatial airspace constraints. Each time the aircraft was about to violate the airspace boundary, the watchdog disengaged the autonomy and sent the aircraft to a predetermined safe remediation waypoint, where it loitered until commanded to do otherwise by the ground station.

In addition to preventing unwanted autonomy commands being sent to the autopilot, TACE can also manipulate the autonomy's view of the world to provide more realistic live-virtual-constructive (LVC) environments for testing autonomy without jeopardizing the aircraft. LVC enables both preflight simulation of missions as well as the injection of virtual entities into a live test.

Using APEX's flying testbeds and infrastructure, "the idea is that the two-pizza-box team with their computer-vision algorithm can show up at Eglin, plug that sensor into our open architecture, upload their software and fly," Sterling Alley, Agility Prime technology transition team lead, said in May.

"They can get the data out that day; we can write a test report, and together we learn a lot and just keep iterating that process," he said. "We think that autonomy development is autonomy testing . . . [and] we need to be able to do more autonomy testing."

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Aviation Week & Space Technology
Sept. 18-Oct. 1, 2023
VOL. 185, NO. 18 (ISSN 0005-2175)

Aerospace Calendar

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Sept. 18-Oct. 24—RTCA Plenary Sessions/Committee Meetings. Virtual or various locations. See rtca.org/content/upcoming-committee-meetings

Sept. 19-21—International Air Transport Association (IATA) World Safety and Operations Conference. JW Marriott Hotel Hanoi. Hanoi, Vietnam. See iata.org/en/events/all/wsoc

Sept. 25-30—China International Aviation & Aerospace Industry Expo. Beijing Daxing International Airport. Beijing. See en.airexpo.org.cn

Sept. 27-28—Electric & Hybrid Aerospace Technology Symposium. Bremen Exhibition Hall. Bremen, Germany. See electricandhybridaerospacetechnology.com/en

Sept. 27-30—Society of Experimental Test Pilots Annual Symposium & Banquet. Grand Californian Hotel. Anaheim, California. See setp.org/symposium/meetings/annual-symposium-banquet

Oct. 1-3—International Society of Transport Aircraft Trading Europe, Middle East and Africa (ISTAT EMEA). Hilton London Metropole. London. See connect.istat.org/emea

Oct. 2-6—International Astronautical Congress 2023. Baku Convention Complex. Baku, Azerbaijan. See iac2023.org

Oct. 3-4—IATA World Sustainability Symposium. Marriott Auditorium. Madrid. See iata.org/en/events/world-sustainability-symposium

Oct. 3-4—Defence in Space Conference 2023. Etc.Venues—155 Bishopsgate. London. See defenceinspace.com

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Sept. 26-28—MRO Asia-Pacific. Singapore.

Oct. 3-4—Digital Transformation Summit. Seattle.

Oct. 15-17—Routes World 2023. Istanbul.

Oct. 17-19—MRO Europe. Amsterdam.

Oct. 26—CTC Shanghai Corporate Travel Summit 2023. Shanghai.

Nov. 2-3—CAPA Asia Aviation Summit & Sustainability Awards. Kuala Lumpur.

Nov. 7-8—A&D Programs. Washington.

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VIEWPOINT

The FAA's Safety Challenge

By **Andy Pasztor**

The latest safety problem affecting Pratt & Whitney's geared turbofan engines highlights the FAA's lack of resolve confronting persistent safety challenges.

The engine troubles, following durability issues that have plagued the model for years, have sparked serious concerns among airline executives worldwide because hundreds of popular single-aisle Airbus A320neo jets face accelerated engine inspections, and some may need emergency part replacements soon. Certain carriers are girding for financial heartburn and painful schedule disruptions.

What hasn't received enough attention, however, is the FAA's initial limp response to these long-simmering challenges. More scrutiny also is warranted to examine its ambivalence combating a broad range of hazards, including overreliance on cockpit automation and little-known shortcomings analyzing commuter and charter incidents.

TOM TRACY PHOTOGRAPHY/ALAMY STOCK PHOTO

"WITH A REVOLVING DOOR OF FAA LEADERS, OFFICIALS COULD NOT ACT DECISIVELY."

The FAA had a distinctly passive reaction to heightened dangers posed by a rare but potentially catastrophic engine manufacturing defect. Pratt started to uncover the new hazards last winter but did not reveal them publicly until summer. In its surprise July disclosure, the company warned that contaminated powder metal used in certain turbine disks required stepped-up checks of many more geared turbofan engines than previously anticipated.

Before that announcement, FAA officials quietly weighed forceful moves, from ordering immediate ultrasound inspections for a segment of the fleet to temporarily grounding some jets, according to industry officials not authorized to comment publicly. But company executives pushed back hard, citing negative economic and public relations fallout.

The FAA opted against mandates, foregoing an immediate airworthiness directive—the way U.S. regulators typically handle the most pressing unsafe conditions.

Instead, FAA officials permitted Pratt to take the lead with its own voluntary inspections, despite a pattern of mistaken company predictions regarding failure modes on other engines. The agency effectively ceded control of messaging about the extent of hazards, prompting news reports that downplayed the latest dangers and used the term "recall," usually frowned on in aviation settings.

It took another month for a high-priority FAA directive to spell out the additional risks. Without waiting for typical public comment, the FAA mandated a late-September deadline for initial inspections. Following a series of more limited mandatory directives covering geared turbofan engines, the FAA ultimately acknowledged internal cracks could emerge faster than projected, potentially causing "damage to the engine, damage to the airplane and loss of the airplane."

The longer inspections take, the August document said, "the higher the probability of failure." An FAA spokesman didn't elaborate on the timing of the directive's release. Over the years, the agency decided against strong and rapid action in other areas:

- Years of bureaucratic disagreements delayed definitive guidance recommending that airline crews perform substantially more manual flying to reverse excessive pilot dependence on automation. It wasn't until last fall that the FAA formally urged pilots to sometimes hand-fly "entire departure and arrival routes" or "potentially the entire flight."
- Agency leaders also have been reluctant to revamp some voluntary incident reporting efforts. Those programs have been immensely successful at alleviating risks pertaining to major carriers. But former FAA officials and other critics describe how agency staff shortages and reorganizations can impede effective data sharing by regional carriers and charter operators.
- Long before the recent flurry of high-profile runway incidents, outside safety experts urged tougher action to curb spikes in midair close calls around hubs. Yielding to industry pressure, for example, the FAA over roughly a decade routinely allowed pilots to turn off critical airborne collision-avoidance warnings during specified approaches to Denver International Airport. That increased capacity on selected runways, but a drumbeat of incidents finally soured the FAA on the practice. Last August, it publicly warned of significant risks if pilots forget to turn the collision-avoidance warnings back on after a missed approach.

The last 18 months featured a revolving door of acting agency administrators and other interim policymakers. These officials often lacked standing to take decisive action. President Joe Biden's latest nominee for agency chief, former FAA Deputy Administrator Michael Whitaker, was delayed by a wrangling with labor.

Despite FAA missteps, industry has maintained a phenomenal safety record. Since 2009, scheduled U.S. passenger airlines have carried the equivalent of the entire world's population—without a single fatal jetliner crash.

Lately, the FAA emphasizes that even one close call is too many. Considering Pratt's engine woes, the agency has fallen short of that vaunted standard.

Andy Pasztor, a former aviation reporter for The Wall Street Journal, is working on a book about the history of flight safety.

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