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48 *Joby Experimental Test Pilot Zach Reeder conducted flight tests onboard the Joby aircraft in Marina, California.*

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ON THE COVER

The B-21 Raider was designed to limit the risks of cost and schedule growth, argues Bill Sweetman, a former Aviation Week defense editor, in a report that begins on page 14. His coverage includes a microcutaway by Giuseppe Picarella of TheCutawayCompany.com that aims to predict the design features of the U.S. Air Force's next stealth bomber. Northrop Grumman photo.

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FEEDBACK

ROYAL AERONAUTICAL SOCIETY

BEHIND THE SCENES

Graham Warwick (left), Aviation Week executive editor for technology, moderated a lively discussion at the Royal Aeronautical Society's branch in Washington on Oct. 5. The topic: How technology advances, autonomous operations and artificial intelligence are changing the air superiority equation. Joining Warwick onstage were Group Capt. **Pete Warmerdam** (center), assistant space and air attache at the British Embassy in Washington, and U.S. Air Force Lt. Gen. (ret.) **David Deptula**, architect of the U.S. air war in the 2003 Iraq conflict and now dean at the Mitchell Institute for Aerospace Studies. The event was hosted by Airbus.

A 707 MOMENT

I had the pleasure of listening to your podcast with Graham Warwick, Michael Bruno, Joe Anselmo and Bank of America's Ron Epstein ("The Case for a New Boeing Airplane," Sept. 23). I agree with Epstein's assessment that Boeing needs to start yesterday on its next aircraft to get the ball rolling, but I also agree with your comments about technical readiness.

I think the path forward for Boeing is to immediately ramp up investment in the next-generation composite processes and transonic truss-based wing so that they will be ready by the 2028-35 window despite being low on resources. It is a critical long-term investment that will cost them more in market share loss in the future if they wait. This is a 707 moment for them.

They should also, however, make the platform flexible in powerplant because open-rotor engines will very likely be a little late to the game, and introducing a radically new airframe will be less risky to buyers with power from the CFM Ultra Fan or Pratt geared turbofan.

Waiting until an open-rotor engine is reliable will give Airbus too much room to move into the space, so adoption of next-gen powerplants will have to be added later, probably in the late 2030s.

Stephen Yip-Wineman, Murrieta, California

HOW THINGS GO TOGETHER

I am not an engineer, but I cannot understand why Boeing continues to have serious problems aligning the 787 fuselage barrels *("Boeing Is Bolstered by Production, Research and Cash Flow Progress," July 31-Aug. 13, p. 19)*.

Both the Airbus A350 and 787 have composite fuselages, and carbon composites make up roughly the same percentage of each airplane's overall weight (51-53%).

Are the fuselage designs significantly different so Airbus avoids these issues? Or has Boeing's quality control been so poor that these problems were missed? Were their production teams so pressured by upper management to get the airplanes built and delivered that they had to ignore the problems? Was upper management too cheap in buying tooling or molds without the really tight tolerances needed? I don't hear of Airbus having to stop the A350 production line to correct manufacturing problems.

Additionally, I now read that Boeing is putting an emphasis on quality. Quality isn't something that you can just turn on and start getting everything correct. As a young man, I assembled and worked on many racecars that had carbon-fiber chassis, and I have a decent layman's knowledge of how things go together.

John Gimbel, Andover, Massachusetts

TREES, NOT OFFSETS

Rather than airlines participating in carbon-offsetting schemes *("Flight Cap Debate Highlights Growing Political Pressure on Airlines," June 19-July 2, p. 38)*, a better approach would be to give incentives to passengers to plant a tree at their destination. It would work like this: The airline would provide an image of its logo to the passenger to mark the spot where the passenger would plant a tree at the destination and take a selfie showing the airline logo. The passenger would submit the photo to the airline and receive a flight voucher or air miles in return. The airline would have a database of trees planted and their locations.

This is much more credible and traceable than buying carbon offsets. Passengers traveling to Africa, where desertification is a major and growing problem, would be doing a great service to their destination continent.

Peter B. Aikat, Nepean, Ontario

IN MEMORIAM

It saddens me to hear about the passing of longtime Aviation Week journalist David Bond *("An Appreciation," Aug. 14-Sept. 3, p. 66)*. For years, he was my go-to person to read for the "deep dive into the details." His life and journalistic career spanned the golden age of space and aviation. He witnessed as a child the move from props to jets and later Chuck Yeager breaking the sound barrier, the launch of Russia's Sputnik and the U.S. Explorer 1, John Glenn's three orbits in Friendship 7 and Apollo 11 landing on the Moon.

In September 2001, I was American Airlines' environmental response coordinator for 9/11 in New York; I read all his articles. Godspeed, David Bond, Godspeed.

Jim Sherrard, Plano, Texas

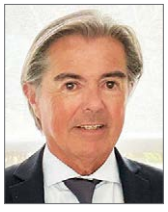
Address letters to the Editor-in-Chief, *Aviation Week & Space Technology*, 2121 K Street, NW, Suite 210, Washington, DC, 20037 or send via email to: **awstletters@aviationweek.com** Letters may be edited for length and clarity; a verifiable address and daytime telephone number are required.

WHO'S WHERE

Charity Weeden has joined *NASA* as associate administrator for the Office of Technology, Policy and Strategy, succeeding Ellen Gertsen, who held the role in an acting capacity since Bhavya Lal's departure. Weeden was vice president for global space policy and government relations at Astroscale, as well as a fellow with the Canadian Global Affairs Institute.

Satellite Applications Catapult has named **John Abbott** as CEO. He was chief digital officer for the Saudi Arabia Real Estate Registry and previously worked for the HM Land Registry.

Bill Moore has been promoted to president of *UPS Airlines* from vice president of the company and president of its aircraft maintenance and engineering sector, succeeding Jim Joseph.



Philippe Blatt has been appointed managing director at *Astroscale France*. He oversaw Thales' digitialization efforts and before that served as program director for the UK Defense Ministry's Marshall Program and CEO of Thales Alenia Space Germany.

Greg Heine has been appointed senior vice president for maintenance software strategy and operations at *Jet Support Services Inc*. Previously the CEO of Vessel Vanguard, he also founded GHC Interactive and held leadership positions at Rizse, ATP and Flightdocs.

Northrop Grumman has brought on **Krzysztof Krystowski** as country lead executive for Poland. With past employers such as Leonardo Helicopters Poland, Avio Polska and the Polish Ministry of the Economy, he currently serves as president of both the Polish Clusters Association and Silesian Aviation Cluster. **Robert Fleming** also moves up to corporate vice president and president for space systems from vice president and general manager for strategic space systems, effective Oct. 9, succeeding Tom Wilson as he moves into a new role.

U.S. Army Gen. (ret.) **Jim McConville** has been hired by *AE Industrial Partners* as an operating partner. He was the Army's 40th chief of staff in 2019-23 and commanded the service's 101st Airborne Division in 2011-14—the longest tenure in the position.

Tim Allen has joined *MagniX* as vice president for sales and marketing. He was commercial aviation OEM sales manager for Garmin International, before which he worked at Astronics Ballard Technologis, Thales Avionics and the U.S. Air Force.

The *Aerospace Industries Association* has hired **Tim White** as vice president for engineering and technology. He was the aerospace and defense industry principal at Interos and previously worked at Raytheon, Honeywell and Bechtel.

Dietmar Thelen has been hired by *Hensoldt* to head its spectrum dominance and airborne solutions business unit. He was head of electronic warfare at Airbus Defense and Space's military air systems division.

The Aerospace Corp. has announced the merging of its Space Systems and Defense Systems groups into a new group oriented toward its Defense Department customers, headed by Senior Vice President **Marty Whelan**. Making up the new group are: **Randy Kendall**, overseeing launch, missiles and mobility; **Jamie Morin**, leading defense strategic space; **Todd Nygren**, heading defense space acquisition; and **Lara Schmidt**, succeeding Jay Santee as vice president for defense architectures and integration. **Kevin Bell** moves into Nygren's role as senior vice president for the Engineering and Technology Group from his former position as Space Systems Group head. **Kevin Keating** will also join the corporation as senior vice president for the National Systems Group, effective Jan. 1. Keating joins from the Central Intelligence Agency, where he was a science and technology senior advisor, and worked at the National Reconnaissance Office previous to that.

Skyllence has hired **Paul Travis** as senior charter broker, a title he held in his previous role at Premier Aviation.

Patrick Etie has joined *Duncan Aviation* as a turbine engine service sales representative. He was a senior regional sales manager at Turbine Engine Specialists, with prior positions at Honeywell Aerospace, Bombardier and KC Aviation.

The *Metropolitan Nashville Airport Authority* has announced its latest board of commissioners. Members include: prominent local real estate developer **Tony Giarratana**, president of Giarratana LLC; **Jack Johnson**, state senator for the 27th district in Tennessee's General Assembly; and **Stuart C. McWhorter**, commissioner at the Tennessee Department of Economic and Community Development. **Jimmy Granbery**, chair and CEO of H.G. Hill Realty Company, has been named board chair, while **Bobby Joslin**, president of Joslin & Son Sign Co. and member of the State Leadership Council of the National Federation of Independent Business, will serve as vice chair. **Masami I. Tyson**, a partner and head of the Japan practice at Womble Bond Dickinson, joins as board secretary.

Kay Kapoor has joined the board of *Frontier Technology Inc.,* a provider of technology and data expertise to the U.S. government. Kapoor is founder and CEO of Arya Technologies, served as president of AT&T's Global Public Sector organization, chairperson/CEO of Accenture Federal Services and had a 20-year career with Lockheed Martin.

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

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DEFENSE

Raytheon Missiles and Defense has received a $29 million DARPA contract to demonstrate a high-speed missile powered by a ramjet-rotating detonation engine under the Gambit program.

Turkey has called for a more effective deconfliction mechanism for air operations over Syria after a U.S. F-16 shot down a Turkish Anka uncrewed aircraft operating near U.S. ground forces on Oct. 5.

The U.S. Army has taken delayed delivery of the first GE Aerospace T901 turboshaft to power competing Future Attack Reconnaissance Aircraft prototypes built by Bell and Sikorsky.

Slovakia has selected Israel Aerospace Industries' Barak ground-based air defense system to fulfill a requirement for a medium-range surface-to-air missile.

Startup X-Bow Systems has received a $64 million contract to be a second-source supplier of solid rocket motors for Lockheed Martin's U.S. Army and Navy hypersonic glide vehicle programs.

AWARDED

Aviation Week Defense Editor **Steve Trimble** won the Outstanding Achievement Award at the Defence Media Awards on Oct. 8. Award organizer Peter Bradfield noted Trimble's exceptional year, which included breaking news about a hobbyist balloon being shot out of the sky by a heat-seeking missile, an explanation of what to expect at the B-21 stealth bomber rollout and numerous podcasts and informative webinars. Aviation Week's **Check 6 podcast** won the Best Digital Media award.

JEN DIMASCIO/AW&ST

VIEW FROM WASHINGTON

NRO Plots Massive Expansion

The U.S. National Reconnaissance Office (NRO) plans to quadruple the number of satellites it has in orbit and provide 10 times the imagery and signals over the next decade, its deputy director said Oct. 10.

The huge increase in NRO capability comes as China and Russia invest in counterspace capabilities—to include missiles and weapon systems that use electronic warfare and cyberattacks, Space Force Maj. Gen. Christopher Povak told the Air and Space Force Association's Mitchell Institute.

"The proliferation and diversification of the architecture will provide increased coverage, greater capacity and resilience, and more timely delivery of data will create more persistent coverage over any area of the Earth, provide faster revisit rates and increase the accuracy and fidelity of our data," he said.

A recently launched NRO network of spacecraft in geosynchronous orbit will work with existing satellite systems to limit strategic or tactical surprises. The U.S. Space Force launched an unknown number of Silent Barker satellites Sept. 10 to monitor geosynchronous orbit in a more granular way than the U.S. has been able to do with its network of ground radar and optical systems, Povak said.

"It allows us the ability to collect smaller and smaller signals and to maintain custody of those objects throughout their entire life so that there is very little opportunity for us to be surprised in the geosynchronous domain," Povak said.


SIERRA NEVADA CORP.

The U.S. Army has selected Sierra Nevada Corp. to provide two modified Bombardier Global 6500s for the Athena-S prototyping effort ahead of fielding a high-altitude intelligence, surveillance and reconnaissance fleet.

COMMERCIAL

United Airlines has ordered 110 aircraft—50 Boeing 787-9s and 60 Airbus A321neos—filling out the carrier's orderbook for the latter part of the decade (page 27).

A consortium including Air France-KLM has been chosen to take a 19.9% stake in Scandinavian Airlines as part of its ongoing Chapter 11 restructuring (page 28).

EasyJet is the first airline to buy carbon credits from Airbus' direct air capture and storage scheme. Airbus has purchased 400,000 metric tons of CO_2 sequestration by U.S. startup 1PointFive beginning in 2025.

The government of Portugal announced

plans to sell at least 51% of TAP Air Portugal as it launched the long-awaited privatization process on Sept. 28 (page 28).

Malta plans to create a new national airline and shut down its existing loss-making flag-carrier, Air Malta. The new company is planned to take over on March 31, 2024.

United Airlines has invested in Electric Hydrogen, a U.S. startup manufacturing electrolyzer plants to produce green hydrogen, which could be used in the production of sustainable aviation fuel.

QUOTED

"WE FIND OURSELVES WITH AN AIR FORCE THAT **IS THE OLDEST, SMALLEST AND THE LEAST READY** IT HAS EVER BEEN IN ITS HISTORY."

–LT. GEN. (RET.) DAVID DEPTULA, now dean of the Mitchell Institute for Aerospace Studies, on the need for autonomous Collaborative Combat Aircraft at a Royal Aeronautical Society event in Washington on Oct. 5.

AERONAUTICA MILITARE

LOCKHEED MARTIN

NASA has pushed back first flight of the X-59 low-boom supersonic demonstrator to 2024 after a series of subsystem issues were encountered during checkout tests at Lockheed Martin's Skunk Works in Palmdale, California.

SPACE

A United Launch Alliance Atlas V flight from Cape Canaveral on Oct. 6 orbited a pair of small prototype satellites for Amazon's planned Kuiper broadband internet constellation (page 13).

Return to flight of Europe's Vega-C light/medium-lift launcher after its December 2022 failure has been delayed to the fourth quarter of 2024 because of the need to redesign the second-stage nozzle.

Northrop Grumman is halting plans to develop and operate a commercial space station in low Earth orbit and instead will join the Voyager Space-led Starlab program (page 26).

Russia's attempt to land a spacecraft on the Moon in August failed because of a mistimed thruster burn that lasted 127 sec. instead of the planned 84 sec. due to a malfunctioning control system.

APPOINTED

Airbus has named Florent Massou as the new executive vice president for operations and Benoit de Saint-Exupery as head of sales for the new Airbus Commercial Aircraft division that is to become operational by the beginning of 2024. The appointments are among changes to the Airbus leadership team following the decision to carve out commercial aircraft as a separate unit under the newly appointed CEO Christian Scherer.

OBITUARY

Earl Exum, International Aero Engines chairman and Pratt & Whitney vice president for mature commercial engines, died on Oct. 1 at age 55. He founded Pratt & Whitney's African American Network, which grew into parent company RTX's Black Excellence Network. "Earl was an active mentor and sponsor for so many across the company," says Rick Deurloo, president of Pratt & Whitney Commercial Engines.

PRATT & WHITNEY

25 YEARS AGO IN AVIATION WEEK

The Boeing 717, the aircraft that almost wasn't, was featured on our Oct. 12, 1998, cover accompanied by a key question: Will big orders follow? Originally conceived as the McDonnell Douglas MD-95, the future of the 106-seat airliner was thrown into doubt when the two companies merged in 1997 because the 717 competed with Boeing's more capable 737-600 and faced new competition from Airbus' upcoming A318. But Boeing decided to press ahead with the project, believing that by pricing the 717 lower than the 737-600 it could create a "solid niche" for short-range flights in the 100-seat market. That initially proved to be a tough sell, with the 717 winning just 55 orders from launch customer AirTran Airways and Bavaria International Aircraft Leasing Co. The jet entered service in 1999, and orders did pick up for a while before Boeing shut the line down in 2006. Today there are 109 Boeing 717s still in operation, according to Aviation Week Fleet Discovery.

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

GOING CONCERNS
MICHAEL BRUNO

TO WOO PATRICK SHANAHAN TO suddenly take the helm at Spirit AeroSystems, the board of directors of the Wichita aerostructures giant had to offer a 54% raise compared with his predecessor, plus $8 million more in future stock rewards. And that was just to make Shanahan the caretaker while Spirit ostensibly searches for a permanent CEO.

Of course, Shanahan is a leading contender to become the permanent CEO of Spirit—after the board ousted seven-year CEO and President Tom Gentile on Sept. 30. If he stays for the long term, Shanahan probably will want even more money. Ironically, that is maybe the last thing Spirit can afford to do.

Spirit AeroSystems has become the sick man of industry. More than three years after the onset of the COVID-19 pandemic in North America and the worst of the Boeing 737 MAX debacle, Spirit has yet to begin recovering while the rest of industry is moving on.

Investors in Spirit, a leading Tier 1 aerostructures supplier, once expected to see a positive cash flow from operations by now as airliner production rates creep up and price increases prove stickier this cycle. Instead, Spirit has gone further into the red this year: Its net loss by the midyear point was $488 million, compared with $175 million halfway through 2022.

The third quarter, which ended the day Gentile departed, could be another gusher when results are reported Nov. 1. The revelation and fallout of mistakes in assembling Boeing 737 aft pressure bulkheads happened during the third quarter, as did a weeklong strike in early July by Wichita workers, who eventually negotiated guaranteed annual wage increases up to 34% combined over four years. Those events followed the announcement in the second quarter of a quality escape on tail fin assembly.

Thus, the list of to-do tasks for Spirit's next chief executive is clear and daunting: stabilize and increase 737 ship sets, fix other money-losing commercial programs, repair investor relations and figure out how to manage looming debt repayments.

Shanahan, 61, could be up to the job, according to financial analysts who reacted to the news on Oct. 2 that the veteran Boeing commercial executive was taking over immediately from Gentile, 58. The move, while surprising, was not shocking.

The Boeing 737 MAX debacle, the coronavirus pandemic and continued manufacturing mistakes on several aircraft programs have overwhelmed progress. Supply chain issues also have come to haunt Spirit with a vengeance. Beyond MAX production issues, which stem from unidentified suppliers to Spirit, aerostructures work on the Airbus A220 and A350 and Boeing 787 programs remains in a forward loss position. Meanwhile, corporate debt has reached almost $4 billion, including $1.2 billion due in 2025, as interest rates continue to rise.

"We are uncertain on the ability of the interim CEO to change the near-term execution challenges facing Spirit, but we do believe Gentile had lost substantial credibility with investors and even within the company and industry," RBC Capital Markets analyst Ken Herbert says. "The focus for Spirit will remain production execution, potential customer contract renegotiations and then debt refinance."

Shanahan "is well regarded and very well-qualified for the job," analysts with TD Cowen add, echoing other analysts. Shanahan spent more than 30 years at Boeing, rising to help run airplane programs such as the 787 as well as supply chain management and operations. In the Trump administration, Shanahan served as deputy defense secretary and then was acting defense secretary for six months during cabinet turnover in the first half of 2019. Nomination for Senate-approved permanence reportedly was derailed by alleged domestic violence within Shanahan's family.

Other issues notwithstanding, Shanahan's familiarity with Boeing is attractive because the OEM is Spirit's biggest challenge. While Spirit is hobbled by its own mistakes, it cannot fully reach its pricing, margins or market positioning because of Boeing's proverbial golden share. It is more plausible—if improbable—for Boeing to move work among aerostructures providers than it is for Spirit to find a new OEM customer.

Gentile hinted recently that an existential reproach with leading OEMs was coming: "All of those programs are under pressure, and it really is not sustainable for Spirit," he told a Jefferies conference on Sept. 7. "We are having discussions with our customers, with Boeing and Airbus, about these pressures that we're facing and how we address them."

According to analysts, Shanahan has indicated that his key priorities include boosting Spirit's production rates, improving supply chain execution and meeting customer commitments. "But we assume reaching agreement with Boeing regarding price relief also is a key objective," Cowen analysts say.

Meet the New Boss

The task list at Spirit AeroSystems is **familiar and formidable**

Tom Gentile

Patrick Shanahan

SPIRIT AEROSYSTEMS PHOTOS

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LEADING EDGE
GRAHAM WARWICK

ARE THERE TECHNOLOGIES available today that could produce a better airliner? Yes. Are there technologies mature and ready today that could enable double the traditional generational improvement in aircraft fuel efficiency, to 30% from 15%, to help accelerate the decarbonization of aviation? No.

Given a choice, would airlines trade efficiency for maturity at entry into service? Probably.

That is the mathematics Airbus and Boeing are working through as they look ahead to launching their first clean-sheet single-aisle airliners in decades. When to launch, what technologies to use and what performance will the airlines expect?

A key variable in the equation is technology maturity. Airlines expect a trouble-free entry into service, but pushing the envelope on technology makes that harder to achieve. The CFM Leap and Pratt & Whitney PW1000G underwent the most exhaustive development and certification testing efforts ever for new commercial turbofans—26,500 cycles for the PW1000G family—yet both engines experienced significant teething problems, largely due to new technologies.

As aircraft and engine manufacturers develop an array of technologies that could dramatically improve the efficiency and reduce the emissions of next-generation airliners—from open-rotor engines and low-drag wings to electrified systems and high-rate composites—the question uppermost in their minds is: When will they be mature enough to incorporate into a product?

The measure of maturity that aerospace traditionally uses is technology readiness level (TRL). But experience with development and introduction of the latest generation of commercial engines—and with complex military programs such as the Lockheed Martin F-35 Joint Strike Fighter—raises the question of whether TRL is up to the task as the industry pushes the envelope.

TRL was pioneered by NASA in 1974, but its nine levels were not formally defined until 1989. Since then, TRL 6—prototype demonstration in a relevant environment—has come to be viewed as the gate to product development. But aerospace development is not about technologies in isolation, and many advances have been tripped up during their integration into a system.

In the 1990s, recognizing a gap between technology readiness assessments and successful development programs, the U.S. Defense Department augmented TRL with integration readiness level (IRL) and manufacturing readiness level (MRL). In 2006, the system readiness level (SRL) was defined to provide a more holistic integration between TRL and IRL.

"Industry experience has been that technology readiness TRL 6, while necessary, is not fully sufficient to assess the potential for application onto a platform," says a 2021 report by a NASA/Boeing team. "The most successful seamless technology transitions rely on consideration of TRL, MRL, IRL and SRL in both technology development and vehicle design."

BOEING

Research technologists face a conundrum, the report says. They must initiate technology research without knowing the requirements of a specific application, while shorter product development cycles leave them with insufficient time to meet all the additional design requirements levied after TRL 6 when the application is known.

The report examines three technologies that reached TRL 6 but did not make it onto a new aircraft: drag-reducing riblets, bugphobic coatings and active flow control. The team concludes they failed to transition due to challenges in the operational environment.

"Missing from the TRL assessment were significant in-service operational environment '-ilities' such as maintainability and reliability," the report says. Other "-ilities" include the wearability of riblets, operability of bugphobic coatings and certifiability of active flow control.

The team proposed a total technology readiness level (TTRL) model that brings together TRL, MRL, IRL and the "-ilities" into a more robust tool set. "The TTRL process can accelerate technology readiness and enable an earlier pragmatic understanding of feasibility, practicality and applicability," the report says.

"Total technology readiness serves as a holistic model that can encompass all elements to more sufficiently bridge a new technology into an application," the team says, adding it is critical that technology developers and vehicle designers are together responsible for the early identification of significant "-ilities" that may become showstoppers in a later business decision on whether a technology can transition or not.

What does this mean for the next Airbus or Boeing? It means flying an open-fan engine or long-span wing at full scale by 2028 may tick the TRL 6 box—prototype demonstration in a relevant environment—but that alone may not be enough to win it a place on the next-generation single-aisle.

Add sustainability to the list of "-ilities" that must be considered, and how hard the airlines are pushing—and how long they are willing to wait—for significant emission reductions becomes part of the technology readiness equation.

THE LAUNCHPAD
IRENE KLOTZ

Big Rocket, Little Payload

Amazon becomes a **satellite operator**

USING A HEAVY-LIFT ATLAS V TO launch a pair of mini-fridge-size satellites into orbit may set a record for the most expensive ride to space. But Amazon, which bought the launch, considers it key for a potentially lucrative new business line selling high-speed internet services to consumers, companies and other entities.

Amazon's KuiperSat-1 and -2, prototypes for the company's planned satellite-based broadband internet service, rode solo onboard a United Launch Alliance (ULA) Atlas V that lifted off from Cape Canaveral SFS on Oct. 6.

The rocket's core stage—powered by a single 860,200-lb.-thrust RD-180 engine—could have carried 27 KuiperSats into low Earth orbit (LEO), which was the plan when Amazon bought nine Atlas V rides in 2021. The price of an Atlas V ride starts at $109 million, ULA's website states. Amazon's splurge on an Atlas V to fly a pair of small satellites came after technical issues delayed two previous bookings.

Originally, KuiperSat-1 and -2 were to fly separately onboard RS1 small-satellite launchers, developed and operated by startup ABL Space Systems. Amazon wanted the prototypes in orbit by late 2022 so it could begin the critical task of testing crosslinks and other systems prior to ramping up production for a planned 3,236-member operational network.

As ABL wrestled with technical issues that delayed the RS1 debut—the rocket ended up flying for the first time (unsuccessfully) on Jan. 10—Amazon in October bought new rides for KuiperSat-1 and -2. This time, the satellites would launch together as secondary payloads on the first flight of ULA's Vulcan rocket, which at the time was targeted to launch in early 2023.

UNITED LAUNCH ALLIANCE

Amazon waited out delays to Vulcan's debut until August, when the company decided to use one of the nine previously purchased Atlas V flights for a dedicated ride for the test satellites. The rocket lifted off at 2:06 p.m. EDT on Oct. 6, and 18 min. later deployed the spacecraft into orbit 318 mi. above Earth and inclined 30 deg. relative to the equator. At 2:53 p.m., Amazon's mission operations center in Redmond, Washington, confirmed contact with KuiperSat-2, followed 1 min. later by a confirmed telemetry link with KuiperSat-1, marking Amazon's debut as a space operations company.

"There's a long way to go, but it's an exciting milestone all the same," Rajeev Badyal, vice president for technology for Project Kuiper, said in an update on Amazon's website.

Amazon is spending some $10 billion to develop and launch the Kuiper system, which is designed to provide high-speed, low-latency global internet services. OneWeb in May became the first company to complete its LEO broadband system, while SpaceX is continuing to add satellites to its Starlink system, which is nearing 5,000 operational spacecraft.

KuiperSat-1 and -2 include much of the technology and subsystems in the production version of the Kuiper satellite design, including phased array and parabolic antennas, power and propulsion systems, and custom modems.

According to a Federal Communications Commission (FCC) filing, Amazon's prototypes feature three telemetry, tracking and control receivers; two Global Navigation Satellite System receivers for space-to-space navigation; L-band transmitters to relay position to satellites in the Globalstar non-geostationary satellite orbit (NGSO) Mobile Satellite Services network; three phased array antennas for customer terminal links (two to transmit, one to receive); and three parabolic antennas to communicate with gateway stations on Earth.

"On the ground, we will test our advanced networking hardware and software to refine how they support the flow of data through the Kuiper System and AWS [Amazon Web Services]. Gateway antennas positioned around the world will track and communicate with the satellites and also connect the Kuiper System to the internet," Amazon said in a statement.

"As the mission progresses, we will test the network from end to end, sending data back and forth between the internet, our ground gateways, the satellites and our customer terminals," it added.

Following what is expected to be several months to a year of testing, the satellites will attempt to conduct propulsive maneuvers to drop out of orbit.

Amazon plans to launch the first batch of operational Kuiper satellites in the first half of 2024. Beta testing with early commercial customers would begin by the end of 2024. Amazon has contracts for up to 92 launches with ULA, Arianespace and Blue Origin to deploy the Kuiper constellation, a K_a-band, NGSO network of more than 3,200 satellites.

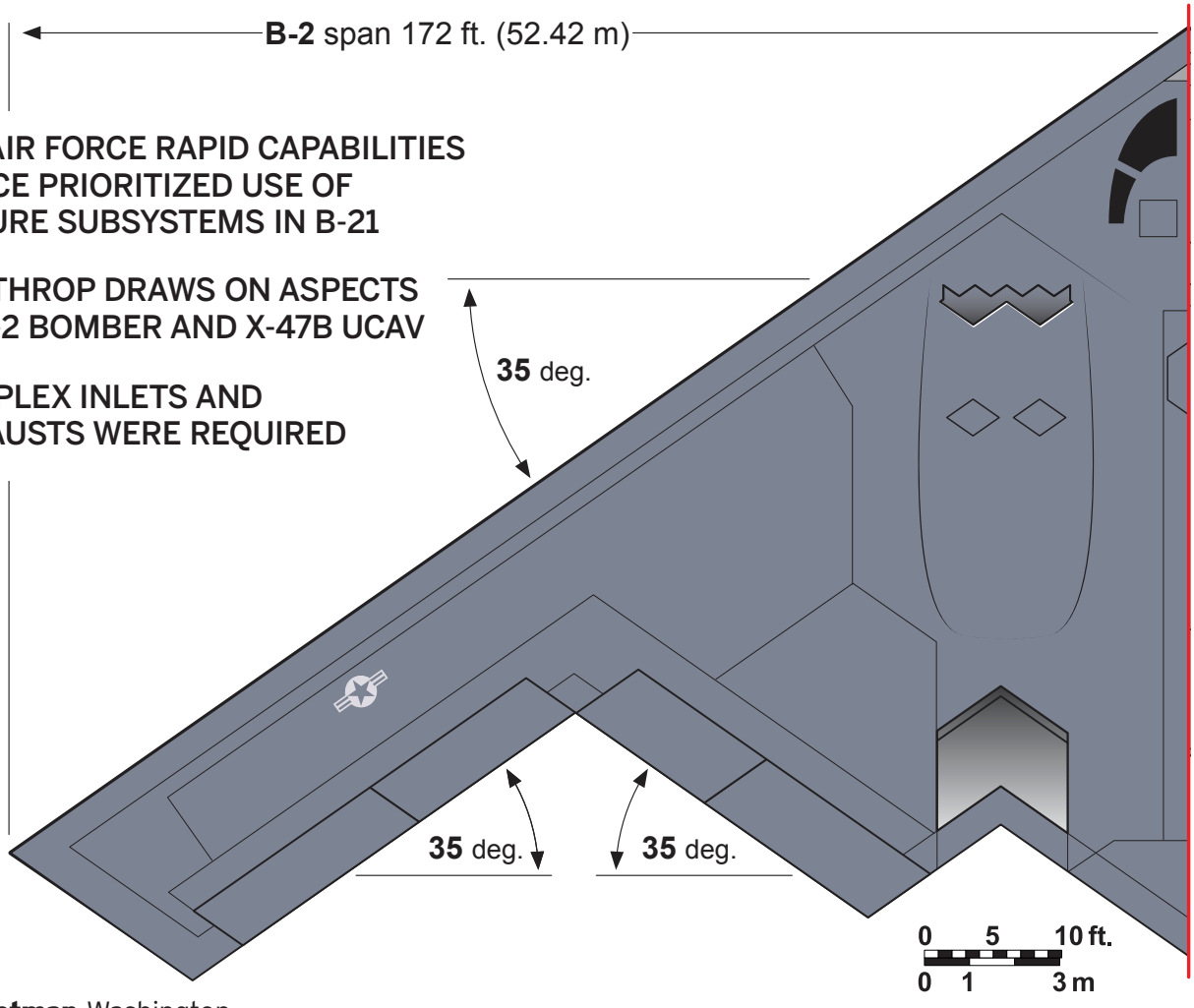
The system is to be deployed in five phases, with service beginning once the first 578 satellites are in orbit. The FCC stipulates that 50% of the satellites must be launched by the end of July 2026, and the rest of the constellation by mid-2029. Amazon also is requesting FCC approval for an additional 7,774 satellites that would use V- and K_u-band frequencies. That request is pending.

DESIGNED FOR L

> U.S. AIR FORCE RAPID CAPABILITIES OFFICE PRIORITIZED USE OF MATURE SUBSYSTEMS IN B-21

> NORTHROP DRAWS ON ASPECTS OF B-2 BOMBER AND X-47B UCAV

> COMPLEX INLETS AND EXHAUSTS WERE REQUIRED



CREDIT: GIUSEPPE PICARELLA/THECUTAWAYCOMPANY.COM

Bill Sweetman Washington

The design of Northrop Grumman's B-21 Raider points to a conservative approach on the part of the U.S. Air Force's Rapid Capabilities Office. The B-21's resemblance to the original B-2 bomber design is close, but it is a smaller aircraft, with a wingspan estimated at 132 ft. compared with the B-2's 172 ft., and is approximately half the empty weight. The planform itself is driven by the need to accommodate complex inlets and exhausts and a large weapon bay within the flying-wing profile while staying within a maximum thickness-to-chord ratio compatible with efficient flight above Mach 0.8.

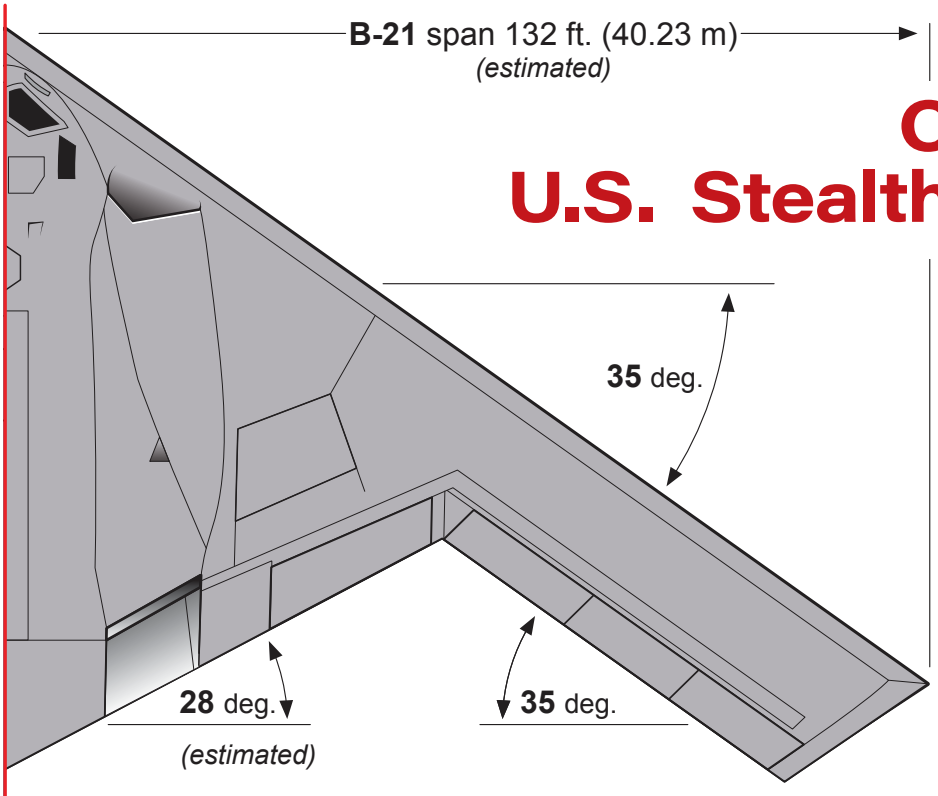
The B-21 planform, which has not been officially released, was depicted in a video that accompanied a presentation by Gen. Duke Richardson, commander of the U.S. Air Force Materiel Command, on Sept. 11 at the Air and Space Force Association's (AFA) Air, Space & Cyber Conference at National Harbor, Maryland. A new set of images released that week included an undistorted head-on view that permitted a reliable estimate of the wingspan. Recently recovered unclassified imagery from Pratt & Whitney presentations dating back to the early 2010s proved to be a close match for the B-21's inlets.

The B-21's low-risk design in part stems from the program's origins. Before 2009, the Air Force was working to a requirement known as Next-Generation Bomber (NGB). It has been characterized as complex and ambitious, with a full suite of intelligence, surveillance and reconnaissance (ISR) sensors, a self-defense capability and long endurance. This was canceled in April 2009 by then-Defense Secretary Robert Gates.

The following year, the Air Force proposed a different approach to the mission, which Pentagon leadership found

AFRL weapon development digitization p. 25

OW RISK



Comparing U.S. Stealth Bombers

B-2 and B-21 Specifications

	B-21 (estimated)	B-2*
Dimensions (ft.)		
Span	132	172
Length	54	69
Engines		
	2 X P&W PW9000 (27,000 lb. thrust)	4 X GE F118 (17,300 lb. thrust)
Weights (lb.)		
Maximum Takeoff	180,000	336,500
Maximum in Flight	N/A	357,500
Operating Empty	70,000	149,900
Weapon Load	20,000	44,000

*Air Force Institute of Technology Systems Engineering Case Study, 2004

Source: Bill Sweetman

acceptable: a Long-Range Strike family of systems including classified uncrewed aircraft systems for ISR and electronic attack (the former becoming the Northrop Grumman RQ-180), a replacement cruise missile (now the Raytheon AGM-181) and the Long-Range Strike-Bomber (LRS-B), for which a contract was awarded to Northrop Grumman in October 2015.

Aside from scrubbed and scaled-back requirements, the LRS-B project differed from NGB in three ways: Unit cost was a key performance parameter; two competing teams were funded through preliminary design review, which normally takes place after contract award; and management was assigned to the Air Force's Rapid Capabilities Office (RCO). The RCO modeled its approach on the Lockheed F-117, developed using mature subsystems in a new platform so that the program could focus on applying new technology.

The B-21 emerging today is evidence that these principles have been adhered to. Its configuration and stealth technology have evolved from the "flying saucer" approach used on the B-2, but originally proposed in the late 1950s. Remarkably, Lockheed Martin Skunk Works founder and former chief Clarence "Kelly" Johnson, in a retrospective paper delivered in 1975 and quoting pre-SR-71 Blackbird work, noted that "a shape similar to flying saucers, with a sharp edge and no protuberances, has a very low radar cross-section without any anti-radar treatment." And at a February 1959 conference with President Dwight Eisenhower, also discussing the future Blackbird, Harvard physicist Edward Purcell remarked that "the best shape would be a flying saucer."

No documents found so far have explained the exact connection between the flying saucer phenomenon—the original popular term for unidentified aerial phenomena—and

early stealth developments. But one part of the explanation may be that the mysterious craft were often believed to evade radar detection and that it would naturally occur to anyone with knowledge of radar that the shape might have something to do with it.

The classic 1950s flying saucer shape—seamless and continuously curved, with a domed center flaring out to a sharp edge—is visible on the B-21. Some details, though, are reminiscent of the X-47B—the uncrewed combat air vehicle (UCAV) designed by Northrop Grumman—such as the longer nose, or "beak." This feature is a result of the need for continuous sharp leading edges, but with a curved-down nose to improve stall characteristics. As on the B-2, however, the saucer profile in elevation is matched with a straight-edge planform to concentrate residual radar reflections—reduced by deep-section radar-absorbent material (RAM) edges—in the smallest possible number of "spikes."

The design benefits from advances in computational engineering and simulation. The B-2 was designed with the help of early 2D computational fluid dynamics (CFD), but airflows on a blended wing body shape are highly 3D with effects propagating from the center-body outward, and more recent designs using 3D CFD are more efficient.

Computational electromagnetics allows for better low radar cross-section (RCS) shapes and more efficient use of RAM and eliminates much of the empirical cut-and-try methods used in earlier programs: Northrop Grumman closed its Tejon Ranch, California, outdoor RCS test range in 2011.

The B-21 is also the first known major U.S. military aircraft program to be fully designed on a digital thread, with not only the shape but the physical characteristics of each part built into a digital prototype. This has allowed errors to be caught early and has made it possible, according to program officials, to incorporate all core systems on the first aircraft.

The differences from the B-2 include the new bomber's planform. In fact, the B-2 planform at contract award in October 1981 was similar to the B-21's now, but a low-altitude dash capability was added to the requirement late in its evolution. In early 1983, Northrop engineers discovered that the original design had insufficient control power to alleviate gust loads at the same time as controlling the aircraft, and it was necessary to add control area farther aft, close to the centerline, for rigidity. The fix resulted in the B-2's unique planform, but at a price in time, weight and cost—and the low-altitude capability was never used.

Some of the features carried over from the X-47B include the apparent absence of split brake-rudder surfaces. Instead, the plan-view sketch suggests the presence of "inlay" surfaces above the wing, which would not be used in stealth mode. Instead, lateral and longitudinal control are provided by eight trailing-edge surfaces, augmented by differential thrust as on the B-2.

The center-body section matches images of highly serpentine inlets mated to a medium-bypass engine. Pratt & Whitney discussed such an engine, the PW9000, as a future bomber powerplant in 2010 but has not mentioned it since. The PW9000 used the core of the PW1000G commercial engine family, mated to a direct-drive fan with a 4:1 bypass ratio. On the B-2, the low-bypass GE F118 engine was selected because it was too risky to place a higher-bypass engine, more sensitive to flow distortion, behind the curved and RAM-treated inlet ducts needed to hide the fan face from radar. With the aid of better CFD, that problem can be eliminated: Northrop Grumman proposed a large bomber UAV in 2005, powered by two modified GE CF34 turbofans, and Lockheed Martin flew the Polecat demonstrator in 2006 with two Williams FJ44s.

Further evidence of innovation in the propulsion installation is that it is one of very few specific B-21 problem areas mentioned in public. Rep. Rob Wittman (R-Va), a member of the House Armed Services Committee, mentioned potential inlet and exhaust issues in March 2018. In March 2021, then-RCO Director Randall Walden said that a redesign was completed before the design was frozen, without affecting the schedule.

A higher bypass ratio provides much better specific fuel consumption than the B-2's fighter-type engine, improving range, and would enable a cooler, lower-velocity exhaust, not only lowering the B-21's infrared signature but also alleviating thermomechanical stress on the open "aft deck" area of the exhaust, immediately ahead of the trailing edge.

The B-21's structure benefits from the absence of a low-level flight requirement and improvements in both composite materials and RAM, reducing the use of fillers and tapes. While the RAM itself would perform the same functions as on earlier stealth aircraft, with multiple layers to absorb energy, diffuse surface currents and protect the skin from lightning, it would require less maintenance than the notoriously finicky B-2 surface.

Internally, the B-21 apparently uses many proven systems. At the AFA meeting, Doug Young, Northrop Grumman vice president and general manager for strike systems, noted that where possible, the company has used commercial components and systems on the aircraft, reducing costs and taking advantage of long-lasting commercial supply networks. Early in the program, one Washington consultant with close ties to BAE Systems disclosed that the electronic warfare system of the B-21 is closely related to the Lockheed Martin F-35's ASQ-239.

The most important feature of the avionics, however, is an open mission systems architecture. Young compares older systems with adding peripherals to a computer in the early PC age, where "you had to go through a whole rigmarole to make it work." But the B-21 has standard interfaces and a partitioned architecture where changes to the mission systems cannot affect flight-critical functions.

The B-21 program includes a "software factory," Young said, which is already developing capabilities beyond the service-entry baseline. And under a program called Spirit Realm, a partitioned architecture is being developed for the B-2 fleet.

After Lockheed Martin and Boeing unsuccessfully protested the Air Force's B-21 contract award to Northrop Grumman, a consultant to both companies wrote that "there's a real possibility that the B-21 program isn't executable at the price the winning team bid—which would mean either big cost overruns or program termination."

Northrop has warned that it faces up to a $1.2 billion charge on the first five years of low-rate initial production for the B-21 due to inflation-related cost increases not anticipated when bids were submitted in 2015.

But a lesson to be drawn from the B-21's appearance is that the designers of the B-2 did an amazingly good job "inventing to schedule" while existing materials and subsystems were inadequate and produced a basic vehicle architecture that was still considered the best choice almost 40 years later.

THE B-21 WHAT WE THINK WE KNOW

PROPULSION SYSTEM
1 Conformal intake
2 Serpentine inlet duct (blocks line of sight to engine)
3 Pratt & Whitney PW9000 with 4:1 bypass ratio
4 Serpentine exhaust duct
5 Fixed-geometry exhaust slot
6 Exhaust trough with heat-resistant RAM

WEAPON BAY
7 Single weapon bay, similar in size to a single B-2 bay
8 Weapon bay doors (two flight control surfaces)

FLIGHT CONTROL SURFACES
9 Outboard flight control surfaces, three per side
10 Inboard flight control surfaces, locked in stealth mode

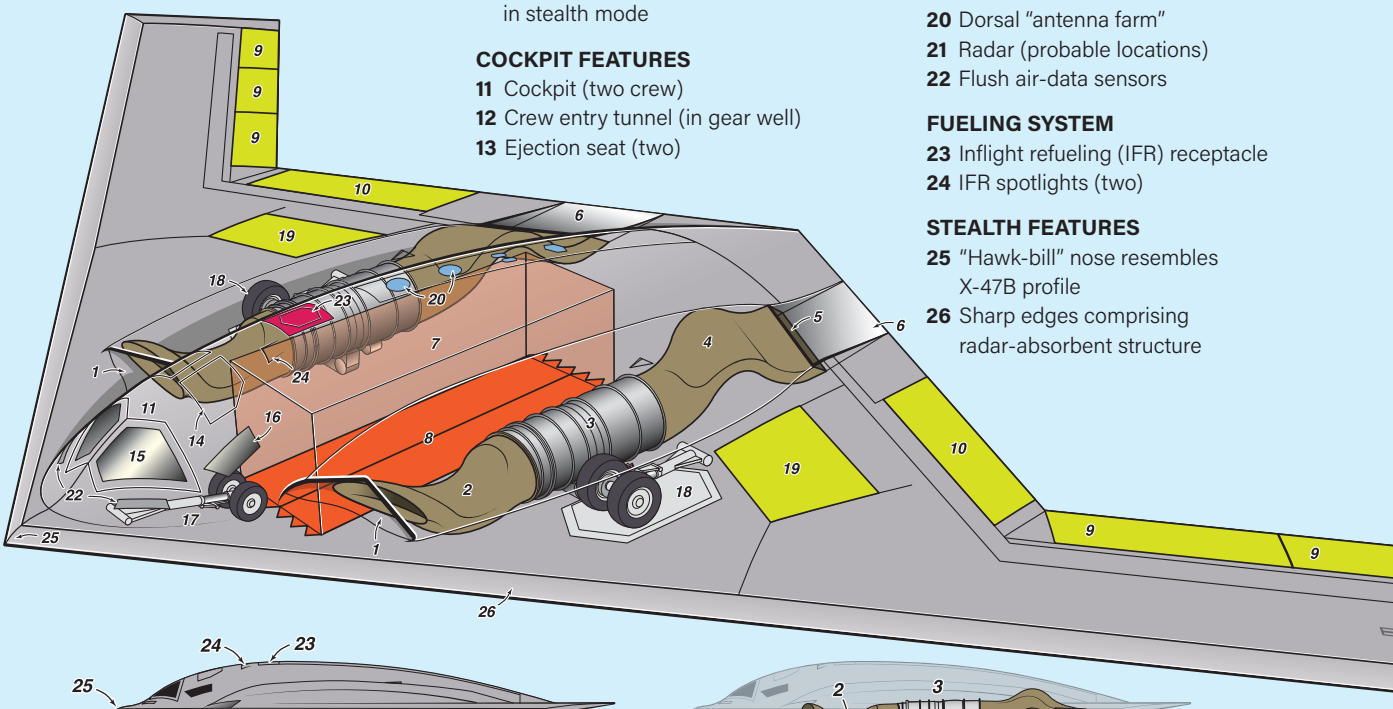
COCKPIT FEATURES
11 Cockpit (two crew)
12 Crew entry tunnel (in gear well)
13 Ejection seat (two)
14 Ejection seat hatches
15 Windshield (two-piece)
16 Side-view windows

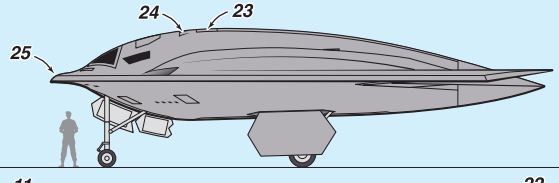
LANDING GEAR
17 Nose landing gear
18 Main landing gear
19 Possible "inlay" speed brake/spoilers

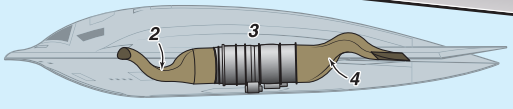
ELECTRONIC SYSTEMS
20 Dorsal "antenna farm"
21 Radar (probable locations)
22 Flush air-data sensors

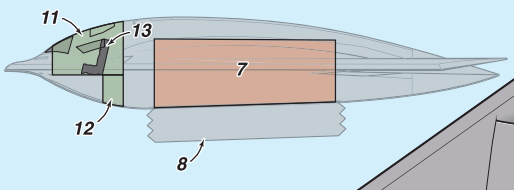
FUELING SYSTEM
23 Inflight refueling (IFR) receptacle
24 IFR spotlights (two)

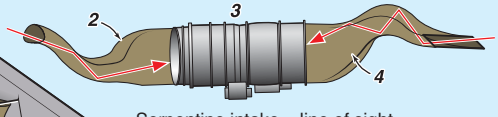
STEALTH FEATURES
25 "Hawk-bill" nose resembles X-47B profile
26 Sharp edges comprising radar-absorbent structure



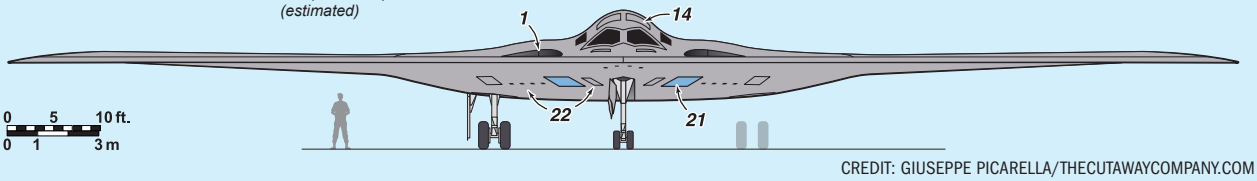








Serpentine intake – line of sight



CREDIT: GIUSEPPE PICARELLA/THECUTAWAYCOMPANY.COM

Israel-Hamas War Widens Munitions Strain as Ukraine Battle Drags On

> U.S. SHIPMENTS STARTED ARRIVING IN ISRAEL OCT. 11

> ISRAELI EXPORTS COULD BE PRESSURED BY PROLONGED CONFLICT

Steve Trimble Washington

A Belgian-flagged Boeing 747 commercial freighter landed at Nevatim air base, Israel, on Oct. 11 carrying one of the first shipments of U.S.-built munitions rushed to the world's newest war zone.

Additional shipments from the U.S. are likely to continue arriving in Israel for weeks or months to come, adding further pressure on a munitions industrial base straining to meet the demands of U.S. aid to the Ukrainian military and the Defense Department's dwindling stockpile of munition reserves.

ISRAELI AIR FORCE

An Israeli F-15A Baz fighter in 133 Sqdn. colors took off on a mission during Operation Swords of Iron in Gaza, carrying at least two Joint Direct Attack Munitions.

Tens of thousands of Israeli troops were massed along the border of Gaza as this article went to press, readying for a land invasion of the densely populated Palestinian territory. Meanwhile, Israeli fighter jets and artillery pounded hundreds of targets inside Gaza and as far away as the airports of Aleppo and Damascus in Syria. Hamas-controlled forces had shocked the Israeli military on Oct. 7 by launching a multidomain, cross-border assault on dozens of remote settlements and military bases. The terrorizing surprise attack killed more than 1,000 civilians and 200 Israeli troops, triggering several days of Israeli airstrikes that have killed hundreds more in Gaza.

In response, U.S. officials surged naval and air forces to the region and pledged to supply Israel with whatever it needs to execute a war that threatens to spread beyond Gaza, as reports grew of sporadic violence in the West Bank and Hezbollah's strongholds in southern Lebanon.

"We'll continue to ensure that Israel has what it needs to keep itself and its citizens safe," U.S. Defense Secretary Lloyd Austin said Oct. 11.

Austin spoke to reporters about efforts to support Israel at the latest Ukraine Defense Contact Group meeting, which gathered in Brussels Oct. 11 to be briefed on Kyiv's specific needs for weapons by Ukrainian President Volodymyr Zelenskyy.

The U.S. has shipped $43.9 billion worth of military equipment to Ukraine since Russia launched its full-scale invasion in February 2022, including more than 2 million artillery rounds alone. Sending more aid to Ukraine, however, may depend on breaking an impasse over who will be the next Republican speaker of the House of Representatives.

Enough residual funding remains to keep U.S. equipment flowing to Kyiv through the end of December, Gen. Charles Q. Brown, Jr., chairman of the Joint Chiefs of Staff, told reporters in Brussels. The White House approved an additional $200 million in military aid for Ukraine on Oct. 10.

With congressional appropriations for fiscal 2024 logjammed by the House Republican leadership impasse, U.S. Army officials pleaded for lawmakers to approve legislative proposals to surge munitions spending.

"We need the support of Congress to replenish critical stockpiles of munitions and equipment," Army Secretary Christine Wormuth said in an Oct. 9 speech that opened the Association of the U.S. Army's (AUSA) Annual Meeting. Wormuth, however, noted that the drain on the American stockpile to support Ukraine is worth it because it weakens Russia's military.

Although some munitions suppliers are struggling to keep up with existing demand from Ukraine and the U.S., there are signs that supporting Israel in the Gaza conflict will not add significantly to the industrial burden.

So far, the U.S. has simply fast-tracked deliveries of certain munitions from previous orders placed by Israel, a senior U.S. defense official told reporters at the Pentagon Oct. 9. "What we're looking at is what was already on the books," the official said. "And we're working to accelerate that."

The nature of Israel's needs for munitions may also be fundamentally different than Ukraine's. The first shipments to Israel contained munitions that included Tamir missiles, coproduced in the U.S. by RTX for Israel's Iron Dome air defense system that has not been supplied to Ukraine. Israel also relies more on airpower to deliver precision-guided munitions than artillery. Finally, Israel has a robust defense industry capable of surging capacity from domestic and international facilities.

"The Israelis do have significant indigenous capacity, so it is a different situation than Ukraine," Tim Cahill, executive vice president for Lockheed Martin's Missiles and Fire Control unit, told reporters at AUSA Oct. 9.

If the conflict between Israel, Hamas and perhaps other groups in the region is prolonged, concerns may grow about Israel's capacity to meet export commitments. Israeli defense industry officials had touted their ability to deliver munitions to foreign customers markedly faster than backlogged alternatives from U.S. and European companies. Those material and human resources may eventually be diverted to backfill Israel's own stockpiles.

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A League of Their Drones

> REPLICATOR MAY OFFER END RUN AROUND U.S. MILITARY SERVICES' GRIP ON ACQUISITION

> COMBATANT COMMANDERS SEEK MORE CONTROL OF SHORT-TERM ACQUISITION PRIORITIES

Steve Trimble Washington

A previously unknown, 3D-printed drone named the Kestrel costs $2,500 to make and has been flying over hot spots in the Middle East for months, using a 3-kg (6.6-lb.), high-definition camera for aerial intelligence, surveillance and reconnaissance missions.

Nothing about the Kestrel's performance is remarkable. It flies low, slow and only about 100 km (62 mi.) on each flight. "Not a huge range, but something that can be relevant on the battlefield," Lt. Gen. Alexus Grynkewich, the head of U.S. Air Forces Central (Centaf), told reporters on Oct. 5.

What makes the Kestrel remarkable is the way it was fielded by Task Force 99, an experimental cell established last year at Al Udeid air base, Qatar, to leverage digital and uncrewed technologies.

Centaf's small drone—and several others like it that have not been identified—was produced virtually overnight by operators in the field. There was no need to involve the Pentagon's elaborate Planning, Programming, Budgeting and Execution (PPBE) system, with its yearslong process required for defining requirements, securing line-item budgetary approval from Congress and then engaging the defense industry.

Task Force 99's small crew of eight or nine U.S. airmen and several others on detail from five international partners handled the entire process in the field.

In Grynkewich's personal opinion, the Task Force 99 model should be expanded and scaled up, allowing the operational forces in the field to bypass the "organize, train and equip" function of the military services to rapidly develop and field their own surveillance drones, one-way attack munitions and similar technologies.

"[Centaf] organized Task Force 99 on our own. That wasn't presented by the Air Force to us," Grynkewich said."We're equipping it on our own, so I think there is a role for that."

The military has been governed by a PPBE process defined by then-Defense Secretary Robert McNamara in 1961, with few major alterations over the last six decades. The PPBE defines the combatant commands like Centaf as the users and military services such as the Air Force as the providers. The process then requires the services to subject all weapon systems to largely the same yearslong procedure, whether the intention is to buy a $15 billion Columbia-class submarine or a $15,000 quadcopter drone.

Meanwhile, the combatant commands are developing new operating concepts gleaned from the war between Ukraine and Russia. Indo-Pacific Command (IndoPacom), for example, has described a new approach for the Taiwan Strait known as Hellscape (*AW&ST* Oct. 2-15, p. 14), which calls for unleashing hundreds or thousands of drones and one-way attack munitions in all domains to defend against an amphibious assault by China.

But the regional commands are concerned that the PPBE process is incapable of fielding and updating such technologies at the scale and pace the threat demands. For Grynkewich, the issue with the PPBE's reliance on the military services to "organize, train and equip" the forces that are employed by regional commanders is a lack of focus on short-term priorities within such an unwieldy system.

Small drones and one-way attack munitions such as the Switchblade (pictured) are the focus of a new effort to empower combatant commands to develop and field their own capabilities.

U.S. DEFENSE DEPARTMENT

Traditionally, the combatant commands are expected to take a short-term focus while the military services adopt a long-term perspective. Ideally, Grynkewich said, the military services and combatant commanders would expand their planning horizons in both directions.

"It would be a more powerful system if the services thought a little bit more short-term, because there's opportunities in that short-term space and we're identifying those things with Task Force 99," Grynkewich said. "Conversely, if combatant commands think a little bit longer-term, you build something that's maybe a little bit more sustainable. So I think there's some shared space there, and it will take some experimentation and moving back and forth to figure out where that overlap is best for us."

The pressure from the combatant commands on the cur-

rent PPBE extends beyond Centaf's Task Force 99. In fact, the Centaf experimentation cell started after the Navy launched Task Force 59 in Central Command to focus on developing uncrewed surface and underwater vehicles and the Army started Task Force 39 with a similar focus on uncrewed ground vehicles.

All three task forces are the product, to some degree, of frustration with the long-term bias the current PPBE structure imposes on the military services. A representative of Task Force 59, for example, noted during an industry day briefing last March that more than 70% of the Navy's funding for uncrewed systems was allocated to capabilities that would not be delivered until after fiscal 2028. The product of each task force also is intended to be shared with other combatant commands.

"If we get a capability in Task Force 99 that scales really well, wouldn't that be neat to get it in IndoPacom?" Grynkewich asked. "We're not thinking of something that's just applicable to Centaf."

The Task Force 99 approach has limitations. The small cell of about 15 U.S. and international members has developed and fielded their own operational drones in small quantities. But such organizations lack the resources, expertise and sheer numbers required to field and operate thousands of systems in bursts in less than two years.

For the first time, however, the combatant commands now also see a path to bypassing the PPBE process and gaining authority to organize, train and equip their own forces with certain technologies at scale, including relatively cheap surveillance drones and one-way attack munitions.

In late August, Deputy Defense Secretary Kathleen Hicks unveiled the Replicator initiative. Hicks described a plan to field thousands of cheap drones in all domains within 18-24 months without asking for additional funds or adding new organizations to the Pentagon's bureaucracy. She did not describe the mechanisms for accomplishing that goal, but the combatant commands see an opportunity to scale up the approach used by Task Force 99, leveraging defense-wide acquisition agencies and nontraditional suppliers.

"I think what Replicator will do is help us make that shift," Grynkewich said. "It will help us understand a couple of different sides of this—one is going to be the production side of it. Can companies that are offering these off-the-shelf drones scale production to meet our requirements, and what would that look like? And then we'll also learn what kind of training we do and what kind of airmen we need operating these systems."

The members of Task Force 99, including only one or two members who are pilots or navigators, form much of the traditional pool of Air Force personnel that operate aircraft in the field. "Most of the people in there who are flying those drones every day are young sergeants who are communicators, cyberoperators, engineers or something like that," Grynkewich said. "They just happen to be the right people with the right skills who we discovered knew how to code or knew how to 3D-print."

In that sense, Replicator does not represent a new program of record but instead defines a new approach to organizing, training and equipping forces in the field. At the same time, such an approach will require the combatant commands to rethink how they employ drones at such a scale. The new approach could differ greatly from the traditional path used by the military services, which often

U.S. NAVAL FORCES CENTRAL COMMAND

A small UAS launched by the Navy's Task Force 59 surveilled an Iranian warship in the Persian Gulf in early October.

forms dedicated squadrons or wings equipped with a new weapon system.

"There'll be new doctrine," Grynkewich said. "How do you force-present this capability? How do you make sure that you don't create a unit that operates, say, that drone I was describing—the $2,500 Kestrel? You don't want a unit that's a Kestrel unit. You want a unit that is a drone unit. Kestrel might work for a little bit, but then you dispose of it and come up with the next one.

"How do you even build that into our DNA in our organization?" Grynkewich added. "I think those are a lot of things that we're going to go through."

Czech Republic Extends Europe's F-35 Buying Streak

- FIRST CZECH DELIVERIES ARE PLANNED FOR 2029
- F-35s TO REPLACE BOTH GRIPENS AND L-159s IN 2035

TONY OSBORNE/AW&ST

The F-35 continues to dominate the European fighter market, with more nations slated to sign up to buy the combat aircraft.

Tony Osborne London

The Czech Republic has joined the growing list of nations purchasing the Lockheed Martin F-35, making it arguably the preeminent combat aircraft in Europe. It is now in service with five nations and has been ordered or selected by another seven, with Greece and Spain likely to follow in their footsteps.

Although Prague selected the aircraft in July 2022, defense ministers and procurement officials have been working to convince the government that the F-35 was the right choice—and they finally made up their minds on Sept. 27. "The F-35 system is essentially becoming the standard," Czech Prime Minister Petr Fiala told journalists at the announcement.

"[The F-35] is purchased by most of the member countries of the North Atlantic Alliance, and in this case, we are also betting on safety. . . . And with this step we actually tell our allies that we take the defense of our country seriously and that they can count on us," Fiala added.

With the government green light and backing from Washington, Prague can push ahead with the Foreign Military Sale of 24 F-35As, along with pilot training, equipment, spares and a weapons package for 106 billion Czech korunas ($4.6 billion) to be paid over 11 years.

Sweden's Saab, whose Gripen C/D fighter is currently the backbone of the Czech Air Force, had pushed hard to have its Gripen proposal heard, including making an offer to Prague to keep its current leased fleet of 14 aircraft for free if the government also ordered a dozen Gripen Es. The Czech government did not consider that offer.

In light of the Gripen proposal, former air force pilots and officials questioned the F-35 choice in the country's media. One concern raised has been whether the air force, with such a small fleet—the smallest ordered in Europe so far—will be able to make full use of the platform's capabilities. The air force's Gripens are largely used only for air defense and air policing missions, although they added an air-to-ground mission in recent years.

Critics also questioned the F-35's operating costs. That issue has been a hot topic among even mature operators of the aircraft, including the U.S. and UK. The Czech Republic must also prepare Caslav air base for F-35 operations. The price for that, including fuel and training of base personnel, is expected to be 44 billion korunas.

Criticisms in the media prior to the Sept. 27 decision prompted an angry 2,400-word rebuttal from the Czech defense ministry earlier in September, which asserted that "inaccurate and misleading information" had been published. The government stated that acquiring the F-35 would be cheaper than purchasing the E-model Gripen.

Saab later rebutted that statement, using data provided to the company by Aviation Week analysts that detailed the estimated through-life costs of both types. That analysis suggests that each F-35 would cost around $452 million over a 37-year life span when operated 200 hr. a year. The Gripen E would cost $239 million over the same lifetime, according to the analysis. The Czech defense ministry released more data after the F-35 decision, based on information provided by

The F-35 will replace both the Gripen (foreground) and the L-159 ALCA in Czech Air Force service.

CZECH REPUBLIC MINISTRY OF DEFENSE AND ARMED FORCES

Sweden in July, showing that 24 Gripen Es would have been more expensive to procure, at 128 billion korunas, versus the F-35 procurement price of 106 billion korunas. Other nations have come to similar conclusions about their relative costs.

The F-35's operating costs are also expected to be higher—4.9 billion korunas per year, including fuel and weaponry after 2034, based on U.S. government data, compared with 3.7 billion korunas for the Gripen E. The Czech defense ministry states that the F-35 is 30% more expensive in terms of real estate infrastructure as well.

The Czech government said the purchase price and operating costs were not the sole factors in its decision-making process. Examining six additional criteria, it concluded that "the F-35 finished first, and the Gripen wasn't even second," it said. The government noted that the F-35's longer development road map and planned service life into the 2060s suggests it could remain in service longer than the Gripen E. Opposition parties have suggested that the procurement plans be delayed for two years so further analysis of the country's air defense can be carried out.

Defense Minister Jana Cernochova admitted that the cost of the F-35 was indeed a high price to pay, but she insisted it represented just 7.5% of annual upcoming defense spending in 2024-34 and that it would not harm the modernization of the rest of the armed forces. She said the purchase and life cycle of the aircraft would cost each Czech citizen 700 korunas, the equivalent of $30 a year. "[It is] the price of defending our airspace that is necessary. It is the solution for a secure future for all of us," she said.

Lt Gen. Karel Rehka, chief of the Czech military's general staff, told journalists at the Sept. 27 announcement: "We have to realize that with the large number of these machines that will operate in Europe and their interconnections, we will be able to use sensors and information from our allies. We're talking about a network of more than 600 aircraft here, and that's a force with major deterrence potential to deter a possible adversary from trying to attack us. . . . Thanks to these aircraft, our army will be able to fully operate in all operational domains for the conduct of war and ensure the effective defense of the Czech Republic."

With deliveries of its F-35s not due to start until 2029—to the U.S. initially for training and to the Czech Republic two years later—and run through 2034, Prague will have to extend its lease of the Gripens. The contract was originally due to end in 2027 but would need to run for another eight years until the transition from the Gripen to the F-35 is complete.

The Czech Air Force is also slated to retain half of its locally developed Aero Vodochody L-159 Advanced Light Combat Aircraft (ALCA) through 2035, with the other half planned to be withdrawn from use in 2029. Initial operational capability with the F-35 is envisaged for 2032, and full operational capability is planned three years later.

The Czech defense ministry says it has secured 14 work packages for local industry—11 from Lockheed Martin and three from engine-maker Pratt & Whitney—that include the "possibility of direct involvement in the global supply chain for F-35 aircraft." These projects will localize pilot training, research and development, and maintenance, service and repairs of the Czech F-35 fleet, officials say. The contracts are valued at 15 billion korunas.

It is unclear whether Prague will seek production of some of its F-35s in Italy, as is done for the Netherlands and Switzerland. That option is mentioned fleetingly in infographics published by the defense ministry.

Lockheed Martin said it was honored that the Czech Republic selected the aircraft. Its partnership with the country's industry would "deliver benefits in research and development, manufacturing and sustainment," the OEM said in a statement. "The F-35's growing presence across Europe is a powerful example of alliance-based deterrence and is setting the foundation for NATO and allied nations' next-generation airpower capability," it added.

As the Czech decision was being made, Romania also began its process for acquiring the F-35. It plans to purchase 48 aircraft in a multiphase program, paid for through increases in the country's defense budget to the equivalent of 2.5% of GDP during 2023-24.

U.S. Air Force Engine Request Points to Need for Larger CCAs

- THE THRUST RANGE IS SET AT 3,000-8,000 LB.
- THE REQUIREMENT FOLLOWS A TREND OF INCREASING SIZES OF COLLABORATIVE COMBAT AIRCRAFT DESIGNS

Steve Trimble Washington

A future class of collaborative combat aircraft have a publicly released mission as well as a quantity and fielding schedule, yet still little is known about the desired size and performance of these future autonomous warplanes sought by the U.S. Air Force and Navy.

The prolonged ambiguity over requirements lends significance to the appearance of any new detail. The Air Force has now published a suggested thrust range for the family of collaborative combat aircraft (CCA). If it emerges into a firm requirement, the range points to aircraft types that may be larger and more powerful than the two industry-built demonstrators that have flown to date: the Boeing MQ-28 Ghost Bat and Kratos XQ-58 Valkyrie.

The newly released range of 3,000-8,000 lb. of thrust for the aircraft engine instead follows a trend of CCA designs released since the unveiling of the MQ-28 and XQ-58 before 2020.

An engine delivering at least 3,000 lb. of thrust represents a common thread among the several designs in various stages of design or development, including the Northrop Grumman Model 437, the General Atomics Aeronautical Systems Inc. (GA-ASI) air-launched LongShot, a combat version of the Sierra Technical Services Fifth-Generation Aerial Target and Anduril's newly acquired Fury. GA-ASI also has released a proposal for a multimission family of Gambit CCAs, apparently derived from the Air Force Research Laboratory's Off-Board Sensing Station.

NORTHROP GRUMMAN

Northrop Grumman unveiled the Model 437 concept in 2021, promising an FJ44-powered autonomous system for under $6 million.

By contrast, the sole engine of the MQ-28 demonstrator jointly funded by Boeing and Australia produces about 2,000 lb. of thrust, Aviation Week reported after its rollout in February 2019 (*AW&ST* March 11-24, 2019, p. 16). Kratos also lists the slightly smaller XQ-58 with an unidentified turbofan in the 2,000-lb.-thrust class.

The Air Force has decided, however, that the future CCAs will need up to four times more engine thrust, according to the market survey released to industry on Sept. 29.

The schedule for fielding the first increment of CCAs does not offer industry much time to design a new aircraft from scratch. The first aircraft should be delivered within three years of a planned CCA program launch in the first quarter of fiscal 2025, which begins next October. Subsequent increments of different CCAs are then scheduled to be delivered in two-year intervals, starting in fiscal 2030.

"For these intervals, the government questions seek information on: capability versus cost; schedule; and risk centered on off-the-shelf, modified off-the-shelf, derivative and new engine designs," the market survey notice states.

Off-the-shelf options in the Air Force's desired thrust range include the Honeywell TFE731 and F124, Pratt & Whitney Canada PW300 and PW500, Rolls-Royce AE3007 and the Williams International FJ44.

Those engines power a broad spectrum of single-engine aircraft, ranging from the 12,800-lb. Aero Vodochody L-39 training jet to the 33,000-lb. Northrop Grumman RQ-4 Global Hawk.

The unclassified version of the request for information describes a general list of "desired aircraft characteristics," but the document does not provide a baseline for comparison. The description instead calls for engines with "increased range, reduced runway takeoff distance, increased Mach capability, increased power and thermal capacity and increased payload."

As the Air Force's appetite grows for CCAs with more range, speed and payload, the pressure also will increase on cost. The Air Force no longer defines the attritable quality for CCAs as less than $20 million each. Instead, the Air Force describes attritable as an aircraft that lacks a human crew on board. But officials also are clear that such aircraft must be affordable enough to be acquired in volumes of 1,000 or more.

Industry marketers have been careful to promise more capability but not substantially more cost. When Northrop unveiled the Model 437 two years ago as an uncrewed derivative of the Model 401 Sierra, company officials estimated that the unit cost could stay below $6 million. If realized, the Model 437 could be sold at the same price as Kratos now estimates for the smaller XQ-58 yet offer the capability to carry two Raytheon AIM-120 advanced medium-range, air-to-air missiles internally.

Air Force Research Laboratory Tries To Digitize Weapon Development

> USAF COULD FIELD CAPABILITIES FASTER WITH DIGITAL TESTING

> CLEAVER CRUISE MISSILE AN ATTEMPT TO VALIDATE A DIGITAL TWIN

Garrett Reim Seattle

The U.S. Air Force Research Laboratory is trying to break open the traditional—and often lengthy and difficult—process of updating weapons and uncrewed air vehicles by using new simulation tools that could in theory allow new vendors, including fast-moving startups, to test their software and hardware virtually. Faster updates, additions and fixes to aircraft could allow the Air Force to field capabilities more quickly and stay ahead of adversaries.

The Air Force Research Laboratory's (AFRL) plans to demonstrate these ideas via Cleaver, a quasi-cruise missile and uncrewed air vehicle (UAV) scheduled for first powered flight in December. Developed by Zone 5 Technologies, Cleaver is intended as validation of hardware-in-the-loop and software-in-the-loop simulation processes, which the AFRL has been using to test updates to that system's digital twin, dubbed the Open Weapon Platform.

Simulation efforts are an important piece of the AFRL's Golden Horde program, an overarching effort to develop and demonstrate collaborative, semi-autonomous munitions and UAVs. The laboratory's "Colosseum" efforts are a collection of virtual testing and demonstration projects to validate new capabilities, especially autonomy algorithms, for those munitions and UAVs.

Conventional processes and systems usually require writing software programs that are specific to hardware configurations and operating systems, says Steve Stockbridge, Golden Horde program lead at the AFRL's Munitions Directorate at Eglin AFB, Florida.

"In the early stages of the life cycle, this proves cumbersome because complete architectures usually need to be defined before any software development can begin," he says. "This constraint also limits reuse and refactoring during hardware end-of-life or hardware refreshes, which leads to higher and longer lifetime costs."

That process has restricted the Air Force to making updates to lines of code in operational flight programs every two years, Stockbridge says. "They only change [the code] so much, and then they've got to certify everything," he says.

However, if flight-critical and non-flight-critical software modules could be separated, and then changes tested virtually, in theory it would be easier to rapidly update and recertify weapons and UAVs, Stockbridge says. That is useful for uploading better autonomy software, integrating new sensors or hardening a munition against the latest cyberthreats, for instance.

The AFRL would like to adopt an agile development process, a method popular in Silicon Valley for developing and updating software in small chunks while continuously seeking feedback from users.

Using software-in-the-loop and hardware-in-the-loop simulations, the AFRL would like to develop an automated "continuous integration, continuous delivery pipeline" process to test code and detect integration issues early, Stockbridge says. "This encourages frequent code commits and rapid feedback."

Much like Tesla is constantly gathering data from sensors on its automobiles and using it to improve its electric cars, the AFRL would like to use sensors on its weapons and UAVs to guide system changes.

"You know, bombs are one-way—they don't typically report back to us," Stockbridge says. Software-enabled weapons might give feedback up until the point of impact.

Ultimately, the AFRL wants to use virtual testing to lower the barrier to doing business with the Air Force, thus expanding the U.S. industrial base with which it can work. It imagines Colosseum as a sandbox for companies to test and compete their hardware and software offerings.

Software-in-the-loop simulations could allow a virtual munition running an autonomy algorithm to be tested in different scenarios, Stockbridge says. Algorithm developers—what the AFRL calls Gladiators—could also compete against each other in thousands of Colosseum simulations.

After running thousands of simulations, the best software and hardware could be tested and integrated into the physical munition. Cleaver, which is based on the service's Weapon Open System Architecture standard, is designed with modular components such as a swappable nosecone, interchangeable payload bay and changeable wings.

For the time being, Cleaver is not a program of record and is more of a testbed, Stockbridge says. "It's really to show you how to do things faster, better," he says. "It's really about transferring ideas out there."

AIR FORCE RESEARCH LABORATORY

The AFRL is trying to iron out best practices for developing software-enabled weapons.

Northrop Grumman Shifts Focus on Commercial LEO Station

> NASA AGREES TO CANCEL STATION DEVELOPMENT CONTRACT

> NORTHROP JOINS AIRBUS ON TEAM HEADED BY VOYAGER SPACE'S NANORACKS

Irene Klotz Cape Canaveral

Rather than develop and operate a commercial space station in low Earth orbit, Northrop Grumman has decided instead to expand a tried-and-true business line: flying station resupply missions onboard Cygnus cargo ships.

NASA

To support Voyager Space's Starlab station, Northrop Grumman plans to develop a fully autonomous docking system for its Cygnus cargo ship, pictured being captured by the International Space Station's robotic arm for berthing on Aug. 4.

Northrop was one of four teams awarded NASA funding to begin developing commercial stations in low Earth orbit (LEO). The agency is looking for options to host its microgravity research experiments and technology demonstrations after the International Space Station (ISS) is decommissioned, which is targeted for 2030.

But on Oct. 4, Northrop announced it was withdrawing from its 2021 Space Act Agreement—with NASA's blessing—and joining a once-rival team headed by Voyager Space-owned Nanoracks. The Nanoracks station, known as Starlab, will be developed, built and operated in partnership with Airbus Space and Defense.

"Northrop Grumman has determined that its best strategy is to join the Nanoracks team," Phil McAlister, NASA's director of commercial space, said in a statement. "NASA respects and supports that decision. We continue to see a strong competitive landscape for future commercial destinations, and I am pleased that Northrop is staying with the program."

"We are fully committed to the future of commercial LEO," added Steve Krein, vice president for Northrop's Civil and Commercial Space unit. "Our new role with Starlab supports NASA's initiatives to encourage commercial space station development as part of a growing LEO economy."

Northrop plans to develop an upgraded version of its Cygnus cargo ship, which has provided ISS resupply services since 2014. SpaceX also operates an ISS resupply line, and Sierra Space's Dream Chaser spaceplane is expected to join the ISS fleet next year. Cygnus spacecraft, which are captured and berthed with the station's robotic arm, so far have completed 19 resupply missions to the ISS, delivering more than 138,000 lb. of cargo.

"Under this teaming agreement, Voyager Space and Northrop Grumman agreed to a framework under which Northrop Grumman will perform services to upgrade its flight-proven Cygnus cargo vehicle with a fully autonomous docking system to support Starlab missions," Voyager said in a statement.

Northrop plans to provide Cygnus spacecraft over an initial five-year period to support Starlab. The contract is not exclusive, leaving Northrop free to pursue cargo resupply business and services for other station operators. Northrop also is expected to provide engineering services to support Starlab's design and development.

"This collaboration is a major step forward for the Starlab program," Voyager Chairman and CEO Dylan Taylor said. "Northrop Grumman's technical capability and proven success in cargo resupply services will play a pivotal role as we accelerate Starlab's development."

Northrop was awarded a milestone-based, $125.6-million agreement in December 2021 to develop a commercial station. The company so far has received $36.6 million. NASA said it intends to take the remaining funding from Northrop's agreement, along with other program funding, and add paid milestones for the remaining participants in the Commercial LEO Destinations program.

In addition to Northrop, NASA agreed to fund Voyager Space's Nanoracks, which was awarded $160 million, and Blue Origin, which won $130 million for its Orbital Reef project. The funded Space Act Agreements 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.

The base Starlab space station features a large inflatable habitat designed and built by Lockheed Martin, a metallic docking node, a power and propulsion element, a large robotic arm for servicing cargo and payloads and the George Washington Carver Science Park—a multipurpose laboratory for research, science and manufacturing.

With a 26-ft.-dia. module, the multilevel station is designed to launch onboard a Blue Origin New Glenn rocket or SpaceX's upcoming Starship transport in 2028 or 2029. Starlab, which is designed to house a crew of four, is expected to reach initial operational capability with just one launch.

MARKUS MAINKA/ALAMY STOCK PHOTO

United Airlines Firms Up Its Orderbook for the Next Decade

> BOEING 787s ARE BACKBONE OF UNITED'S TWIN-AISLE JET ORDERS

> AMERICAN AND DELTA ARE ADOPTING DIFFERENT APPROACHES TO MANAGING THEIR LONG-HAUL FLEETS

Lori Ranson Washington

United Airlines' latest order for 110 aircraft cements its status as the carrier with the largest aircraft orderbook in North America and begs the question of when its major U.S. competitors will bolster their own, particularly for widebodies.

Chicago-based United has ordered 50 Boeing 787-9s and 60 Airbus A321neos for delivery in 2028-31. The latest additions solidify the airline's orderbook through the end of the decade. During an Oct. 3 conference call, United Chief Commercial Officer Andrew Nocella explained that aircraft production lines are now regularly plagued by supply chain disruptions and delivery delays and "are also increasingly sold out for the entire decade."

The Aviation Week Network Fleet Discovery database shows that United has 771 aircraft on firm order, compared with Delta Air Lines' 313 and American Airlines' 184.

United has placed 202 firm orders for widebody jets, compared with 32 from Delta and 30 from American. United's widebody portfolio still includes 45 Airbus A350-900s it has on order. The carrier ordered 25 of the aircraft at the beginning of the last decade and later expanded that to 45.

Nocella fielded a question regarding the A350s, saying the aircraft remain on firm order. He described the twin-aisle jet as "a great machine," but added that United is very focused in the short term on the 787.

The airline's international ambitions are running high. "We expect a disproportionate part of our growth in the second half of this decade to come from global long-haul flying, as the U.S. domestic market is mature," Nocella noted.

He explained that United is on course to retire its Boeing 767 and 757 fleet this decade. The airline's higher-gauge Boeing 777s, which the CAPA – Centre for Aviation Fleet Database indicates have an average age of roughly 20 years, will need to be replaced at some point.

United's 318-seat 787-10s and 257-seat 787-9s are a lower gauge than the 777-200ER/300ERs in the airline's fleet. The Fleet Discovery database shows that United operates 16 777-200s, 50 777-200ERs and 21 777-300ERs, with nine 777s inactive.

It used to be that the 777-200ER and then the -300ER were natural choices for longer-haul operations. But international network fragmentation is "going to play out for much longer than people expected," says Richard Aboulafia, managing director of aviation consultancy AeroDynamic Advisory.

United's aircraft orderbook dwarfs those of its global U.S. network peers.

"One reason people loved the 777 was because it was just so perfect for the transatlantic," Aboulafia points out. But now transatlantic routes for many carriers include a mix of 787s and narrowbodies.

United sees potential in its international growth "not only in the biggest cities in Europe and Asia, but even some of those smaller-to-medium-size cities in those regions as well as Africa and the Middle East," Nocella noted.

Like United, Delta will need to determine its future widebody needs eventually. Although speculation emerged that the airline would place an order during the Paris Air Show in June, nothing materialized. Its widebody orderbook of 32 aircraft is split evenly between the A330-900 and the A350-900, according to Fleet Discovery.

During the company's investor day in June, Delta President Glen Hauenstein said the airline is starting to retire its 767-300ERs, retaining just 30-odd of the type by next summer. Fleet Discovery shows Delta has 41 767-300ERs in service and four parked. Those aircraft would be replaced mostly with A330-900s but also with A350-900s, he said.

Delta also operates 19 767-400ERs with two parked, the Fleet Discovery database shows, and older A330-300s, 30 of which are in service, and 11 A330-200s also in operation. A single -200 is parked.

Hauenstein said Delta has "a lot of innings to go on" the continuous improvement of its fleet.

Of Delta's aircraft on order, 61% are Airbus and 39% are Boeing, according to the CAPA Fleet Database. On the sidelines of a Wings Club luncheon in May, Delta CEO Ed Bastian said the airline was primarily taking Airbus aircraft "at the current time." But he added that "keeping a balance between Boeing and Airbus product is really important to us."

While American is a significant international player, it focuses less on long-haul operations than Delta or United. According to CAPA, United and Delta deployed roughly 47% of their available seat kilometers in international markets for the week of Oct. 9, compared with 34% for American.

American's widebody fleet includes 35 787-8s and 20 787-9s in service, with four 787s inactive. The airline also operates 43 777-200ERs and 18 777-300ERs, with six 777s inactive. American's widebody orderbook encompasses 30 787-9s.

During a second-quarter earnings call, American executives pointed out

Air France-KLM's SAS Stake Gives European Consolidation a Boost

> CONSORTIUM TO TAKE 19.9% SHARE OF SCANDINAVIAN AIRLINES

> SAS WOULD NEED TO LEAVE THE STAR ALLIANCE FOR SKYTEAM

Helen Massy-Beresford Paris

Industry watchers have been predicting a wave of consolidation in Europe's airline industry for the past few years. But it is fair to say that Air France-KLM's agreement to buy a stake in Scandinavian Airlines was not what they had in mind.

Air France-KLM made its surprise announcement Oct. 3. In a consortium with Castlelake and Lind Invest, the Franco-Dutch group plans to take an initial 19.9% stake in Scandinavian Airlines (SAS) as part of that carrier's ongoing restructuring and Chapter 11 bankruptcy process.

"This is an important day for SAS and for Air France-KLM," Air France-KLM CEO Ben Smith said in a statement announcing the deal. "Air France-KLM looks forward to establishing strong commercial ties with SAS. With its well-established position in Scandinavia and strong brand, SAS offers tremendous potential to Air France-KLM. This cooperation will allow Air France-KLM to enhance its position in the Nordics and improve connectivity for Scandinavian and European travelers."

As it prepared its SAS bid behind the scenes, Air France-KLM had been loudly voicing its interest in another consolidation project in European aviation: TAP Air Portugal.

A stake in the Lisbon-based carrier, whose privatization the Portuguese government formally launched in late September, is seen as a logical move for Air France-KLM, which missed out on the chance to boost its network to the south when Lufthansa Group's bid for an ITA Airways stake succeeded.

Air France-KLM is not the only major carrier expressing an interest in TAP. Both International Airlines Group (IAG), the parent company of British Airways and Iberia, and Lufthansa Group have also flagged their interest.

But the SAS deal does not necessarily rule out Air France-KLM going for a slice of TAP as well, particularly as the initial SAS investment—$144.5 million—is relatively small.

"That's quite manageable, and I don't think they're overextending themselves," says Patrick Edmond, managing director of airline strategy consultancy Altair Advisory. "I don't think the SAS deal makes a TAP bid materially less likely."

That is in part because SAS has done a significant amount of restructuring, so Air France-KLM is not buy-

JOEPRIESAVIATION.NET PHOTOS

After restructuring, a new chapter is starting for SAS.

If all goes well—and notably if SAS leaves the Star Alliance in favor of SkyTeam—Air France-KLM plans to establish a commercial partnership between its airlines and SAS, and it could in time take a controlling stake.

BACKGROUND: JULIARSTUDIO/GETTY IMAGES

that a refleeting it pursued in 2014-19 and accelerated during the COVID-19 pandemic differentiated it from many network peers in terms of the motivations behind new aircraft orders.

"We don't have any fleet replacement needs between now and the end of the decade," Chief Financial Officer Devon May said on the call. "So when we are investing in aircraft, that is an investment to grow the network and to grow the airline."

Boeing has an edge in widebody orders among North American commercial airlines. According to Fleet Discovery, North American airlines have orders for 214 787s, compared with 77 for Airbus A330s/A350s. The Airbus total includes United's A350 order.

"It sure seems like the way it will shake out in North America is Airbus gets an increasing share of the narrowbodies because of the A321neo's capabilities, while the 787 is just a natural choice for widebodies," Aboulafia says.

While the advantage in widebody orders in North America is a boon for Boeing, operators worldwide increasingly prefer narrowbody aircraft as the range of those jets continues to grow, and that gives Airbus an advantage.

The latest Aviation Week Network forecast for commercial aviation shows the Airbus A320 fleet will outnumber the Boeing 737 by more than 1,500 aircraft by 2033.

ing an airline in disarray that would demand huge resources to put in order.

In fact, Edmond still sees Air France-KLM and Lufthansa as the two most likely candidates to take a stake in TAP, which would add Southern European and South American destinations to its network. "I struggle to see IAG getting much value out of TAP," he says. "They've got Iberia, and they're likely to get Air Europa. The concentration involved means they would have to divest so much it would become less valuable for them. For Air France-KLM or Lufthansa, this still represents quite a large chunk of the jigsaw."

JLS Consulting Director John Strickland also notes that SAS and KLM have at least one thing in common: strength in the Nordic region. In addition, SAS CEO and Dutch national Anko van der Werff used to work at KLM. SAS has done a lot of the hard work involved in restructuring, too, with its Chapter 11 process getting underway last year.

"The long-haul fleet is now more efficient, and SAS will be able to tap into the Delta [Air Lines]-Air France-KLM joint venture, which makes a lot of sense," Strickland says.

And in network terms, the deal would make sense for SAS, Strickland points out. "They will be able to build a stronger North Atlantic presence in Scandinavia [by] being part of that bigger-picture [joint venture]," he says. "That could also work in the other direction toward Asia with Air France-KLM's strength there, in the scenario in the future in which we get back to more direct routings over Siberia."

Air France-KLM is eager to take part in European consolidation.

SAS has been working hard to address its cost base and compete better with low-cost carriers. As for Air France-KLM, Strickland notes: "There was skepticism about the Air France-KLM merger because of the proximity of the hubs. But they have proven clearly that they can use those hubs wisely in different ways and play to their strengths."

The tie-up could mean that some of SAS' current transatlantic traffic to major U.S. cities could be lost to Amsterdam or Paris. But the airline has been investing in its Airbus A321 long-haul narrowbody fleet, so routes between secondary Scandinavian and U.S. cities might well still make sense.

While the departure of a founding member of an alliance is still unusual—ITA's (formerly Alitalia) likely departure from SkyTeam for the Star Alliance notwithstanding—the move to SkyTeam could make sense for SAS, Edmond says. "A big chunk of its long-haul traffic in the past was Asia, which still has a problem with detours, so SAS is not entirely out of the woods," he notes. "But I would like to think that moving into SkyTeam will actually bring a significant strategic benefit. In Star Alliance, it was always a little hard to see the geographical strategic benefit SAS was bringing—with Lufthansa and LOT [Polish Airlines] there it was a bit of a crowded neighborhood."

Edmond adds: "This brings additional network benefit for SkyTeam, which would be complemented nicely if they also manage to get TAP."

However, Air France-KLM should not underestimate the investment in terms of time and integration tie-ups involved—nor is it likely to, given the scale of integration Air France and KLM faced when they joined forces, Strickland notes. "I don't think you can underestimate the human, cultural side of these mergers as well as sorting out revenue management and network planning systems," he says. "Even at Air France-KLM there was a real struggle for integration. It all takes management time."

Strickland adds: "I hope that with this sudden quickening of pace in European consolidation we don't see tensions and challenges in years to come because there was a haste to do this, instead of concentrating on one thing at a time."

Getting Closer

> BOOM IS ENTERING CRUCIAL PERIOD FOR SUPERSONIC PLAN

> SYMPHONY ENGINE COMBUSTOR RIG TESTS ARE SET FOR 2024

Guy Norris Colorado Springs

Almost exactly 20 years to the month after the Concorde's retirement, the first of several long-planned projects promising to restore commercial supersonic flight is edging closer to reality.

Boom Supersonic has engaged with regulators to begin the certification process for its Mach 1.7 Overture airliner and is close to starting flight tests of its XB-1 subscale demonstrator at the Mojave Air & Space Port in California. The company's assembly facility is being constructed in Greensboro, North Carolina, and engine design work is underway in Jupiter, Florida.

But the world has changed significantly since the Concorde was developed in the 1960s, and the Colorado-based developer knows its credibility and long-term success depend on more than building a production site and flying a demonstrator. With everything still to prove and facing an array of formidable environmental, commercial and technical challenges, the nine-year-old company is aware that much depends on successfully finalizing the Overture airframe and its propulsion system design over the coming months.

"There are some big design milestones coming up on Overture and Symphony—our engine," Boom founder and CEO Blake Scholl says. "We will be at firm configuration on both engine and airplane by the end of this year. That means closing the design on the engine and the design readiness review on the airplane. Then we'll be in supplier joint development come Jan. 1, so the teams from our suppliers will be headed out to Denver to be working alongside us on their piece of the development."

Aernnova and Aciturri, both based in Spain, are working with Boom to supply the Overture's wings and empennage, respectively, while Italian company Leonardo is slated to provide the fuselage and wingbox. Other systems suppliers previously announced by Boom include Collins Aerospace, Eaton, FlightSafety International and Safran Landing Systems.

"On Symphony we'll have our first rig tests next year," Scholl says. "We're planning to start with the combustor, and so we will make fire next year." The new centerline engine is under development by an industry team including Kratos subsidiary Florida Turbine Technologies, GE Additive and StandardAero. The two-spool, 35,000-lb.-thrust, medium-bypass turbofan engine is planned to be equipped with a single-stage 72-in.-dia. fan and optimized for prolonged supersonic operation with an air-cooled, single-stage, high-pressure turbine and a three-stage low-pressure turbine.

The Symphony's compressor will consist of a six-stage high-pressure unit and a three-stage low-pressure section. The supersonic inlet, diffuser and exhaust design is crafted to meet Chapter 14 noise levels. "The engine will start to appear in hardware from the heart of it and begin working outward [from the core]," Scholl says. "This will be a hardware buildup test with lots of demonstrations and validations along the way. This is not engineers using computer-aided design for years, putting it all together, then hoping it all works."

Taking a leaf out of SpaceX's "fail fast, find problems and fix them" test-and-development handbook, Scholl says: "Our engineering philosophy is to really get the concept right. Don't rush the concept because that's where 80% of the cost is locked. But once the concept is locked, get the parts quickly and learn quickly. And we are taking a tooling approach that allows us to make changes with low cost when we find that we want to."

In another development, Boom has received its G-1 Issue paper from the FAA, marking a key step in the multi-stage process toward clearing the Overture airliner for commercial service by the end of the decade. The G-1 certification basis spells out the specific airworthiness and environmental standards, including special conditions, required for FAA type certification.

Under the second stage of the G-1 process, the FAA is to lay out its view on what the certification basis—including special conditions—should be for the Overture. In the third stage of the G-1 process, Boom would coordinate with the FAA on what it intends to do to meet the requirements. This could result in an updated issue paper from the FAA if required, or—if agreement is reached—would lead to a fourth stage to conclude the G-1.

While the requirements are established, Boom is set to work in parallel on finalizing its G-2 Issue Paper with the FAA, which would set forth the means of compliance to meet the requirements laid out in the G-1 Issue Paper. "We can confirm that the FAA G-1 Issue Paper: Certification Basis has been provided to Boom for Overture, and we're now in Stage 2 of the process," Boom says.

"We know where the attention is going to be—it's areas like higher-altitude operation, which is going to put a lot of energy around things like cabin depressurization and rotor burst," Scholl says, commenting on certification, the means of compliance and the likely special conditions.

"We are planning for all of that in the design of the aircraft," he continues, referencing features such as the intentional positioning of the engine turbomachinery aft of the cabin rear pressure bulkhead. "This is how we build in safety. This is how we build in

BOOM SUPERSONIC PHOTOS

Boom's XB-1 demonstrator is nearing first flight at Mojave, California.

certification from the start. This concept has been studied very carefully from a certification perspective."

Meanwhile, construction of the Greensboro production site where Boom plans to assemble the Mach 1.7 airliner remains on or slightly ahead of schedule, Scholl says. "We were originally targeting to have it done by the end of next year, and we find ourselves in the somewhat surprising position of having a $100 million construction project that's ahead of schedule," he says. "It'll certainly be done by the summer, and possibly by early [in the] second quarter. I don't want to promise that, but it's ahead of schedule. And so we are in danger of having a supersonic jet factory in relatively short order."

line, which would boost capacity up to 66 Overtures per year. The Overture facility, which Boom announced in 2022, is roughly 150,000 ft.^{2} with an additional 24,000 ft.^{2} of office space. Initial tooling is slated to be installed late next year, paving the way for assembly of the first aircraft, with rollout targeted for 2026.

"It's going to be one of the more state-of-the-art assembly processes with a reasonable amount of automation, and one of the things that's different is we're limiting the use of hard tooling," Scholl says. "There's a lot of use of digitally positioned vehicles that carry sections of the airplane for assembly, which are then put together using automated match drilling. It's not bleeding edge, but we are using the very latest techniques that ultimately will reduce assembly cost and hard tooling. We're also futureproofing the 'super factory' to get to Overture Two and Three."

Texas-based Advanced Integration Technology (AIT) is the tooling and automation provider and integrator for the Overture final assembly line. As well as covering the design, fabrication and installation of custom tooling, AIT is providing transportation and positioning tools for fuselage assembly, wing assembly, wing-to-fuselage joining and final assembly. Some of the major hardware to be provided by AIT include automated drilling machinery, mobile transport equipment and positioning and joining setups.

In the more immediate future attention is on the XB-1 and its progress toward flight tests. "The aircraft is very close to the finish line," Scholl says, noting that the aircraft reached ground speeds of almost 90 kt during runway tests at Mojave in late September. "The aircraft is performing very well and showing us that it's getting ready for flight. When we have enough times in a row when everything has gone flawlessly, then it's time to go do it," he adds.

Configured with three afterburning General Electric J85-15s, the slender delta-wing XB-1 is intended to pave the way for the Overture by proving out design processes, engineering software, digital modeling, production methods and flight-test procedures. Scholl says the XB-1 therefore remains highly relevant despite Boom's 2022 announcement of a complete redesign of the Overture airliner with four engines and a cranked-arrow planform in place of the original trijet, ogive-wing configuration. "There's tons of programmatic and technical learning there, as well as the calibration of all of our big design tools that we're using for Overture," he says.

Flight testing is based out of Mojave to take advantage of the nearby restricted airspace and the wide main runway. "We didn't know what our ground handling qualities would be like, but it turns out the pilots compare them quite favorably to what they've seen on a [Northrop] F-5 or T-38," Scholl says. Recent ground tests have included evaluation of an auxiliary flow path that has been added to the left and right inlets to improve static engine performance. Boom adds that while the 2D inlet design is different than the Overture's axisymmetric configuration, the added auxiliary doors on the XB-1 "bring it closer to Overture's intake architecture."

The preliminary test plan covers envelope expansion over 10-20 flights, targeting supersonic speeds as close as possible to Mach 1.7. "I'm sure as we learn things in flight test, the plan will inevitably evolve, but our goal is to gradually expand the envelope. As the airplane shows us that it's doing what we expected it to do, then we'll continue to push it further and further," Scholl says.

Construction of the Overture final assembly line in North Carolina is ahead of schedule.

Concrete has been poured for floors, following the raising of the final beam into place in September to finish the frame of the main building. The "topping out" ceremony at the 62-acre Boom site at Greensboro's Piedmont Triad International Airport was in September, nine months after the start of construction on what is intended to be the final assembly line building.

Boom has sized the facility to produce up to 33 Overture aircraft per year. There is space to add a second

REASONABLE

> AIRBUS AND FEDEX DISCUSSED SINGLE-PILOT A321 AND A350 PLANS

> EASA IS STUDYING CONCEPTS BUT DOES NOT HAVE A TIMETABLE

> PILOT GROUPS ARE UNIFIED IN OPPOSITION

Sean Broderick Chicago, **Jens Flottau** Seville, Spain, and **Thierry Dubois** Lyon

A push to develop procedures and new flight deck functionality that supplant a pilot even for short time periods is receiving increased attention from global labor groups that fear a direct path to aircraft designed for single-pilot operations.

The Air Line Pilots Association (ALPA), International Federation of Air Line Pilots' Associations and European Cockpit Association launched a joint campaign against single-pilot operations (SPO) this year without flagging any specific projects. Soon, targets emerged: projects underway at Airbus and Dassault as well as a European Union Aviation Safety Agency (EASA) study on extended minimum crew operations (EMCO) and SPO (*AW&ST* June 13-26, 2022, p. 32). EASA now says nothing will change before 2027, and SPO for commercial airline operations—if they ever happen—are much further off.

While regulators will drive any reduced-crew operations (RCO) timelines, at least two large industry stakeholders have considered plans with far more ambitious timetables than EASA's latest public statements.

Airbus has pitched two new freighters to FedEx that would leverage having fewer pilots on board, Aviation Week has learned.

The more radical proposal is an A321F that would be type-rated for two pilots at the outset but would attain single-pilot approval over time, documents seen by Aviation Week suggest. The second concept is an A350F approved for EMCO—essentially permitting one pilot on the flight deck during low-workload cruise portions of the flight, which could lead to needing fewer pilots on long-haul flights that require relief crews under current regulations.

The ideas, pitched in early 2022 and dubbed Project Morgan, are not moving forward at the pace Airbus envisioned due primarily to regulatory hurdles. But details in the documents lay out the manufacturer's thinking on how SPO could evolve.

The A350F could be an early platform to test reduced flight crew operations scenarios.

Under Project Morgan, Airbus would further develop concepts trialed under its Dragonfly program, such as automated emergency descents. These would converge with EASA's EMCO work, which focuses on evaluating the risks and potential benefits of allowing a single pilot on the flight deck during low-workload periods (*AW&ST* Jan. 24-Feb. 6, 2022, p. 50).

The A350F plan proposed to FedEx envisioned a formal application in 2022 and entry into service—with at least some RCO approvals—in 2026. This would follow rulemaking and standards development by both EASA and the FAA.

When EASA unveiled its EMCO and SPO study last year, its timeline

REDUCTIONS?

aligned with Airbus' FedEx pitch. Its original target was industry consensus on EMCO and some approved operational applications such as single-pilot flight decks during long-range cruise by the middle of the decade. While the broad vision remains in place, both the regulator and the manufacturer have throttled back.

"We have been asked to look at single-pilot operations [for freighters] as industry has been approaching us to look at the viability of the case," EASA Acting Executive Director Luc Tytgat tells Aviation Week. "We don't have yet a pre-application, just . . . a partnership agreement with the industry actor. They want to question us [on] whether it is realistic or not. We are at step zero of the process."

Regarding timing, he adds: "There is not so much activity. We don't see [entry into service in 2025 or 2026]. Single-pilot operations is not something immediate."

Airbus "is constantly looking for ways to improve and advance its range of products to deliver higher levels of safety, efficiency and performance," the manufacturer tells Aviation Week. "We believe that pilots will remain at the heart of operations for the foreseeable future and that automation can play a crucial role by assisting them in the cockpit and reducing workload. . . . Our studies are based on a minimum of two operating crew per flight and do not involve flights with only one pilot on board. As we do so, we are in constant dialog with our customers and the authorities."

Airbus is developing an A350F that is scheduled to enter service in 2026. It has not launched a new-build A321F.

"We have no further comment about the launch of an A321 freighter version," the manufacturer says. "There are many studies, but not all of them see the light of day."

Whether Airbus has shelved its A321F SPO plan or simply set it aside is unclear. But as recently as last year, it was crafting a sales strategy around the concept.

The A321F SPO plan included application to both EASA and FAA in 2023 and entry into service in 2027, according to the documents seen by Aviation Week. In parallel, Airbus would support development of what it dubs the "single pilot/second pilot-optional" certification project that would pave the way for full-mission SPO. FedEx would work with the FAA on operational details, including a pool of pilots trained to fly either alone or in traditional crew pairs. The ambitious project aimed for entry into service by 2030.

Several industry sources said the FAA's list of near-term priorities does not include any substantial RCO work.

A FedEx pilot union source said Project Morgan has not been discussed with its ALPA-represented membership. FedEx did not respond to Aviation Week's inquiries.

Single-pilot operations would require enhancements to current-generation flight decks.

HERVE GOUSSE/AIRBUS

AIRBUS CONCEPT

The increasing activity around RCO and pilot unions' concerns stem from multiple concepts converging.

Automation's evolution is bringing capabilities to the flight deck that supplant pilots. Airbus last year selected Thales' PureFlyt as one flight management system (FMS) option for the A320, A330 and A350. Among the functionalities that Thales is building into the system is a "pilot assist" function, Yannick Assouad, executive vice president for avionics, revealed during this year's Paris Air Show.

Designed to automate weather-related route changes and other unexpected flight plan diversions, PureFlyt will start as a function pilots must opt to use. Remove that critical step, however, and it becomes part of a truly automated FMS functionality.

"You can easily imagine a system that has [data from] millions of flights integrated—all the failure scenarios that you can imagine in the airplane and procedures to answer them are automatically loaded in that system," Assouad said. "It can become a flight assistant with no pilot [activation]. It has the power to absolutely do that."

While true SPO will require a step change in automation, aircraft designs also must evolve.

When industry shifted away from having a flight engineer as the third person on the flight deck, aircraft designs changed. Boeing Chief Pilot and Vice President for Flight Operations Craig Bomben suggests a similar shift would be needed to introduce single-pilot scenarios safely.

"As far as I know, there has not been a commercial airplane built yet that

was designed for single-pilot operations," Bomben said at a recent ALPA conference. "Because of that, there are certain things you cannot do from a single seat," he added, using a jammed control as one example. "Solving that requires both pilots."

As aircraft designs evolve, industry is exploring more reduced-crew scenarios on today's aircraft. The concept dates back decades, starting with so-called controlled rest—or planned naps—in the cockpit.

EASA is among many regulators that, under very specific guidelines, allow one pilot to take a nap in their seat while the other stays at the controls. The European air transport industry took advantage of a 1989 NASA study published in the International Civil Aviation Organization's journal the following year, flight safety consultant Bertrand de Courville explains.

"As a guiding principle, taking some rest in flight helps being in a good shape for critical flight phases, such as approach and landing," says the French Air and Space Academy member and former Air France captain. "Electroencephalography shows sleep is a physiological need; it is no use trying to fight it. If you do not rest to recover vigilance, you will have a drop in alertness or fall asleep before you know it."

The idea is to take a nap without settling into deep sleep. The total duration should be around 30 min., including a wake-up phase. Proponents say the practice helps prevent loss of vigilance but has limited impact on fatigue. Loss of vigilance and fatigue are different, even though building up fatigue paves the way for losing vigilance.

"Briefings are key," de Courville says. Under the framework set by EASA for each operator to create its own procedures, briefings take place before and after the controlled rest period. Before, the crew discusses the situation, upcoming tasks and the possible need to wake up the sleeping pilot. After the rest period, the pilot who stayed awake briefs the other on the situation.

The FAA has studied it and even prepared a draft advisory circular (AC) in the early 1990s that would have allowed it. But opposition from pilot unions, notably ALPA and the American Airlines-affiliated Allied Pilots Association, kept the AC from being adopted, and subsequent guidance has codified the FAA's position.

"The FAA authorizes inflight naps for flight crew if there is an augmented complement so that two pilots are on the flight deck while the augmented crewmembers are resting," states a 2010 Basics of Aviation Fatigue AC. "Although a number of foreign air carriers authorized in-seat cockpit naps during flight, the FAA does not authorize such in-seat cockpit naps."

ALPA President Jason Ambrosi says the union's position has not changed. "Controlled rest is not a solution for fatigue," he says. "That should not be a stopgap for proper rules. Our fatigue rules here in the U.S. allow for multiple pilots on long legs. There's fatigue mitigation through actual rest, not controlled rest."

ALPA sees controlled rest and EMCO's allowance of one pilot on the flight deck while a second pilot naps as not just poor regulatory policy, but steps toward true SPO.

"There is no safety argument to be made" for having one pilot on duty at a time, Ambrosi says.

ALPA is backing its stance with contract language. Recently crafted pilot agreements at Delta Air Lines and United Airlines include provisions that require two pilots, for example. United's contract updated the previous language that specified having two pilots on the aircraft. Now they must be on the flight deck.

Boeing's Bomben acknowledges that the company's automation-related research, which CEO David Calhoun has said will be a significant driver in its next clean-sheet airplane design (*AW&ST* June 19-July 2, p. 42), includes RCO concepts. "This has picked up a head of steam, and we could not ignore it," Bomben said. "So we're looking at it."

Boeing's approach is straightforward, Bomben said. It is looking at failure scenarios one by one and determining whether automated functionality might assist. It also is examining how the same scenarios would be affected by having one pilot at the controls, even for a short stretch.

So far, the results are sobering. One example is a notional EMCO scenario with one pilot on the flight deck while a second is napping in the crew rest area. The pilot flying has a seizure and inadvertently disconnects the autopilot. "Now you have an airplane that is not being flown," Bomben said.

Malicious actor scenarios are another category that seems to conflict with permitting only one trained pilot on the flight deck, he added.

"There is a lot of technology being developed out there right now being touted as the technology required to go to reduced crew ops," Bomben said. "Boeing is not going to support an effort that doesn't meet an equal or greater level of safety.

"I'm not saying we're not going to get there at some point," he added. "But I'm telling you right now there are a lot of questions that need to be answered."

—With Christine Boynton in Boston

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Airbus has discussed an A321F with single-pilot approvals as a replacement for FedEx's large narrowbodies.

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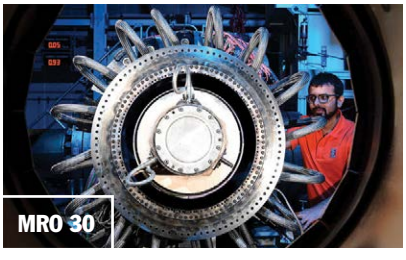

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MAINTENANCE CHECK

Exposed or Exposed?

Exposure to the arts and to new opportunities is fortuitous. Exposure to cyberattacks and disease is unfavorable—or a revelation. In other words, "being exposed to" can be a good or bad thing.

That's the crux of the aviation supply chain: Several of the exposures—sole-source suppliers, congested MRO shops, production delays, labor shortages, parts that need rework—fall into the negative category. Simply put, there's a lot of risk exposure.

"The entire supply chain is stretched, stressed and distressed," says Kin Chong, Evergreen Aviation Technologies (EGAT) executive vice president. Costs for raw material, parts, labor, fuel and logistics are all up post-pandemic—and throw in big production ramp-ups for Airbus and Boeing, and geopolitical tensions to aggravate things. "I personally don't see an equilibrium for the next five years," he said at Aviation Week's MRO Asia-Pacific Sept. 27. "I believe that the high costs that we are seeing post-COVID is structural and are here to stay."

Chong, like other panelists during the event, highlighted several supply chain pain points and offered ways to build strength into the system.

■ **QUALITY CONTROL** The industry reacted quickly when news surfaced that AOG Technics parts were not what their paperwork claimed—but several big airlines had flown engines with falsified parts. From supplier audits to receiving inspections and documentation verification, now is the time to make sure quality systems are solid.

■ **TIER 1-4 SUPPLIERS** Pre-pandemic, the "supply chain became so efficient" and was lean, but at the Tier 4-5 levels, several companies were small, family-owned businesses building sole-source parts in big volumes, says Desmond Goh, Eaton's managing director for aerospace in the Asia-Pacific. "We're in the transition phase of rebuilding those links in the supply chain," he says.

■ **LONGER-TERM CONTRACTS** Airlines traditionally have had a "shopping mentality" for base maintenance, said Gerald Steinhoff, HAECO chief commercial officer. The MRO is seeing airlines looking longer-term—18-24 months—to secure slots. "In turn, that changes our strategy" for holding slots, Steinhoff said.

And long-term partners get priority when there are disruptions, noted EGAT's Chong. Long-term partnership usually benefit both sides if there's trust.

■ **PROXIMITY** Several OEMs forged deals with Asian airline aftermarket suppliers at MRO Asia-Pacific to bring repair capabilities closer to customers. This diversifies aftermarket networks, adds capabilities and brings those capabilities closer to customers, which decreases logistics costs and turnaround times. Doing this also should increase customer service satisfaction.

■ **FORECASTING & DIGITALIZATION** Aligning with customers to understand needs—and using digital tools and predictive maintenance as much as possible to forecast repairs needs—is imperative. For Tier 1 OEMs, the challenge is to align resources and ramp-ups with aftermarket needs. Understanding these priorities is critical to relieving supply chain pressures.

—Lee Ann Shay

"The entire supply chain is stretched, stressed and distressed."

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Highlights

IAI Picks Ascent for 777 P2F Conversions

Israel Aerospace Industries (IAI) has chosen its first North American site for passenger-to-freighter conversions on Boeing 777 aircraft. It has signed an agreement with Ascent Aviation Services that will see the U.S.-based MRO provider carry out Boeing 777-300ERSF conversion services from its site in Marana, Arizona.

IAI

IAI completed its first test flight of a converted Boeing 777-300ERSF in March.

Under the 15-year agreement, Ascent will operate two conversion lines for 777-300ERSF aircraft starting in 2024. Scott Butler, chief commercial officer at Ascent, says the company plans to convert three aircraft annually per line.

To support the program, Ascent is building two new hangars for widebodies, the preconstruction for which already has commenced. It expects both hangars to be completed prior to first aircraft induction.

IAI completed its first test flight of a converted 777-300ERSF in March, and it is in the final stages of the certification process. It expects to receive supplemental type certificates from the FAA and the Civil Aviation Authority of Israel by the end of 2023.

ADE Expands Nacelle Capability

Asia Digital Engineering (ADE), the MRO arm of the Malaysia-based Capital A group, has signed an agreement with Collins Aerospace to grow the former's capability in CFM56-5B nacelle services.

ADE will also be expanding its collaboration with GMF AeroAsia as part of a greater collaboration between Capital A and Garuda Indonesia.

Collins will be providing knowledge transfer and training for nacelle inspection, composite and mechanical repairs to ADE engineers, and will support AirAsia's Airbus A320ceo aircraft life cycle until the type's lease ends.

ADE CEO Mahesh Kumar told Aviation Week that training has commenced, and the company has an ambitious target of attaining the capability within 12 months. He noted there are plans to expand nacelle capabilities further to the A320neo and A330 engines.

Air India Plans A320neo Retrofits

Air India will begin retrofitting its legacy widebody and Airbus A320neo aircraft next year as part of its fleet transformation strategy.

The retrofit project will run from April 2024-27, according to Sisira Dash, Air India's chief technical officer, speaking at Aviation Week's MRO Asia in Singapore on Sept. 27. It will include the installation of new seats and updated inflight entertainment connectivity, along with newly added premium-economy cabins. The project also includes painting the aircraft with Air India's new branding.

"By that time [2024], we expect the parts, seating and other required items to be available," says Dash. "It's not only the seats but the A/V system and the connectivity—everything has to come together."

Dash did not disclose which partners or vendors the airline is working with.

Contracts

AAI Morocco was selected to perform extensive maintenance on three ex-ExpressJet Embraer ERJ145s for delivery to **a new European operator** for entry into service in mid-2024.

Boeing won a five-year **Philippine Airlines** contract to provide its upgraded Airplane Health Management Select product for prognostics and diagnostics to help the airline maintain its 777-300ER fleet.

Cebu Pacific selected **Lufthansa Technik** for CFM56-5B MRO, Cyclean engine washing and aircraft transition services for Airbus A320-200s.

Embraer signed a Pool Program services agreement with **Scoot** for component exchange and repair for nine E190-E2s.

Japan Airlines selected **ST Engineering** to provide component maintenance-by-the-hour programs for Boeing 737-800s and Airbus A321P2Fs.

Joramco won a **Philippine Airlines** contract to perform maintenance and modifications on five more Boeing 777s.

Lufthansa Technik renewed its **Philippine Airlines** contract to provide CFM56 maintenance for another three years.

Magnetic Line signed a strategic partnership with **Xiamen Airlines** to provide line maintenance at Schiphol Amsterdam Airport.

PDQ Airspares secured a consignment agreement from **GMF AeroAsia** to provide consumables stock inventory.

Spirit Aerosystems was selected by **VAECO** to provide aftermarket engineering support.

ST Engineering won a five-year **Lion Air Group** contract to provide Leap 1B MRO.

Contract Source: SpeedNews


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Skywise, to help transform these challenges into opportunities.
AIRBUS

FAA and Boeing Agree on 737 Nacelle Retrofit Plan

Four years after investigators recommended that the FAA and Boeing develop retrofits for nacelles on older 737s, the agency has finally signed off on a plan that calls for the work to be done by August 2028.

Boeing will start by finalizing service bulletins detailing the modification work by the end of 2024. Operators will then have until July 31, 2028—or another 43 months—to retrofit their fleets.

The FAA confirmed its approval in an exemption granted to Boeing in early September. The formal exemption process was necessary to allow Boeing to introduce the series of changes incrementally, instead of having the entire redesign approved as a system before retrofits begin. This would put the individual modifications into the fleet more quickly, Boeing reasoned in its exemption request; the FAA agreed.

Boeing's 737 Next Generation (NG) nacelle redesign focuses on three main areas: new inlet spacers and fasteners, a fan cowl support beam, and a stiffer exhaust nozzle.

The company will add a spacer to the inlet attachment bolts to improve structural integrity. It also will upgrade inlet aft bulkhead fasteners.

Radial restraint fittings on fan cowls will be modified and venting will be added to help ensure they stay closed, intact and attached to the airplane during broken fan blade, or "fan blade out," events. Fan cowl support beam bolts are also being upgraded.

Finally, Boeing will change the exhaust nozzle attachment area structure to improve its load-handling ability.

The combination is meant to make nacelles less susceptible to breaking apart if a fan blade breaks. Boeing agreed to make the changes following two Southwest Airlines accidents that started with CFM International CFM56-7B engine failures.

During one of those accidents, in April 2018, a piece of fan cowl struck the left-side fuselage and broke the window, starting a chain of events that killed one passenger. That fatality, combined with hazards posed by pieces of nacelle breaking away and endangering the airframe, prompted the NTSB to recommend a redesign.

Boeing filed its initial exemption request in July 2021. It asked for seven years to develop the modifications and get them into the fleet.

The FAA exemption adopts this schedule, with one notable change. Boeing has until the end of 2029 to deliver "solutions to address potential maintenance errors," such as ensuring fan cowl doors are always secured before flight.

SEAN BRODERICK/AW&ST

As many as 6,000 737 Next Generation aircraft will be fitted with new nacelles in the next five years.

Boeing asked for the relief in mid-July 2023, citing FAA "policy guidance" that requires manufacturers to identify and mitigate human factors-related risks, such as a mechanic leaving a fan cowl door unlatched, as part of certification.

The nacelle redesign must demonstrate compliance with applicable Part 25 regulations. Among them is a requirement to show "no single failure or combination of failures will jeopardize the safe operation of the airplane," unless the failure involves a structural part and is calculated as being "extremely remote." This regulation, plus one on extended operations, covers the potential maintenance mishaps that Boeing said it needs additional time to satisfy.

"The FAA finds that while Boeing's plan to demonstrate full compliance [with applicable regulations] did not fully account for FAA guidance on potential maintenance errors . . . Boeing's plan does address the potential of an engine fan blade failure," the FAA wrote in granting the exemption. "Boeing's requested extension of the exemption maintains the level of safety of the existing exemption by ensuring operators will have service instructions available to begin implementing design changes without change to the original schedule. The revised exemption will allow both Boeing and operators more time to address appropriate solutions to potential maintenance errors, further improving the level of safety of the airplane."

Regulators around the world are likely to mandate the retrofits, setting the stage for as many as 6,500 aircraft to undergo modifications. Aviation Week Fleet Discovery shows 6,300 737NGs of all types in service and another 230 in storage.

Boeing's changes are part of a multipronged strategy to address safety concerns raised by the two Southwest accidents. Enginemaker CFM also revised inspection requirements and fan blade life limits.

In each accident, cracked fan blades fractured, triggering a chain of events that included parts of the inlet structure breaking away.

In the April 2018 accident that led to an emergency landing in Philadelphia, parts of the fan cowl structure also broke off. Investigators determined that the blade struck the fan case and transmitted loads to a latch mechanism.

Part of the latch broke away, struck a window and dislodged it, causing a rapid decompression and a passenger fatality.

—Sean Broderick


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ARSA UPDATE

Simple or Complex?

GOVERNMENT HAND-WRINGING IS FRUSTRATING. Regulators make a particular art out of covering their hindquarters with complex and often unfounded demands of the industry. New technologies and tools create yearslong debates over how the "old" rules can meet updated standards rather than using performance-based language that is agnostic about technical specifics. The poetry of 14 CFR Part 43's "original or properly altered condition" rhymes on a fabric-covered biplane just as it does for a carbon-fiber air taxi.

In June, the FAA published a notice of proposed rulemaking (NPRM) "integrating" powered-lift aircraft operations into the aviation safety rules. The agency provided a mere two months for public comment on thousands of pages of information that, if promulgated into the promised Special Federal Aviation Regulation (SFAR), would directly affect all pilots, examiners, operators, and design and production approval holders—as well as the public. Across those many pages is a fundamentally conflicted view of advancing technologies that illustrates the agency's general struggle to embrace anything "new."

To the FAA, powered-lift aircraft are either simple equipment air operations or a complex regulatory burden entering the aviation market. This is the heart of the conflict in the rulemaking, and it raises the question: "Which is it—simple or complex?"

On the one hand, the agency assumes each aircraft will "have complex and unique design, flight and handling characteristics with varying degrees of automation." On the other, it cites the numerous benefits that will be derived from vehicles that are "easier to design, simpler to construct, less complicated to maneuver, quieter to fly and more economical to operate compared to traditional aircraft."

This "simplicity side" of the FAA's argument against itself stems from the U.S. Government Accountability Office's assertion that the aircraft will be less complicated, quieter to fly and more economical. The agency fails to use this foundational insight to establish basic standards for pilots and operators, to propose appropriate classes of powered-lift aircraft or to simplify pilot certification. Instead, the rulemaking would solidify the type-rating requirements in Part 61 because of the "lack of commonality in the design" and "complicated and distinctive operating characteristics" of the aircraft.

Both assertions cannot be true. To assume the aircraft will be more complicated is belied by the old methods the agency is using to determine the certification basis—the design elements dictate the aircraft usage, which in turn determines the qualifications required to operate it. When used with the appropriate tests required for helicopter and airplane pilots, it would not burden the agency or the industry to provide an alternative path to qualifying pilots until appropriate classes of powered lift are identified. There is no doubt that many advanced air mobility aircraft will not need type ratings to be operated safely.

There is another core problem in the rulemaking: The FAA's definition of powered-lift aircraft shows how adherence to consistency does not always square with reality. The agency relied on the definition provided by the International Civil Aviation Organization (ICAO): "A heavier-than-air aircraft capable of vertical takeoff, vertical landing and low-speed flight, which depends principally on engine-driven lift devices or engine thrust for the lift during these flight regimes and on nonrotating aerofoil(s) for lift during horizontal flight."

Relying strictly on the ICAO definition limits the proposed rule's applicability to aircraft with some kind of fixed wing. The rulemaking preamble embraced this standard—yet vertical-takeoff-and-landing, short-takeoff-and-landing aircraft and those powered by electric or nonconventional engines do not all depend on "nonrotating airfoil(s) for lift during horizontal flight."

The agency asserts that the rulemaking is meant to cover configurations with thrust vectoring and direct lift schemes that do not depend on nonrotating airfoils, yet the definition chosen would exclude those aircraft from the rule. Practically speaking, the agency should not, after considerable time and investment in developing an SFAR, leave new entrants caught in a loophole.

The lesson, amid exasperation, is to invest focused attention into rulemaking. Despite the short comment period (which can always be extended should the public provide reasonable requests for more time), submitting feedback to an NPRM helps steer the agency and guarantees standing to challenge issues in the final rule. From basic definitions to complexity determinations, the public cannot allow regulators—or a small collection of the industry's most engaged companies—to shape new markets.

Sarah MacLeod is 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.

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New European Aftermarket Forecast

Most MRO visits in Europe to come from narrowbodies over the next decade

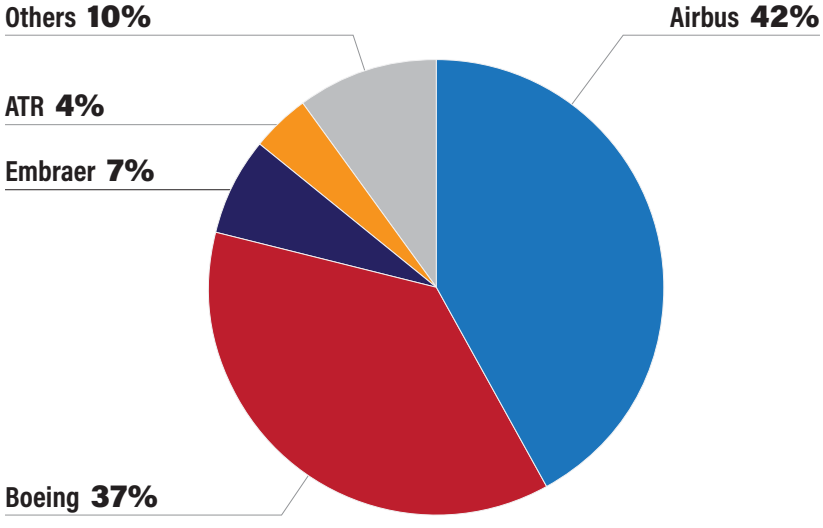
Christian Albertson

The 2024 preliminary edition of Aviation Week's Commercial Aviation Fleet & MRO Forecast projects how the world's aircraft fleet and aftermarket will evolve over the next 10 years. Commercial aviation MRO visits in Europe are expected to surpass 60,500 by 2033. Europe's fleet is forecast to account for nearly 23% of worldwide MRO events.

Airbus is forecast to account for 42% of these visits, followed by Boeing (37%) and Embraer (7%). The Airbus A320 comprises the largest share with 38%, followed by the Boeing 737 with 25%.

The forecast projects that the majority of Europe's commercial aviation MRO visits will be for narrowbody aircraft, comprising more than 65% of total visits, followed by widebody aircraft at 18% and turboprops at 8%.

MRO Visits by Type Certificate Holder



Source: Aviation Week Network 2024 Commercial Aviation Fleet & MRO Forecast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Like It's 1999

The last 25 years show change and continuity for MRO in Europe

Lee Ann Shay Chicago

As we mark the 25th anniversary of the first MRO Europe held in Shannon, Ireland, Sept. 7-9, 1999, here is a look at notable news from the 1999 archives of *Overhaul & Maintenance* (*Inside MRO's* previous name). E-commerce was taking off, and the first MRO forecast pegged industry revenue at $29.3 billion.

CREATING EASA

The Aviation Safety and Security Directorate of the European Commission early this year expect to complete a draft of the treaty that will establish the long-debated European Aviation Safety Authority (EASA). The treaty will be presented to a committee of experts representing the 15 member states of the European Union, and, once it has been approved by them, will be presented to the non-EU states wishing to adopt it. . . .

***O&M*'s March 1999 cover**

Initially, the EC will negotiate on behalf of the EU member states with those non-member countries that are full members of the Joint Airworthiness Authorities (currently Norway, Iceland, Switzerland and Monaco). The other 18 states that are members of the European Civil Aviation Conference may be invited to attend the negotiations as observers, but are not expected to be among the initial signatories to the EASA treaty" (*Overhaul & Maintenance* January/February 1999, p. 55).

QUIET, PLEASE

Europe is breaking ranks with the rest of the worldwide aviation community and moving unilaterally to impose stricter noise standards on airlines operating to and within its borders.

Until recently, operators of Chapter 2 aircraft had until April 1, 2002, to comply with Chapter 3 noise rules. That included any Chapter 2 aircraft operators added to their fleets between now and then. But if a proposal before Europe's Council of Ministers becomes law, any additions to EU registers of jet aircraft recertificated (hush-kitted or reengined) to Chapter 3 will be banned as of April 1, 1999. The 37 member states of ECAC, the Paris-based European Civil Aviation Conference, also are thought likely to adopt such a measure (*Overhaul & Maintenance* January/February 1999, p. 26).

E-COMMERCE TAKES OFF

■ Boeing introduced its internet-based parts ordering and tracking website, known as PART Page, in November 1996 and handled 1.6 million transactions in 1998, which was double the volume from the previous year. The service includes real-time tracking information. Boeing planned to add a distribution center in Amsterdam by the end of 1999.

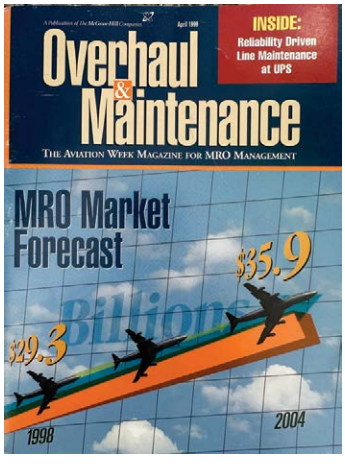
■ AirLiance, established in mid-1998 by Star Alliance partners United Airlines, Air Canada and Lufthansa Technik, takes its first steps to get into electronic commerce. "I think that electronic commerce through the use of the internet with respect to parts ordering and management is definitely the wave of the future," said company president David Sisson. "In fact, it will be a requirement for our business, especially considering the global nature of the aircraft parts business. Because of that, I have proposals on my desk that would put in place an electronic infrastructure to provide 24-hr. access along with text and graphics data (*Overhaul & Maintenance* March 1999, p. 22).

■ AAR offers two internet-based parts support services (AAR SuperSpares and AAR On-Line Parts Warehouse) and is developing a third (AAR On-Line) to allow customers to check on the real-time status of components they have sent to the company for repair.

■ *Aviall planned to place its* "entire 1,500-page parts catalog online with a link to an order entry form" by the end of 1999" (*Overhaul & Maintenance* March 1999, p. 25).

FIRST MRO FORECAST

Overhaul & Maintenance *produced its first MRO forecast, prepared in conjunction with and based on the models and calculations of The Canaan Group. The first commercial jet transport MRO market pegged the market at $29.3 billion and predicted it would grow to $35.9 billion by the end of 2004:* "The largest percentage increase will be seen in the airframe heavy maintenance segment, which is forecast to grow 33% to $6.8 billion. Despite that increase, however, the engine MRO segment will remain the industry's largest, with a projected increase of 23.4% to $9.5 billion" (*Overhaul & Maintenance* April 1999, p. 22).



***O&M*'s April 1999 cover**

BRITISH AIRWAYS BUYS FIRST AIRBUS

British Airways broke from its Boeing-only short-haul fleet and decided to buy from Airbus: "The first batch of 14 A319s for British Airways Regional is slated for delivery in September, with the rest following the end of 2000. These will

replace BAR's fleet of Boeing 737-236s, while its 737-300s will be replaced by seven more A319s in 2003. British Airways' Euro-Gatwick operation will take 10 A320s by the end of 2001, plus 18 A319s between 2001-02. Ten more A320s join the fleet in 2004" (*Overhaul & Maintenance* April 1999, p. 42).

EUROPEAN ENGINEER SHORTAGE

Worldwide worries about the shortage of engineers could have a greater impact on aviation than has yet been foreseen. Not only will the shortfall not support the massive fleet-growth forecasts, but the huge salary hikes needed to stop such skills from migrating to other industries could starve the regulators of experienced people.

In addition, in Europe, with 350,000 directly employed in 7,000 firms, the supply of trained labor in aerospace manufacturing is stretched as Airbus marches toward its stated goal of securing 50% of the aircraft market (*Overhaul & Maintenance* August 1999, p. 25).

SELECT NEWS BRIEFS FROM 1999

■ TRW agreed to purchase Lucas Aerospace parent company LucasVarity for about $6.6 billion. TRW Chairman and CEO Joseph Gorman said that adding Lucas Aerospace would enable TRW to expand the breadth of its aerospace activities, which had previously been more focused on space and defense. The long-term impact of the transaction on Lucas Aerospace and its operations are unclear.

■ Lufthansa Technik (LHT) invested an additional $3 million in HEICO Aerospace Holdings. LHT owns 20% of the joint venture with HEICO. LHT has invested $38 million in HEICO Aerospace Holdings.

■ KLM Engineering & Maintenance and Hamilton Sundstrand formed a joint venture to serve the European, Middle East and African MRO markets for large commercial aircraft pneumatic components.

■ KLM, Northwest Airlines and Alitalia will begin joint marketing of their paint facilities. The airlines also are studying joint purchasing, initially for widebodies.

■ Virgin Atlantic launched a $64 million interior/exterior upgrade, including double beds for Upper Class passengers and a new silver metallic paint scheme. Painting all 25 Virgin aircraft will cost about $4 million.

■ SR Technics plans to extend its powerplant service center this year and add a new hangar for A330/A340 widebody maintenance. A new engine test stand with sound mufflers is scheduled for 2004.

■ Revima won a 10-year contract to maintain and service landing gear and APUs on KLM Boeing 747s, DC-10s and MD-11s.

Locations of the first 25 MRO Europes by year.

ALEXEY KABANOV/GETTY IMAGES AND MINACZ/GETTY IMAGES

Digital Extra *Curious about what the hot topics were at the first MRO Europe in 1999? See this* Overhaul & Maintenance *article by Frank Jackman:* **AviationWeek.com/mro/mro-europe-1999-pma-industry-mega-trend**

American Airlines

Mark Miner, *vice president for technical services at American Airlines, discusses with* **Lindsay Bjerregaard** *how it is tackling workforce and supply chain challenges and preparing for emerging technologies.*

American will be seeing some fleet changes over the next decade, and it has a lot of new aircraft on order, including Boom Supersonic Overtures. From the maintenance perspective, how are you preparing to support these new aircraft? For us, it's mostly an expansion of where we have our skills and strengths right now. We're also limited, but right now, outside of the Boom Supersonic, it's just different variants of fleets we already have. We'll see some changes with the entrance of the Airbus A321XLR late next year, but it's the same A321/A320 family we have a lot of experience with. So it's us focusing on continuing to enrich the training we have around those models and understanding, as the aircraft matures, what specific system issues we may need to focus training on to mitigate challenges as they merge with the fleet.

AMERICAN AIRLINES

Mark Miner

[The Boom Supersonic] is further out in the future, so most of us see that as an investment opportunity to understand emerging technology and how it may help the industry advance, but there's just not enough information now to effectively plan around how we would manage that.

Has there been progress on the new widebody MRO facility in Tulsa, Oklahoma, that was announced in early 2020? Are there other maintenance facility growth plans in the works? Facilities are always a challenge for airlines, and where you invest in those facilities becomes especially important because that is a huge capital investment. [Regarding the Tulsa facility], we're now seeing ourselves in a different space. We're still evaluating the facility needs and certainly recognize the many opportunities and advantages it has for us in terms of presence, but also working with Oklahoma state as well as local communities there. So we are looking at that, but it's not just limited to Tulsa—we're looking at our entire maintenance network and understanding on a broader 5-10-year range where we're going to need those types of facilities and where we need to make those capital investments.

How is American managing the supply chain issues that have been plaguing the entire aftermarket? I think it's fair to say it has improved in the last year. We're encouraged because we have suppliers working with us that are very transparent, so when issues come up—regardless of what they may be and whether you might question if they should have earlier warnings or insight—they're very transparent around the situation. They've been very good to tell us when they believe they will recover, and we haven't seen too many of those recovery plans slip.

We're still not out of the woods, and we're still seeing some challenges in some key areas, regardless of who the manufacturer is. Some of these [challenges] go back to the OEMs, with issues they're having with certain components, but we have seen progress. We still have some that just aren't able to get there, but others are certainly at the forefront of getting ahead of their supply chain challenges.

What type of workforce demand are you experiencing, and are you having difficulty finding enough new skilled workers? The entire industry is looking at what we can do to make sure there's a solid pipeline of candidates coming in, given how much has changed post-pandemic in terms of the opportunities. We're working actively with both the airframe and powerplant (A&P) schools and in public education to make sure there's an awareness of opportunities in aircraft maintenance fields. Fortunately, we haven't had significant challenges, but major airlines tend to draw from other sources within the industry, and those areas are challenged.

Because of the pandemic-related loss of talent and that pipeline declining, the applicants we're getting don't have the depth of experience they used to have. Most major airlines had a requirement and were able to attract people who had several years of jet experience, but now we're getting applicants who just don't have that. The challenge for us is to help build that as quickly as we can and get them exposure to what they need to be skilled in at their jobs, but also share with [A&P schools] what's most critical for them to be focused on so when students get their A&P licenses, they're equipped and ready to go.

How does American approach training less experienced new hires to get them up to speed? It's a mix of classroom, on-the-job and web-based training. We also have some virtual training options. It builds from the fundamentals

American Airlines Fact File

HEADQUARTERS: Fort Worth, Texas
FOUNDED: 1926
FLEET: As of the second quarter of 2023, American Airlines operates the world's largest commercial aircraft fleet, which included approximately 948 aircraft in its mainline fleet as of September 2023. It flies Airbus A320-family classic and new-generation variants, Boeing 737 Classic and MAX variants as well as Boeing 777 and 787 widebodies. American is the world's largest operator of the 787-8 variant. More deliveries of 737 MAXs and 787-9s are expected in 2024, along with the introduction of the A321XLR.
MRO CAPABILITY: American Airlines Tech Ops conducts maintenance on American's fleet and does not undertake third-party maintenance work. Its main facility is in Tulsa, Oklahoma, where it employs nearly 5,000 people.

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and understanding our basic practices and processes, and how we manage the workload on the aircraft and the references necessary for them to do their jobs. It also expands into more skill-based areas, whether it's avionics or specific aircraft systems, for more in-depth training.

American has been involved in green initiatives such as the use of sustainable aviation fuel. Are there any sustainability initiatives happening within Tech Ops? For Tech Ops, it not only includes the aircraft, but also ground equipment. We have a lot of initiatives going on around ground support equipment (GSE). We already have electric GSE in a lot of our locations, and in some, that's mandated by local regulations, so we're advancing that in several cities. We're also looking at how to further that as part of our GSE investment, because there's always a replenishment, similar to an aircraft fleet. We're starting to hear more about the possibility of hydrogen-powered equipment, and I think there's a lot of practical applications of that potential technology in the GSE.

Does American have possible hydrogen-powered aircraft on its radar? I think [all airlines] do, but it's not as simple as having hydrogen power because the practicality is similar to electric. The infrastructure to support that is a huge challenge. In some cases, we've had more electric equipment at airports than there was the infrastructure to charge, and that creates more challenges. I think GSE is probably the more practical place for hydrogen than aircraft, because I've heard some speculation of how much payload you can carry, given the challenges of hydrogen.

Which new technologies is American looking into for maintenance? We see huge opportunities from a technology standpoint to dynamically change how we manage maintenance work on aircraft, whether it's predictive or routine, and leveraging artificial intelligence and machine learning. We think we can automate a lot of our processes. We're looking at opportunities, and we think we've got some great ideas, but those are multiyear journeys. We see it as a long-term strategic opportunity to significantly transform how we're managing the maintenance of aircraft and leveraging the value of data to do it more efficiently.

We're also getting ready to roll out electronic logbook capabilities we developed internally along with maintenance and our flight team. We see this as a significant game changer for how we manage maintenance, enabling us to capture much more data throughout the normal management of aircraft logbooks. We think the product we have is superior [to other electronic logbook products], and it certainly is going to be the best product for American Airlines in the fleet we operate.

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Artificial Hype

Will artificial intelligence be the next big game changer in MRO?

Lindsay Bjerregaard Chicago

Since ChatGPT went viral in late 2022, the artificial intelligence craze has permeated discussions in nearly every industry worldwide. Businesses have started to seriously consider how the technology could be used to boost efficiency and profits, while the world's workforce either eagerly embraces its ability to aid in job tasks or watches its progress warily, concerned about which jobs might someday be eliminated by AI.

Within the aftermarket, AI has been gaining traction in the last few years. Startups, MRO providers, airlines and industry research centers have been developing AI-based tools to aid maintenance in a variety of ways, including inspecting aircraft and engines, creating smart hangars, building digital twins of assets and automating technicians' ability to log records and troubleshoot tasks.

Aerospace Xelerated, a Boeing-backed technology accelerator program, has been working with many of these AI-focused startups to evaluate industry use cases and foster connections with companies that are looking to innovate. One such startup is Amygda, a UK-based company founded by former Rolls-Royce engineers that has developed a generative AI (Gen-AI) application it describes as similar to ChatGPT for MRO.

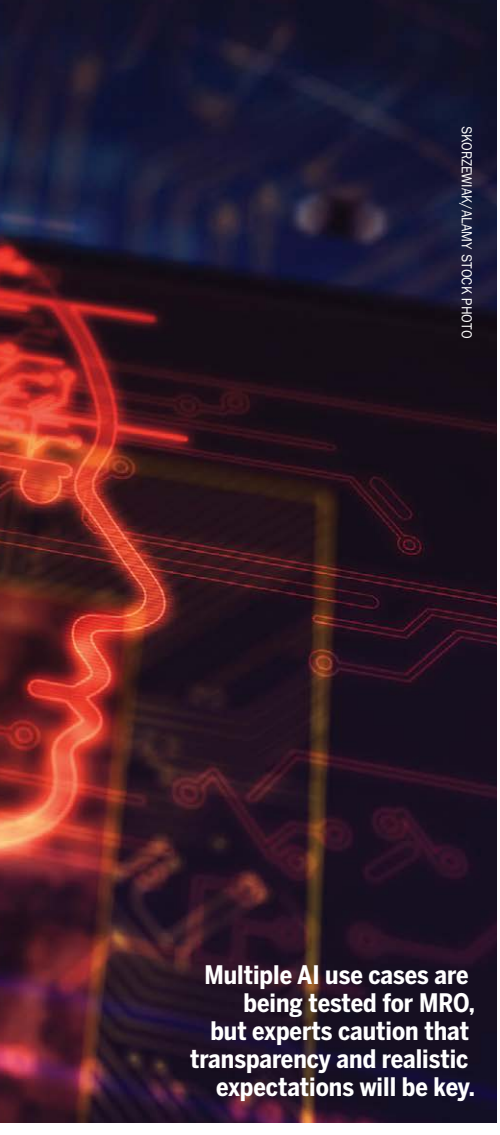
Faizan Patankar, co-founder and CEO of Amygda, says the technology "is sort of a co-pilot for engineering and maintenance teams," accepting input queries in plain text and generating insights in an easily explained and interpreted way. Patankar says technicians can use the application to find answers to "what if" scenarios based on data—such as maintenance logs, flight hours, pilot reports and sensor data—instead of just historical information.

"For example, a technician can decide to open a chat or review an alert generated on the system by talking to the co-pilot application [and] asking questions such as: What are the potential causes for the issue?" Patankar says.

Amygda's technology can also perform logic calculations, such as determining the remaining useful life of an asset, which Patankar says is a unique feature built into the system. "Currently, ChatGPT or other language learning models cannot do such analysis, but we are developing this layer for MRO specifically," he adds.

The hype around ChatGPT has also boosted customer interest for LexX Technologies, another startup that completed the Aerospace Xelerated program. Mike Harris, head of general operations, says the Australian company's AI platform operates like a cross between Apple's Siri virtual assistant and Star Wars' C-3PO droid, automatically digesting data and providing answers to technicians. "So long as it's been recorded somewhere and that can be fed to LexX to read, interpret and understand, then we can answer almost any question," Harris says.

For an industry such as aviation, which operates on a mountain of data and specialized expertise, Harris says the LexX platform could alleviate the limitations of an average worker. "We're now in a world where [we] only retain that which is relevant right now. We are drowning in data," he says. "Wisdom has built up over the years, but what's happening today is transient. But what if what's happening is an urgent safety bulletin?"



SKORZEWIAK/ALAMY STOCK PHOTO

Multiple AI use cases are being tested for MRO, but experts caution that transparency and realistic expectations will be key.

While a worker may read safety bulletins with good intentions, Harris argues that their retention of this information may not last long. However, the LexX platform could remind technicians about the information when it is relevant and provide warnings, such as for tasks in which technicians previously experienced injuries.

Harris stresses that the company's AI technology "learns lessons right along with you," so technicians can benefit from institutional knowledge quickly and easily. For example, he references an industry joke in which a pilot describes an aircraft fault to a maintenance provider, which then sends two technicians to troubleshoot based on the description—one with six months of experience and another with 30 years of experience. "They'll go to different ends of the aircraft because one will go strictly by their checklist of fault-finding and the other one will say, 'I've seen this before,' and will go off and fix it," he says. In a scenario such as this, Harris says LexX could pass down lessons learned by the experienced technician to a company's entire maintenance workforce.

American Airlines is exploring the use of natural language processing (NLP)—a branch of AI focused on enabling computers to understand text and spoken words—in its maintenance operations. The airline is looking at how NLP could be used to instantly log and transcribe maintenance information via speech, to identify which ATA codes should be used to classify faults and simplify the process of searching for corrective actions.

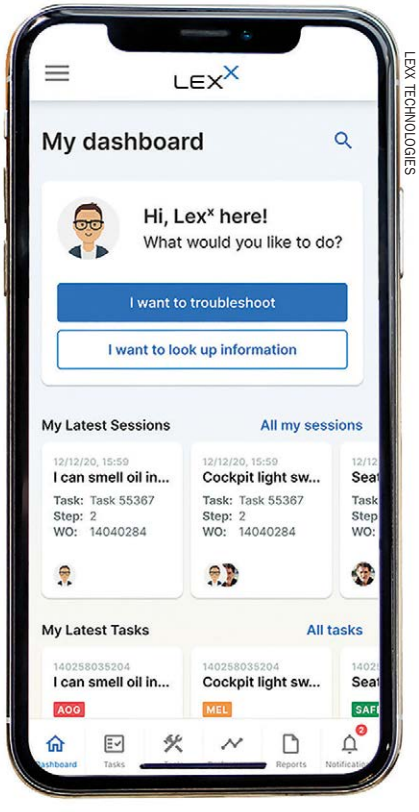
The MRO Lab at AFI KLM E&M is also exploring the use of AI for a variety of tasks. Paul Chun, vice president for technology at KLM Engineering & Maintenance, says the MRO provider is using NLP and computer vision to simplify documentation, to give technicians quicker access to documents and safety processes, and to find part numbers more quickly. It is also incorporating AI into its Prognos predictive maintenance platform.

Within Singapore's Agency for Science, Technology and Research (A*STAR), the Singapore Aerospace Programme has developed machine learning algorithms for both text recognition and defect detection applications. Using a dataset comprised of more than 1,600 data points, it tested the algorithms using both machine-generated and handwritten text under a variety of lighting conditions. Ric Parker, chairman of the program at A*STAR, says it is working to further explore how Gen-AI tools, which learn based on input data and generate new content, could be used in the MRO industry. He adds that the program is also working with industry partners such as Singapore Airlines and SIA Engineering Co. on "several initiatives involving AI solutions and improving manufacturing capabilities," and on AI-based shop floor intelligence projects.

An AI platform targeting improvements in both aerospace manufacturing and maintenance is Basetwo AI, which recently completed the Aerospace Xelerated program. The platform connects data sources, such as aircraft component sensors and maintenance logs, and uses this data to build simulation models of key components in an aircraft. The simulation models can be used to help companies determine when assets and equipment are deviating from expected or normal behavior.

Thouheed Abdul Gaffoor, CEO of Basetwo AI, says this functionality can be used to optimize how companies schedule maintenance activity, as well as expand the life cycle of an asset or increase its utilization rate. He notes that two promising application areas involve maintenance of aircraft engines and environmental control systems.

Some startups are leveraging AI paired with Internet of Things (IoT) technology to create smarter hangars. Fyve By has developed a system that



LEXX TECHNOLOGIES

AI startups are building platforms that could serve as specialized ChatGPT for MRO.

pairs cameras, sensors and software to create a 3D replica of a hangar, providing real-time visual tracking of aircraft, cargo, tools and staff. The aim is to monitor equipment and personnel to reduce potential hazards, such as items that could interfere with the path of an aircraft. Co-founder Preston LaVangie describes the technology as similar to the 360-deg. backup cameras found in cars. The system is

also capable of helping maintenance providers to position aircraft more strategically within the hangar to maximize space.

In the UK, Cranfield University's Digital Aviation Research and Technology Centre is examining how technologies such as AI can realistically be incorporated into maintenance operations in a way that provides business benefits. Ip-Shing Fan, MRO lead for Cranfield's digital aviation research activity, says many different technologies being tested and deployed for MRO fall under the AI label. For instance, text-based machine learning powers paperless digitalization, IoT powers some robotics and sensor technology, and automated image processing and assessment powers image-based inspections.

Cranfield's Intelligent Hangar is putting image-based inspections to the test, combining visual cameras and thermal sensors mounted to hangar infrastructure, drones for above-wing inspections and cameras mounted to

MORE TECHNOLOGIES TO WATCH

HYDROGEN AND ELECTRIC PROPULSION

As aviation industry sustainability deadlines loom, hydrogen- and electric-propulsion initiatives are beginning to gain traction. Electric- and hydrogen-propulsion OEMs such as ZeroAvia, MagniX and Universal Hydrogen are working with

LUFTHANSA TECHNIK

Developing MRO capabilities for hydrogen-powered aircraft is an emerging area of interest in the aftermarket.

engineering partners such as Cranfield University and AeroTEC to retrofit aircraft with these greener propulsion technologies.

MRO specialists are also beginning efforts to study how these technologies will affect maintenance and ground operations. Lufthansa Technik is using a decommissioned Airbus A320 as a field laboratory to research procedures required for handling liquid hydrogen in a maintenance environment. NLR is also exploring converting an aircraft to hydrogen propulsion, and it is beginning efforts to research maintenance requirements for the necessary components, hydrogen systems and electrical systems.

MROs and aftermarket companies are building up maintenance infrastructure for electric vertical-takeoff-and-landing aircraft as well (see page MRO56).

ROBOTICS

The MRO industry has been exploring the use of robotics in maintenance for many years, but several recent and upcoming developments show the technology is still attracting plenty of interest and investment.


GE AEROSPACE

Untethered soft robotics could provide advantages for on-wing engine inspections.

In September, GE Aerospace debuted an inchworm-inspired robot that uses untethered soft robotics technology to move easily through the complex spaces of jet engine parts to detect defects and corrosion. The Sensiworm (Soft ElectroNics Skin-Innervated Robotic Worm) features a sticky, suction-like bottom that allows it to climb and adhere to steep surfaces, while its soft form prevents potential damage to surfaces. Although the technology is still under development, GE says Sensiworm could reduce unnecessary engine removals and downtime.

Dutch robotics specialist Xyrec is working with a major aircraft manufacturer to use its robotics technology to remove aircraft paint and coatings more quickly, safely and cleanly. The company, which operates out of a custom-built facility at Port San Antonio in Texas, is planning to establish several other regional centers in the U.S. by the end of 2024.

DRONE INSPECTIONS

Drone-based aircraft inspections are continuing to gain acceptance in the MRO industry. Over the last year, several airlines and MRO providers have signed agreements with drone inspection providers and ramped up testing in their operations. Donecle, a major provider of drone-based inspections, completed a €5.6 million ($5.9 million) funding round on Oct. 5.


KOREAN AIR

Deploying drone swarms could further reduce inspection time compared to single-drone aircraft inspections.

Korean Air, which has been developing a unique inspection approach using a swarm of multiple drones, was recently awarded maintenance research and development assistance by the South Korean government, and it is working toward obtaining regulatory approval for the technology.

Drones are also gaining traction for defense MRO. In June, Dassault Aviation and the French Armed Forces' Aircraft Maintenance Division signed an agreement with Donecle to implement its drone inspection technology for Rafale aircraft. The UK Royal Air Force recently began exploring the use of drones for aircraft inspections. Drone startup Near Earth Autonomy is developing drones that could be used for both military and commercial aircraft.

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robots for ground-level inspections. "If we manage it right, we can actually see down to a rivet or even smaller than a rivet level," Ip-Shing notes. "If we have the right workflow automation, we can have the coordination of robots and people together and change the way that we are doing things without changing the regulation or the aircraft maintenance manual that operators need to conform to."

On a more micro level, AI is supercharging inspection tasks for aircraft engines. GE Aerospace subsidiary OC Robotics launched an AI-powered Advanced Blade Inspection Tool earlier this year to speed up on-wing inspections of GEnx engines, and it is also using AI to improve fluorescent penetrant inspections and robotics-powered CFM56 airfoil inspections.

CRANFIELD UNIVERSITY

Cranfield's Intelligent Hangar is utilizing a combination of advanced technologies to fully automate aircraft inspections.

AI has also made headway in boosting efficiency and accuracy for engine borescope inspections. GE Aerospace recently partnered with nondestructive testing specialist Waygate Technologies to explore the use of machine learning and AI to improve reliability, cycle time and consistency of these inspections. Waygate is partnered with Dutch startup Aiir Innovations, which uses AI to detect engine defects and automate inspection analysis.

Netherlands Aerospace Center (NLR) is working on several projects to automatically or even autonomously detect damage to components such as helicopter rotor blades using cameras, robotics and software. Arjan de Jong, principal for maintenance and engineering at NLR, says these types of technologies can leverage rule-based algorithms that measure and compare data inputs such as distances and thresholds—which are much easier to quantify—but the research center is also looking into the qualification of AI to perform defect detection.

NLR is also researching the use of AI to improve maintenance planning to increase aircraft availability. "We could also use Gen-AI to fill in paperwork or make decisions," de Jong says. "At continuing airworthiness management organizations, most of their work is done manually and they make decisions about which airworthiness directives or service bulletins to incorporate or when to perform the next maintenance. AI could take over a lot of that thinking and make decisions about whether to incorporate modifications."

POTENTIAL SETBACKS

Despite the plethora of AI-based tools and projects being explored within MRO, the technology will require thoughtful implementation to achieve industry buy-in and deliver tangible improvements.

"The true value really comes out when you embed [AI] in the right software, which needs to be inside the big ecosystem that's already out there," stresses Bart Vredebregt, CEO and co-founder of Aiir Innovations. "Creating a sideshow with new AI technology doesn't help anybody. You need to be able to connect with the existing tooling in a sensible way." The startup is currently working with engineers at Boeing to explore the right strategies for incorporating its AI technology into several of the OEM's business segments.

Cranfield's Ip-Shing says AI "can be an attractive label to talk to the CFO and persuade them to give me money," but he cautions that overhyping the technology could lead to unrealistic expectations and failed investments. "There's probably a bit of overselling by some people in the AI community," he adds, noting that AI "needs to be coupled with the right engineering domain knowledge" to deliver actionable intelligence and results for MRO.

Vredebregt points out that the industry must be careful to avoid another "AI Winter"—or a period in which the technology loses interest and funding due to developers overpromising results and users having unrealistically high expectations, which has happened following previous periods of interest in AI.

"I think there will be moments where the technology doesn't deliver, and the key will be handling that in a sensible way," Vredebregt says. "Our biggest responsibility as AI companies is to make sure that we manage expectations from Day One, don't overpromise too much and focus on delivering."

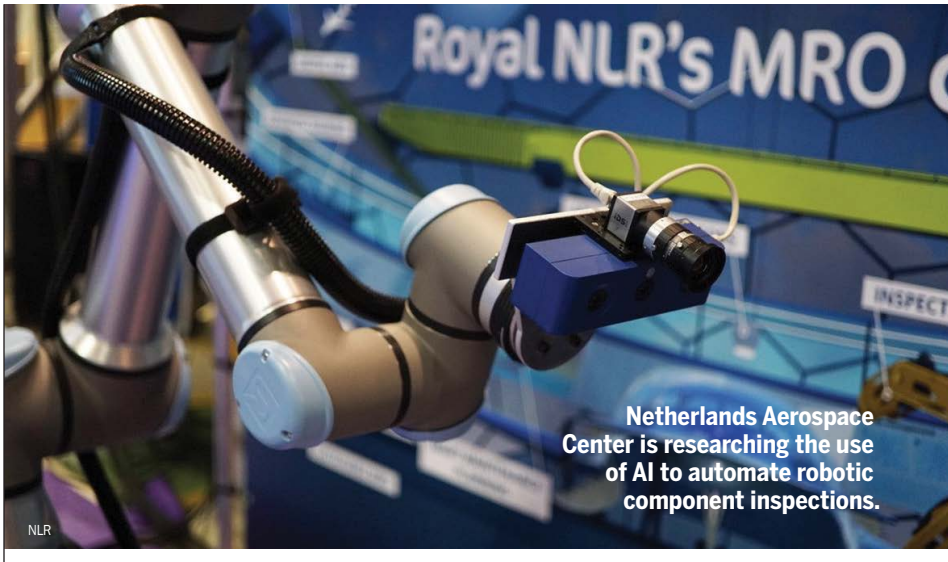
Amygda's Patankar notes that the startup has enocuntered people who expect AI to have perfect accuracy and detection rates, which he argues is a misguided perception. "For example, in medicine, AI that detects cancer has neither a 100% accuracy nor detection rate," he says. "However, even detecting one extra case is potentially one extra life saved. It should be the same with AI in aerospace. One less engine damaged, one less aborted flight, one less flight cancellation, one less unscheduled maintenance . . . are all worth implementing an AI system that doesn't have a 100% detection rate."

In this vein, Vredebregt points out that humans themselves certainly do

not have perfect accuracy. "Research shows humans are about 70% accurate," he says, citing a 2022 study from the University of Canterbury in New Zealand that compared the performance of human operators with image processing, AI software and 3D scanning for different types of engine MRO inspections. The study found that AI-based systems excelled at inspection speed, consistency and reduction in false-positive rates compared with human operators.

Although the study's results were promising, NLR's de Jong says one of AI's biggest hurdles is the difficulty in proving that AI generates correct results. "You put a lot of data in front of the algorithm and you get [results], but you can't say what has happened in between and whether or not you get reliable data, so you need to make it visible," he says. "You need to prove one way or the other that the results that come out have some validity and are reliable and trustworthy."

He suggests the key to overcoming this hurdle is through explainable AI, which helps AI users understand and interpret predictions made by the technology. NLR has been exploring DARPA's explainable AI technology and following initiatives from regulators such as the European Union Aviation Safety Agency to develop guidelines on how to certify the use of AI for aviation purposes.



NLR

Netherlands Aerospace Center is researching the use of AI to automate robotic component inspections.

Basetwo's Gaffoor says the company is using explainable AI, particularly because highly regulated industries such as aviation require this higher level of visibility. "Our approach is to fuse domain knowledge by subject

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matter experts (SME) about specific equipment with the data, so an engineer can always inspect the equation behind the equipment," he says. "If you're simulating an engine, for example, there are well-defined thermodynamic equations and principles that govern how an engine behaves. Our AI system incorporates that knowledge so an engineer can inspect the results and trust the output because they can see how this model looks."

But if AI can outperform humans and its results are transparent and trustworthy enough, does that mean technicians should worry about being replaced by the technology? Gaffoor argues that this fear is unfounded. "The calculator didn't really replace anyone; it just replaced older workflows. Excel spreadsheets did the same thing. That's really what AI is bringing to the table," he says. "It's an enablement tool that will accelerate SMEs and their workflows. It's going to make their jobs easier, but we will always need human validation in the loop and we will always need that domain expertise."

KLM's Chun suggests that the technology could actually drive the creation of new jobs. "More skills will be needed and critical to secure a good usage of [AI]," he notes. "The MRO may need to hire or train new experts, such as prompt engineers, and educate all potential users to make sure they question Gen-AI results."

Amygda's Patankar concedes that AI will likely disrupt some jobs, "but we should be asking ourselves if a human brain that is vastly superior to any AI we have today should be used to do jobs that not-so-smart AI can do," he says. "I believe we will see many more jobs created of a different nature than those that would be lost."

Whether or not technicians will eventually lose jobs to AI, the MRO industry's workforce shortage may actually be an argument in favor of AI adoption. "I understand the sentiment and the concern; however, everyone is also very aware that we've got this talent shortage, and the effects of it are incredibly painful for industry right now and creating ripple effects all across the ecosystem," says Andy Hakes, founder and CEO of AireXpert. The company's digital platform automates the collection and coordination of MRO-related data, aiming to reduce the time, energy and resources required. "I think the combination of AI and automations are simply being used to fill the gaps and won't result in a net loss of people," he adds.

However, Hakes says he does not see AI as a catchall solution for every challenge in MRO. "Probably 80% of the time people think that AI is necessary to solve whatever challenge it is they're dealing with on a daily basis, but I think the majority of time—particularly because we're still kind of lagging where we are with MRO technology—we can solve those problems with structured processes and algorithmic approaches versus jumping headlong into AI," he argues.

Engines of Change

How issues with Pratt's geared turbofan and CFM's Leap engines are affecting the aftermarket

James Pozzi Madrid

Aviation Week's AeroEngines Europe conference in Madrid in September explored issues and the outlook for the Pratt & Whitney geared turbofan and CFM International Leap engines. Here are some key takeaways from the event.

GTF IN THE SPOTLIGHT

The September announcement by Pratt & Whitney's parent company RTX that it intends to ground 350 geared turbofan (GTF) engines powering Airbus A320neo aircraft annually from this year through 2026 not only further disrupts both current and future operators of the new-generation narrowbody, but also has consequences for MRO capacity and the availability of current-generation engine assets. Durability issues on the engine have led to groundings owing to parts and spare engine shortages. The engine market has already seen heavy disruption in recent years from pandemic production cuts and technical issues with not just the GTF but CFM International's Leap engine program as well.

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The GTF groundings will have an inspection timetable, likely making shops more busy. Iberia Maintenance says the GTF groundings will feed much of the initial capacity at its Madrid engine shop, where it plans to induct its first engine in either October or November after having gained approval for the narrowbody engine last year. Further afield, Pratt's Eagle Services Asia joint venture with SIA Engineering Co. announced capacity expansions at its Singapore facility to accommodate more GTF work. The industry anticipates further capacity increases in the form of partnerships and added shop capacity. Pratt has 14 GTF-approved shops in its aftermarket network, while CFM plans to grow its own MRO network for the Leap to 20 shops in the next few years.

In the long term, the engine MRO segment expects the GTF will return to a competitive position once the OEM irons out the engine's durability and parts issues. While concerns about OEM maturity testing during the program's development phase were cited, the scale of the ramp-up is seen as the biggest driver of the program's current challenges. "The issue is that the ramp-ups for the GTF and Leap have been so rapid compared to previous generations of aircraft that there are two orders of magnitude that have had a greater impact as a result," says Keith Brown, group head of procurement for engines, MRO and aircraft interiors at International Airlines Group, parent company of British Airways, Iberia, Aer Lingus and Vueling.

Speaking in a panel discussion on new engine fleets at Aviation Week's AeroEngines conference here, Brown says that while claims that airlines were somewhat naive in their risk assessments of not only the GTF but also the Leap engine program are valid to some degree, orders were dictated by the choice of just two engines in the new-generation narrowbody aircraft market. "If you needed the fleet, you needed to buy the aircraft to pick one of those two engines," he says. While not finding it too soon for operators to abandon the program entirely, the panel agreed that a long-term change in which operators either order their engines separately or later and apart from their airframe commitments could be a possible long-term solution to address technical issues related to GTF and Leap engines.

EXPLORING HOW TO CUT LEAD TIMES

Turnaround times (TAT) in the engine segment remain unusually long compared with other parts of the industry. This has led MROs and airline maintenance facilities to try to bring more services in-house to cut lead times. In the wake of OEM parts cost increases and availability issues, along with soaring used serviceable material (USM) demand, MRO shops and airline maintenance divisions are turning to designated engineering representative (DER) repairs and parts manufacturer approval (PMA) parts to reduce TATs and increase affordability.

"Post-COVID, it's been a challenging environment not just from an operational sense but also related to raw materials as well," says Alex Dulewicz, project director at Chromalloy. He categorizes three main areas the company is seeing in relation to parts shortages: source-controlled repairs sent back to the OEM and incurring additional TATs; parts awaiting raw materials, with industry honeycomb shortages affecting the company's ability to complete repairs within the contracted TATs; and advanced repairs that typically take longer than the standard TAT. "But the intention is we turn a part that would otherwise be destined

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Discussing turnaround times at AeroEngines Europe: (from left) James Pozzi, Aviation Week Network MRO Editor for Europe, the Middle East and Africa (moderator); Alex Dulewicz, project director, Chromalloy; Anca Mihalache, vice president for engine trading and leasing, APOC Aviation; Matthias Niessen, senior director for engine parts repair, Lufthansa Technik; and Luis Filipe Parreira Augusto, head of engine parts repair services, Iberia Maintenance.

for the scrap bin into a serviceable part—these salvaged repairs can significantly increase yield rates," he says.

In addition to engine parts repair activities, Chromalloy has also developed DER and PMA repair services while drawing on its material services business based in Fort Lauderdale, Florida, to overcome supply chain issues. "We can mitigate some of the challenges in terms of the extended lead times that we are seeing through USM," Dulewicz says. "We also have a strategy of putting exchange pools in place—for any repairs taking longer than contracted, there's an opportunity to put those exchange pools in place and mitigate the lead times." He adds that Chromalloy is also developing its own detailed parts, as historically it has been exposed to the external MRO supply chain. "We've previously waited several months in some cases to get detailed parts repairs out of our shops, so we are developing them now in-house," he explains.

Matthias Niessen, senior director for engine parts repair at German MRO giant Lufthansa Technik (LHT)—a company with GTF and Leap 1A and 1B capabilities—says it has seen a lot of repair demand for the more established IAE V2500 over the past year. He says the company has utilized its mobile engine service offerings to keep workscopes on engine maintenance small. "We've also used internal repair capability, especially related to nondestructive testing capability, to enable the quick-turn services needed," he says. Niessen notes that LHT recently acquired additional ultrasonic equipment it will use to help address repair issues. The company had ramped up overhaul and repair capabilities for both the GTF and Leap engines but has adapted to change its plans, given the issues affecting both engine programs. "We have always looked to increase capacity and ramp up engineering manpower to be able to produce repairs and capability quickly aimed at solving the issues at hand," Niessen adds.

NAVIGATING THE SUPPLY CHAIN

With supply chain constraints still affecting the industry on a large scale, forecasting the need for parts required for engine workscopes has become more challenging for the engine MRO segment. While most shops will know which parts they are likely to require in the future, customer engine maintenance demands have shifted as obtaining parts from a constrained supply chain has become more problematic.

Ana Bidarra, engine shop planning and control manager at TAP Portugal, says demand placed on MROs is greater than the supply chain's rate of recovery, and this makes engine shop planning more difficult. "It's very hard to plan in advance because the type of workscopes also changed a lot, because it's customer-by-customer and changing the type of engines," she says. She adds that close partnerships with customers are key to addressing these challenges. "This is so we know in advance what type of workscopes need to be done," Bidarra notes. "We need to know the exact configuration of the engine order to have parts installed into the engine." Lead times related to OEM parts continue to be a problem for TAP. "The strange thing is these are not just for larger parts, but also expendable ones," she says.

Christophe Giraud, senior commercial director at AAR Corp., says he had never envisaged the reality of shop visits with TATs of 200-300 days. "When you have a life-limited part that once took 30 days to repair and now takes 90 days, that is a concern," he says. However, Giraud believes some of the logistics issues would have occurred regardless of COVID-19, comparing the scenario to 17 years ago when he started in the industry and there was an abundance of parts stock to feed then-popular just-in-time material models. The industry is still suffering from factors outside its control, he says, citing the Russia-Ukraine war and rises in inflation levels and interest rates.

From an operational perspective, some MRO providers have reevaluated their parts inventory strategies. Ivan Gonzalez Vallejo, director for strategy and supply chain at Iberia Maintenance, says he has witnessed two parts-stocking scenarios in recent times. "You either stock up because you want to be a stockholder and therefore get some cover from issues with vendors, or the opposite, where a company de-stocks in order to generate cash flow," he says.

Iberia has chosen to hold a bit more inventory, which Vallejo says is not an issue if that inventory is moving around, while it has also expanded in-house repair capability. He notes that good forecasting is important so companies can duly increase stocks and availability, adding that Iberia has enhanced its procedures for this through technology such as machine learning algorithms and artificial intelligence to help forecast planning. Vallejo also expects supply chain constraints to ease within the next 18 months.

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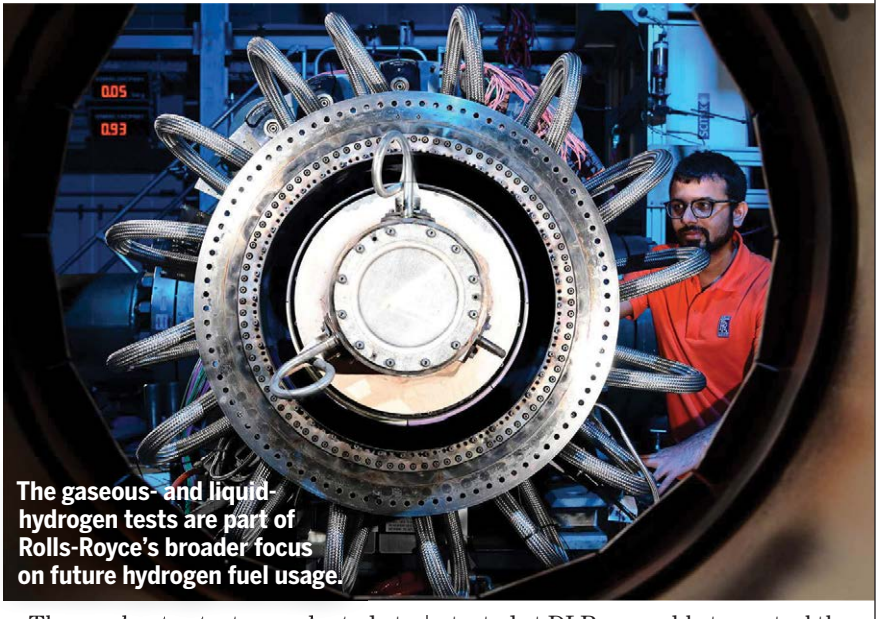
Pioneering Pearl

Rolls-Royce pushes boundaries of alternative fuel with Pearl combustor hydrogen test

Guy Norris Colorado Springs

Rolls-Royce plans to run ground tests of a Pearl business jet engine with gaseous and liquid hydrogen following tests of a modified annular combustor from the Pearl 700 engine variant with 100% hydrogen at conditions representative of maximum takeoff thrust.

ROLLS-ROYCE



The gaseous- and liquid-hydrogen tests are part of Rolls-Royce's broader focus on future hydrogen fuel usage.

The combustor tests, conducted at German aerospace center DLR's Cologne facility, evaluated new fuel spray nozzles developed for hydrogen use by the UK National Center for Combustion and Aerothermal Technology (NCCAT) at Loughborough University. And the tests represent a world first, Rolls-Royce says.

The individual nozzles were initially tested at intermediate pressure at Loughborough's recently upgraded test facilities and at DLR before the final full-pressure combustor tests at Cologne. The tests form part of Rolls-Royce's broader test focus on hydrogen fuel for future use, either for direct combustion in modified zero-carbon turbofans or as part of various hybrid-electric propulsion efforts, including fuel cell-augmented gas turbines.

Both hydrogen-related gas turbine studies support propulsion concepts that Rolls-Royce envisages could power regional, business jet and single-aisle airliners from 2035 onward. However, because hydrogen burns far hotter and more rapidly than kerosene, its use in direct combustion engines is particularly challenging. Rolls says the nozzles tested at DLR were able to control the flame position using a new system that progressively mixes air with hydrogen to manage the fuel's reactivity.

"Combustor operability and emissions were both in line with expectations," it adds.

The buildup to the full annular rig tests at takeoff conditions follows a long series of atmospheric, intermediate-pressure and subatmospheric-pressure testing at NCCAT and continued testing at facilities at Rolls-Royce Germany and DLR. Combustor testing in Germany began in 2022 and has focused more recently on atmospheric single-sector; optical single-sector; full annular high-pressure, multisector; and thermoacoustic rig testing.

Results from the rig tests will feed several new key UK national and European fundamental research programs, including three initiatives awarded by the UK Aerospace Technology Institute (ATI)—HYEST, LH2GT and Rachel—as well as the Clean Aviation Cavendish program.

HYEST (Hydrogen Engine System Technologies) is a £14.8 million ($18.1 million) Rolls-Royce-led project to develop technologies and the subsystem architecture for the combustor element of a liquid-hydrogen (LH_2) gas turbine.

Rachel (Robustly Achievable Combustion of Hydrogen Engine Layout), also led by Rolls, is a £36.6 million project aimed at advanced hydrogen-related technology for the nacelle, engine externals and powerplant itself, and the study looks at the fully integrated propulsion system as well as hydrogen storage.

The third ATI effort, LH2GT (Liquid-Hydrogen Gas Turbine) is a £31.4 million project to develop technologies for the delivery of an LH_2 fuel system for a hydrogen gas turbine. LH2GT is aimed at research into the transport and control of hydrogen, including from the tank to the combustor, and overcoming the challenges associated with cryogenic pumping, fuel metering, thermal management and control systems.

Under Europe's Clean Aviation aeronautics research program, Rolls-Royce Germany is leading the €29.2 million ($30.8 million) Cavendish project targeted at integrating lean-burn hydrogen combustion into a Pearl 15 donor engine for ground testing on LH_2 starting in late 2024. A second objective of Cavendish is to work on aircraft integration and formulate a route to a flight demonstration with Dassault in the second phase of Clean Aviation. The project also will explore technologies for a dual-fuel combustor capable of operating on 100% hydrogen or 100% sustainable aviation fuel and a cryo-compressed LH_2 tank system.

Along with its low-emissions partner EasyJet, Rolls says it aims to flight-test a hydrogen-powered engine and has previously identified the Pearl 15 as a likely candidate. In November 2022, the company completed tests of an AE2100 turboprop powered by liquid hydrogen rather than conventional jet fuel. For the follow-on demo based on the Pearl 15, Rolls intends to develop a more representative integrated hydrogen fuel and combustion system based on lessons learned from recent DLR work.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Europe's Parts Conundrum

High parts demand, lower teardown feedstock are driving up repair times and costs

Rob Hall London

European carriers recorded a 60.6% increase in passenger traffic in January compared with the same month in 2022. Continual growth in traffic numbers throughout the spring and summer brought average European passenger load factors to 87.7% by June.

However, in conjunction with delays in new aircraft production and fewer aircraft teardowns, this growth is increasing pressure within the components and parts supply chain. Operators are retaining older aircraft to address capacity deficits.

"The used serviceable material market is on fire in terms of the ability to sell material," says Lee Carey, vice president for asset management at EirTrade Aviation. "The acquisition of aircraft and engines for disassembly is becoming more difficult due to delays in the delivery of new aircraft."

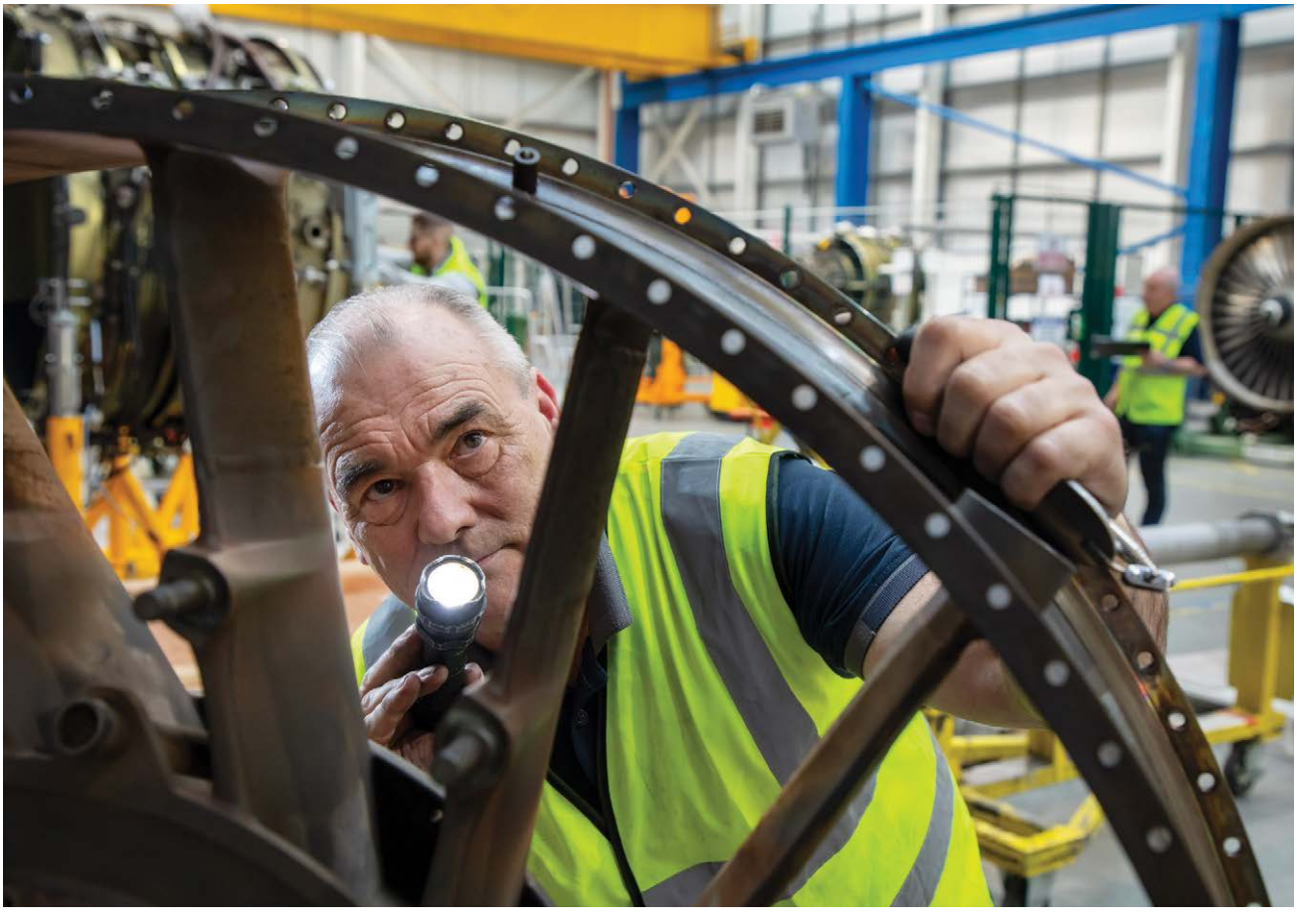
According to Jonathan Berger, managing director at Alton Aviation Consultancy, new global aircraft production halved to just 600 new deliveries in 2020 before increasing to 700 in 2022. The number of aircraft retirements at this time remained relatively low as most of the grounded fleet was placed in long-term storage.

"The lead time for necessary parts and to replenish stock inventory is now typically longer," Berger says. "The component repair shops are flush with work, and there is a shortage of [used serviceable material]. Sometimes airlines and MROs must now buy new because there are no used alternatives available. This is significantly increasing airline cost."

High demand for important engine and airframe parts and components means some are out of stock completely from the OEMs, and lead times remain long. Additionally, manufacturers of new parts must decide which components to make and where to allocate them.

"The OEM must identify the parts needed for new-build aircraft and those needed for spares inventory," Berger says. "In general, the OEM parts supply situation is improving, and it is a lot better than a year ago. It is working itself out. However, engines

A high number of lease extensions is reducing the supply of aircraft and engines that could be torn down for used serviceable material.



EIRTRADE AVIATION

remain the most troublesome area. Supply chain issues and a lack of spare parts, [as well as] manpower, are affecting engine shop visit turnaround times for both new-generation and legacy engine types."

There is little to no used serviceable material (USM) available for new-generation engines, as it is not economical to tear down the expensive assets at an early age. The issue is compounded because new Pratt & Whitney geared turbofan and CFM International Leap engines have not reached maturity, having less time on wing in comparison with legacy alternatives.

Legacy assets are also suffering, as high demand for overhauled parts means many repair specialists cannot keep pace. The long wait for some parts and components means many older-generation assets remain in an unserviceable condition.

According to the Aviation Week Network's Commercial Fleet & MRO Forecast, the European fleet consists of 7,700 active aircraft, 67% of which are narrowbodies, 17% widebodies and the remainder regional jets and turboprops. Most of these aircraft are mid-generation types such as the Boeing 737NG and Airbus A320neo families of aircraft equipped with CFM56 and Pratt & Whitney V2500 engines.

Aviation Week's forecast projects that 546 CFM56-7Bs, 434 CFM56-5Bs and 364 V2500s are scheduled to visit a shop in 2024. New-generation Leap 1A and 1B shop visits are forecast to total 1,958, and PW110G shop visits 1,494. Alton Aviation Consultancy forecasts that 43% fewer aircraft will be retired in 2023 compared with 2019, resulting in less used material for operators and MROs. However, Aviation Week forecasts about 15% more aircraft retirements in 2024 compared with 2019.

"The high number of lease extensions is lowering the supply of aircraft and engines made available," EirTrade Aviation's Carey says. "This reduction in supply leads to a natural increase in terms of price, which naturally rolls on to the USM market. From an availability standpoint, there was once a surplus of material because of the lack of demand during the pandemic. However, it is quite the opposite in the current market."

Carey says continuing consumption of components caused by high passenger traffic and high aircraft utilization rates is drying up material surpluses. Life-limited parts (LLP) for midlife narrowbodies—high-pressure turbine blades and Stage 1 low-pressure turbine vanes—are in "remarkably low supply," he says. "It was even difficult to source this material before the pandemic. It is next to impossible to get them now," he adds.

Turning to the OEMs for high-value parts and components such as LLPs means that asset owners must be committed to that product for a longer period to extract the maximum return from the investment.

"While lead times at the repair shops have improved somewhat, it is still a major delay which we need to plan for on each project," Carey says. "To allow EirTrade to improve efficiencies, we are very focused on acquiring assets which can be disassembled at our own aircraft and engine disassembly facilities in Ireland. This allows us to have more control over any given project and improve the [return on invested capital] by improving these timelines."

EirTrade recently opened an engine disassembly facility in Dublin to help minimize engine teardown time and leverage control across its supply chain. By bringing CFM56-3/-5A/-5B/ and -7B engine disassembly in-house, Carey says EirTrade has better flexibility around its own acquisitions and customer teardowns.

"Secondly, there is a shortage of engine disassembly facilities in Europe," he notes. "Lots of people were reliant on larger MROs in Europe that have a primary focus on lucrative shop visit agreements. As they get busier, they do not necessarily want to disassemble engines, which we believe has created a gap in the market."

Engines earmarked for teardown in 2023 have completed a greater num-

ANTAVIA AMETEK MRO

Ametek is publishing monthly stock forecasts for some of its suppliers to provide better visibility about parts delivery and schedule.

ber of engine flight cycles than forecast. Therefore, assets that would normally have about 5,000 engine flight cycles remaining before teardown now have significantly fewer. The demand for surplus engines with meaningful remaining green time has increased dramatically as a result.

"USM companies such as EirTrade want quick turnaround times from their repair vendors to facilitate material being brought to the market quicker, which helps us serve the needs of our clients better and improve the financial performance of each project," Carey says. "We are now more focused than ever on utilizing specific repair shops which can offer these efficient turnaround times and building very close relationships with these suppliers."

Ametek MRO has six main product lines: actuation, thermal management, landing gear and brakes, avionics, safety equipment and power generation. "Wheel and brake components remain in high demand, and the supply situation has been challenging throughout 2022," says Ismael Fadili, Ametek's vice president for sales for Europe. "Sourcing tires and brake heat sinks has been difficult overall, [but] the situation is now improving. The procurement of printed circuit boards and other small electronic parts has been difficult."

Ametek publishes monthly stock forecasts for some of its suppliers, giving end users an idea of delivery and schedule. In terms of output, Ametek is now ahead of its yearly forecast in many areas.

"Finding skilled technicians is a challenge. On the technical side, it is complicated to find the right people in the right location," Fadili says. "As the supply chain improves, the demand for labor is increasing, so our main focus over the next months will be to find technicians."

Fadili says it can take 6-12 months to train a technician, depending on their focus area. Wheel disassembly, cleaning and reassembly are comparatively simple, yet the nondestructive testing element means it can take up six months before a wheel technician is fully trained. Avionics components take longer to learn, and Fadili says it can take up to 12 months before a technician is at a good standard. "If we are not finding the right technicians today, then this could mean there is an issue in 12 months' time," he adds.

Many more unscheduled landing gear removals have been conducted over the past six months, and the trend is expected to continue due to increased utilization levels of passenger and freighter fleets.

Sourcing single supplier parts can be problematic because of the lack of an alternative, and the number of parts manufacturer approval (PMA) parts and designated engineering representative (DER) repairs is growing steadily as a result.

"In Europe, there is some reluctance to use PMA for engine and safety components. PMA usage is most common in the cabin," Fadili says. "Today, PMA parts can be more dependable than OEM counterparts, yet there is little discussion about that."

Ametek is recoring heat exchangers and can also complete DER repairs on electronic solenoids for cockpit door tracks. A new solenoid will cost thousands of euros, while a DER repair can cost hundreds. "It is difficult for some OEMs to stock all the components needed for DER repairs. It then makes more sense for OEMs to sell an entire new line replaceable unit than parts," Fadili says.

Although delays are improving compared with 2022, European MROs expect to be even busier in the next couple of years as recovery in the region continues, which could lead to other challenges for OEMs and repair vendors in the future.

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Considering Consignments

Aftermarket suppliers weigh the benefits and challenges of selling stock on consignment

HORIX AEROSPACE

Keith Mwanalushi London

Managing surplus material on a consignment basis has gained popularity, but with supply chain issues lingering, MRO providers and parts traders are examining their inventory strategies carefully.

AJW Group has taken more than 30 airframes on consignment since 2021, for example, but the business rarely consigns material to other organizations, says Mark Elliott, director of inventory strategy. He says the only scenario in which AJW would consider passing on consignment stock would be if it is moved to a different sector or region of the aviation industry in which AJW does not operate.

"Given our regional presence, diversity of service and specialist knowledge, these opportunities are few and far between," Elliott notes. "The reason our consignment partners give stock to us is because they're generally not aviation experts or traders and often don't have a viable route to market the aviation assets they have invested in."

This type of activity drives a return of over $1 billion in proceeds to customers, says Jason Reed, president of GA Telesis' Flight Solutions Group. Stocking is something he refers to as a "built-in" cost that comes with the activity.

CARRYING COSTS

"What we see these days is perhaps a different view of consignments, particularly when an operator wants to offer the asset to you but has an extensive list of over 300 parts they want to retain for themselves," Reed says. If the hottest parts are being retained by the operator, he questions what is left to sell and what profit could be earned by the buyer: "There is not much, and again, in today's interest rate environment, the cost to carry those parts longer-term, not to mention the distribution floor space taken, must be a real factor. Overall, it must be a win-win for both parties."

Selling surplus material on a consignment basis can offer benefits such as reduced upfront investment and improved liquidity. However, it also introduces certain challenges that warrant careful management.

"While consignment selling minimizes upfront costs, the seller may still incur carrying charges for storing surplus material until it is sold," says Aaron Shellie, vice president for trading at Setna iO UK. He says these costs encompass storage space, maintenance, insurance and potential obsolescence. The company must strike a balance between minimizing carrying costs and ensuring material availability.

Storing consigned inventory in Switzerland is expensive for Horix Aerospace, but the company still sees market advantages to the practice.

Shellie also stresses that collaboration with consignment partners is crucial. Clear agreements and terms are necessary, he says, to address issues such as pricing, ownership, liability and responsibility for maintenance and repairs. He cites effective communication and mutual understanding as vital to prevent confusion and disputes.

At Setna iO, the preference leans toward maintaining a minimized consignment business model. "We prioritize upholding comprehensive control over our inventory, encompassing various facets such as strategic locations, pricing structures, efficient shipment turnaround times and more," Shellie says. "While we do engage in a limited number of consignment arrangements, we are acutely attuned to

the advantages and dynamics inherent in both approaches."

The overarching objective revolves around sustaining ownership of stock and aligning seamlessly with a steadfast commitment to retaining complete autonomy and oversight. "By cultivating a primarily self-owned inventory strategy, we are empowered to ensure meticulous management, adaptability to market shifts and the ability to swiftly respond to the ever-evolving demands of our industry," Shellie says.

LOGISTICS CONSIDERATIONS

Several industry experts note that one challenge of selling stock via consignment is the logistical cost associated with moving the stock to the location of the entity carrying it.

If stock is held by the consignor, AJW's Elliott says it is important to maintain live stock position electronic data interchanges to ensure units are not being quoted if they have just been sold by the consignor themselves. Keeping data and the stock level system up to date is vital to consignment selling, he says.

Another challenging aspect is reporting. "If you are going to give someone a $5 million bundle of components, you want to know what they are doing with it and how it is performing," he says. "This puts a reporting and administrative burden on the people who are trading that stock on your behalf."

There are also several logistic and administrative costs associated with consignment arrangements, but in certain circumstances, Elliott believes they can work. He says AJW has successfully managed significant quantities of consigned material for partners for many years, but the focus is on AJW taking the consignment, not using consignments as a method of trading its components.

Meanwhile, in Switzerland, Horix Aerospace has identified successes in the consignment supply model but also multiple difficulties, such as fixed costs for space, workforce, enterprise resource planning and selling platforms, variable costs for infrastructure and logistic equipment, quality management on parts, and price fluctuations.

"The cost of storage for us is very high, because Switzerland is one of the most expensive countries in the world," says Marco Taufer, chief commercial officer at Horix Aerospace. However, this is also a market advantage, he says: "It's the guarantee of having the consigned parts as if they were held in a bank and the guarantee of contract law. This is why Horix is recognized as the Swiss trusted solution for aerospace components management."

Overall, Taufer says it is a profitable business, and the company can plan the right material acquisitions, capture the right dismantling opportunities, standardize and streamline the internal processes, and find the right place to store the parts.

While selling via consignment might have spiked early in the COVID-19 pandemic and the early stages of the recovery, Richard O'Grady, vice president for trading and asset management at Magellan Aviation Group, argues that consignments are less desirable for both buyers and sellers today. He says sellers can achieve higher selling prices compared to low-value offers received during the pandemic that forced sellers to consign their assets. "Buyers have capital to spend now and are willing to pay higher prices to secure assets due to strong competition in the surplus market," he notes.

Magellan has a long-established track record of selling surplus inventory on a consignment basis and will continue to do so for the foreseeable future but with a more selective approach due to the high number of assets already managed on consignment.

AJW Group is focused on acquiring consignment stock rather than consigning materials to other organizations.

AJW GROUP

O'Grady sees several benefits of consignment, such as access to new engine and airframe product types, but he is also aware of the difficulties and considerations. "The primary challenge is that the minimum trace requirements from the consignor may be slightly looser than that of the customer," he says. Magellan seeks to communicate this expectation early in the consignment process so that consignment partners can produce adequate records to surpass the requirements of the market space.

Managing surplus inventory packages also requires maintaining close collaboration and transparency with consignment partners. According to O'Grady, regular communication and reporting are necessary to ensure that both parties align on sales, inventory levels and any adjustments needed to meet shifting demands.


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Capacity Crunch

Enrique Robledo, *appointed chief technology officer of Iberia Maintenance in February, discusses with* **James Pozzi** *the MRO's push for more third-party maintenance work and how it plans to manage its first Pratt & Whitney geared turbofan engine induction this year.*

IBERIA

Where has Iberia Maintenance seen strong maintenance demand this year in comparison to the previous two years? The demand is growing because the airlines are flying more than in previous years. We've seen some carriers have either the same or even bigger capacity than they used to have in 2019. Demand has been strong in nearly all areas but especially on the aircraft side with more aircraft being returned to service following extended periods of being grounded. As a result of this, we've seen growth in the heavy maintenance sector. This has led to many new problems being identified, as it is common to find issues on aircraft that have been grounded as opposed to ones that have been in regular service. Also, engine maintenance is growing as their hours on-wing start to increase.

What is the split of MRO work between third-party services and work related to International Airlines Group carriers Iberia, British Airways, Aer Lingus and Vueling? The percentage split has grown somewhat over the past year toward third-party maintenance. Right now, 73% of our MRO work is third-party with the remaining 27% International Airlines Group (IAG) customers. This has been driven toward third-party work mostly through engine MRO because for airframe heavy maintenance, we are still heavily concentrated on IAG carriers because we have the capacity, and with demand so high right now we are very busy servicing those airlines. In engines, we want to grow further and are hiring people and making more slots available. This extra capacity can be filled by third-party work. With new engine types such as the geared turbofan (GTF) and CFM International Leap growing in the fleet, we expect this to reach 80% third-party work. This split would reflect the current percentage split Iberia has in engine services. This would be started by the GTF because we are in the final stages of capacitation for this engine. We've recently finished the correlation of the test cell, so we now have the tooling and the training in place and are expecting the first engine in October or November. There is a high demand for this type of engine, and we are receiving calls to commence work as soon as possible.

How do you plan to manage capacity for the GTF family to begin with? It's going to feed the capacity we will have booked for the GTF. It is a new engine, and we are building a separate workflow for it. We have designated capacity isolated for it, so the capacity of the GTF won't influence the rest of the shop. After beginning as a fixed capacity, we will eventually grow it year by year or maybe every six months. As it is a new engine, it makes sense to do it this way and will ensure slots are freed up for the rest of the non-GTF engine fleet.

Where do you identify a lack of capacity in the MRO market? There is a lack of capacity in heavy maintenance. Our customers tell us how difficult it is for them to find reliable slots at heavy maintenance. When we are at full capacity and they have to subcontract something out, then they suffer. A lack of capacity in this area could be a trend for the next 3-4 years. On the engine side, it is quite similar but more dependent on maintenance peaks. Now after the summer months, there will be another peak of engines, and some of those engines will have to wait a bit longer to be inducted. In other parts of the year, it will be the opposite, when a large volume of engines are flying. In the future, a lot will depend on what happens to the new engine types and whether they'll need a lot of shop visits earlier than expected. More mature engines are still flying, as airlines are extending these. We are preparing for the capacity scenario by growing our facilities, MRO capabilities and skilled people. This year, we've hired more than 150 mechanics just to work in our engine shop. Most of those people were trained by our in-house technical training school.

Have turnaround times and the Iberia Maintenance supply chain settled in 2023 compared with last year? The global supply chain has been very challenged. Across a network of suppliers, just a small number of them not performing can challenge the whole thing. It's been slightly better this year compared with 2022, but it still isn't where it should be. This is very much impacting turnaround times. OEMs and our other suppliers tell us they expect the supply chain network to stabilize in the next 12-18 months.

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Grappling With Inflation

How European MROs are dealing with economic pressures not seen since the early 1990s

Alex Derber London

When inflation spiked in the wake of the COVID-19 pandemic and Russia's full-scale invasion of Ukraine, it was a nasty shock for a generation of Eurozone consumers and businesses used to annual price rises of less than 2.5% for almost all of the previous 25 years. A similar story played out in the UK, where inflation peaked at more than 11% late in 2022, after a quarter-century near the 2.5% mark.

Accompanying this shift was the end of more than a decade of cheap credit, during which businesses and homebuyers had enjoyed near-zero interest rates. The effects of both changes are still playing out in the aviation aftermarket, and while inflation has come down from its 2022 peak, maintenance providers remain challenged by higher prices across their cost bases.

"Absolutely everything we touch has seen varying degrees of cost increases, many of which are double-digit," says Ian Jones, head of sales at UK-based Storm Aviation, a provider of line maintenance and other aviation services.

In Germany, the same is true for MTU Aero Engines. "As is the case across the industry, we are experiencing high inflation across the board," says Wibke Eichhorn, senior vice president for commercial MRO at the OEM and maintenance provider.

COST INCREASES

At the tail end of the pandemic, global supply chains fell under severe strain as demand picked up and encountered shortages of labor, materials and logistics capacity. The problem was particularly acute for aviation, one of the worst-hit industries during the pandemic and which had lost numerous skilled staff and engineers to other sectors. These problems were then exacerbated by Russia's full-scale invasion of Ukraine in early 2022, which led to a spike in energy prices.

While airlines and maintenance companies were somewhat used to price rises, notably the annual above-inflation markups for OEM parts, they soon found that costs were rising in other areas as well.

"Most parts of the business have been under inflationary pressures," says Greg Macleod, managing director of London Stansted-based GT Engine Services, an engine MRO provider.

MTU AERO ENGINES

MTU Aero engines is investing in self-sustaining energy infrastructure to mitigate energy-related cost growth.

One big increase that had not occurred for many years in the aftermarket was energy costs, prompting some maintenance providers to seek more sustainable solutions to power their facilities—particularly in Germany, where many industries had previously enjoyed years of cheap Russian gas.

"Energy, especially at our German locations, is one of the drivers for cost increases," Eichhorn notes. "MTU is counteracting that by investing in self-sustainable energy infrastructure such as photovoltaic technology and dual-use heat pumps."

Macleod also recognizes the significant challenge of energy price inflation. "One of our biggest factors is energy costs, and overnight without warning our energy supplier doubled our prices," he recounts. "Thankfully, we had just installed solar, which mitigates the rise somewhat."

Labor expenses also have grown sharply, given the need to retain skilled personnel and to protect employees against consumer inflation. Macleod notes that this combination of factors led to wages rising even faster than inflation as the aftermarket sought to restore capacity as quickly as possible to meet resurgent demand for flights.

"We still have a huge skill shortfall in the industry, so we try to keep wages attractive, staying competitive," he says. "We also have to look after all of our existing staff and dampen the effect on their rising household bills. The net result has seen our wages outstripping inflation."

Storm Aviation's Jones agrees, noting that MRO providers have to be increasingly creative to retain and attract staff.

"To remain competitive in a market where some of the biggest airlines are offering sizeable package increases to tempt maintenance staff away from MROs, we must listen to our colleagues, reward hard work, pay commensurate salaries and be inventive with other workplace benefits," including health care and dental coverage, he says.

There also have been major price increases for third-party services and for materials, "especially consumables," Macleodsays , adding that "consumable prices are the hardest to pass on."

MTU's Eichhorn sees services and materials cost increases reflecting broader inflationary trends, as well as aviation's specific supply chain challenges in the wake of COVID-19. "Naturally, the share of material cost represents a major portion of our maintenance services and is therefore a significant driver for the overall cost increase," she adds.

MITIGATING INFLATION

If their finances allowed, some MRO providers and airlines sought to preempt higher-than-usual price hikes for parts by buying stock before catalog prices were changed in 2022, when inflation took off.

Asked in mid-2022 whether inflationary trends had influenced spare parts pre-buying by Safran's customers,

ADRIEN DASTE/SAFRAN

Safran reports that it is easier to pass on inflationary costs to customers through time-and-materials contracts than through flight-hour-based support agreements.

CEO Olivier Andries agreed there had been an impact. "We will soon communicate on our catalog price increase that is planned for November of this year [2022]," he said. "But you can expect it's going to be up compared to what we have basically done in previous years, considering the inflation."

Andries also noted that it is easier for Safran, which acts as both an OEM and a maintenance shop, to pass on inflationary costs to customers through time-and-materials contracts than through flight-hour-based support agreements.

Given airlines' urgent need to restore capacity over the past 18 months, one might expect them to be somewhat insensitive to maintenance cost increases, but MRO providers say their ability to pass on inflation-related increases is constrained.

"In our experience, airlines remain razor-focused on securing the best pricing and terms," Jones says. "But the truth is that many operators now have to pay more for maintenance support, certainly in the line maintenance environment."

"Most customers accept that the costs have to be passed on and have been very accepting of the situation," says Macleod at GT Engine Services. "By the nature of their business, we do have some low-cost carriers that struggle with the concept of any type of increase."

Eichhorn points out that MTU's ability to pass on costs depends on the type of contract it has with customers, although it will not always do so. "Even if contracting terms allow us to pass on cost increases, this is not the overall goal as customers are always looking to manage cost, and in turn, so do we," he says.

One way to control costs is to use used serviceable material, parts manufacturer authority parts and designated engineering representative repairs instead of new parts.

"At MTU Maintenance, all the departments directly involved with MRO operations—especially engineering and procurement—work together to design the repair or overhaul of an engine in a way to optimize the costs of a shop visit in accordance with customer needs," Eichhorn explains.

GT ENGINE SERVICES

Wages have been rising as European MRO providers bid to keep staff and insulate them from cost-of-living increases.

She also emphasizes that airlines remain sensitive to maintenance cost increases as they continue to recover from the financial strain of the pandemic. "Price is the No. 1 factor with respect to engine MRO decisions and provider selection. Engine maintenance cost represents a big portion of the overall maintenance costs at airlines," Eichhorn adds.

OTHER ECONOMIC PRESSURES

Accompanying higher inflation have been steadily rising interest rates from central banks in Europe and the U.S. Maintenance providers are less exposed to these fluctuations than finance-focused areas of the aftermarket such as aircraft leasing, although they still face higher debt costs. Some MRO providers also incorporate asset finance—including engine leasing—in their business model.

"Asset finance is not economical now, with interest rates where they are, so we have changed policy and now self-finance even the largest purchases," says Macleod, who also highlights a rise in insurance costs.

Meanwhile, general supply chain tightness endures, impacting procurement and turnaround times, with MTU estimating that overall engine MRO capacity will remain under strain for up to two more years.

At Storm Aviation in the UK, Jones says the company faces slower lead times, as well as clients that have issues importing aircraft and spare parts. "This is time-consuming and costly for them and can have a negative impact when we bid against MROs in mainland Europe," he says.

Then there is the fallout from Russia's war on Ukraine and the resulting sanctions, which have affected many European MRO providers with exposure to the country.

For example, prior to the war, about 400 aircraft in Russia had some form of support contract with Lufthansa Technik, with many served via Lufthansa Technik Vostok, its 100%-owned Russian subsidiary.

Elsewhere in the aftermarket, Rolls-Royce stopped providing Aeroflot with engines, spares and maintenance services. It said Russia accounted for 2% of its global revenues. French company Safran, meanwhile, noted near the start of the war that the crisis would strain global titanium supplies for aircraft and engine production, for which Russia was its main supplier, and that it had begun to stockpile titanium.

MTU was also affected, recognizing impairment charges of €59 million ($62.2 million) in connection with the war in Ukraine.

"This affected the stake in the PW1400G-JM program, which was intended for the Russian Irkut MC-21 and has been permanently written down as a consequence of the Russia-Ukraine war and, to a smaller extent, assets related to the stake in the consortium for the PW1100G-JM aftermarket business and MTU's commercial MRO business," Eichhorn says.

Active Aftermarket

Domestic growth and overseas investment are stimulating Ireland's MRO ecosystem

James Pozzi Shannon, Dublin and Cork, Ireland

For a country of little more than 5 million people, the Irish economy has long punched above its weight. Once mostly an agriculture-driven economy, Ireland has transformed into one based on advanced technologies and global exports. The country's government has actively targeted investment from multinational companies over the past decade, with incentives including a corporate tax rate of 12.5% and strong intellectual property protections.

Ireland's aviation sector has contributed to this trajectory by further growing as a hub for aviation leasing and finance as well as aftermarket services.

IDA Ireland, a quasi-governmental agency encouraging foreign direct investment into the country, has proactively targeted the aviation segment, and specifically MRO, as drivers for economic growth. It typically does this by hosting customized visits to Ireland for prospective investors, along with offering practical support and financial incentives to further entice companies to establish operations in Ireland. Tony Hayes, vice president for engineering, industrial and clean technologies for the U.S. Midwest at IDA Ireland, says of Ireland's status as an aviation hub: "The Irish aviation cluster spans the industry value chain, encompassing everything from aircraft leasing, maintenance and recycling to component manufacture, parts repair and business aviation, avionics, technology and aftermarket solutions and beyond." Hayes says in recent years, technology and innovation have become more important, citing areas such as inflight data acquisition and monitoring instrumentation, flight-testing hardware and software, and cybersecurity and flight management systems.

MROs ADDING CAPACITY

Much of Ireland's MRO activity is based in a cluster at Shannon Airport on Ireland's west coast. Shannon has been an aviation hub since the 1940s, being the destination of the first transatlantic scheduled landplane passenger flight in 1945, and has since served as a gateway between Europe and the U.S.

While strong domestic-based MROs such as the Atlantic Aviation Group have operated in the area for more than 60 years, many MROs at Shannon demonstrate Ireland's drive to capture overseas investment. These include U.S.-based STS Aviation Group, which has run STS Aviation Services Ireland's modifications and interiors business since acquiring UJet in 2018. This investment influx has continued over the past year, with Shannon-based Eirtech Aviation Services included in a deal for U.S. private equity firm Tiger Infrastructure Partners to acquire International Aerospace Coatings in December 2022.

Another example of overseas investment is Lufthansa Technik Turbine Shannon (LTTS), which the German MRO giant has operated since 1992. The company specializes in repairing components for high-and low-pressure turbines for CFM- and GE-manufactured engines, supporting Lufthansa Technik's overhaul shop along with third-party customers.

Pat Foley, who recently became CEO of LTTS, says its revenues and headcount are above 2019 levels, but issues such as supply chain constraints and meeting market demand persist. Inflation in Ireland—running at around 6.3% in August—has affected operations in several areas. "We're seeing pressure on materials, labor costs and areas such as energy costs at our facilities—so it's across the board," Foley says. This year, LTTS opened a new facility close to its existing Shannon site focusing on the repair of engine manifolds to add further capacity, taking its engine repair footprint in Shannon to 1.1 million ft.^{2}

Despite the impact of geopolitical issues on the Irish MRO segment, investment has continued not just at Shannon but also elsewhere in Ireland. U.S.-headquartered Panasonic Avionics, which has operated its Panasonic Technical Services business in Ireland since 2019, recently expanded its MRO center in Dundalk—increasing to 23,000 ft.^{2} from 6,000 ft.^{2} while tripling its workforce at the site. Meanwhile, in Celbridge in County Kildare, located 13 mi. west of Dublin, Lufthansa Technik opened a new mobile engine repair shop, doubling capacity for CFM56-5B and -7B maintenance to 10 engine bays.

Domestic MRO providers are also expanding abroad. Dublin Aerospace, a provider of services for auxiliary power units, base maintenance, integrated drive generator repairs and landing gear maintenance, has been based in the Irish capital since 2009 and operates a four-bay hangar close to the city's airport. The company expanded its footprint into the UK after acquiring the Exeter-based maintenance division of defunct airline Flybe three years ago. The business now operates as Exeter Aerospace and focuses on maintenance for Embraer 170/190 regional jets, Bombardier Dash 8/Q400 and ATR 72 turboprop aircraft.

William Flaherty, CEO of Dublin Aerospace, says it has run Exeter Aerospace specifically to foster organic growth. "We have followed a startup trajectory, aiming to run at its capacity within the first five years," he says. "The strategic plan includes the establishment of five lines of maintenance, which enhances efficiency and enables Exeter to cater to more aircraft in a streamlined manner."

Across its network, Dublin Aerospace is looking to grow capabilities in component repairs and line maintenance, having recently opened a station in Belfast. Flaherty says the need for skilled labor is a particular challenge despite Ireland's relatively strong technical training schools.

"We need governments to recognize and promote the importance of technical training in order to address the skill gaps across a number of industries and foster economic growth and competitiveness," Flaherty says, adding that Dublin Aerospace plans to hire up to 100 more people across the business over the next few years. Meanwhile, Foley says LTTS has increased its head-

count by around 100 over the past 18 months, with a lot of that talent coming from Shannon and surrounding areas.

AIRLINES BUILD IN-HOUSE CAPABILITY

Much of Ireland's commercial fleet is operated by flag carrier Aer Lingus and low-cost carrier Ryanair. Aer Lingus, part of International Airlines Group, has a fleet of 54 aircraft including Airbus A320-family and A330 types.

Like many carriers, Ireland's airlines are looking to bring some MRO capability in-house to hedge against supply chain challenges and extended lead times. Javier Jimenez, chief technical officer at Aer Lingus, told *Inside MRO* this year that it was exploring bringing some component repairs in-house rather than relying too much on new components from constrained OEMs. Jimenez also cited a competitive recruitment market—especially in skilled areas such as B1- and B2-certified engineers—as a challenge but plans to address this by drawing on talent from European Union member states and its apprenticeship scheme, which takes on around 15-20 trainees annually.

Ireland's largest aircraft operator is Ryanair, with more than 500 aircraft in its fleet—a number that will surpass 600 by 2026. This is anticipated to grow with the arrivals of more Boeing 737 MAX aircraft. The airline has commitments for up to 150 of the Leap 1B powered type.

While not engaged in any third-party MRO, Ryanair has been boosting the in-house repair capability of its engineering division, including sites in Dublin and Shannon and across Europe in Kaunas, Lithuania; Wroclaw, Poland; Seville, Spain; and Glasgow, Scotland. This drive gained speed during the pandemic, when the airline sought to in-source more maintenance capability to drive cost efficiencies, particularly in base maintenance up to the C check level. It also uses external MRO providers such as Joramco in Jordan, where it recently increased its maintenance lines to six for the 2023-24 winter season.

Domestically, Ryanair opened a new hangar in Shannon in 2022, which focuses on base maintenance of its fleet. The airline also announced a new €40 million ($42.2 million) four-bay facility at its Dublin main base. The 120,000-ft.^{2} facility is expected to open in the second quarter of 2025, adding capacity and creating 200 new jobs.

Dublin Aerospace is a domestic MRO that is expanding outside of Ireland.

BUOYANT LESSORS FORESEE SPARE ENGINE DEMAND SPIKE

Ireland has become a world center of aviation leasing and finance, owing to tax treaties with numerous countries and the maturity of a liberal aviation legal framework over a 50-year period. There are more than 50 aircraft leasing companies operating in Ireland, with more than 60% of all leased aircraft worldwide managed by Ireland-based lessors. The $30 billion mega-merger in 2021 between AerCap and GECAS further boosted the country's leasing infrastructure. SMBC Capital and Avolon are also headquartered in Ireland. Reflecting its large MRO footprint, Shannon is home to several prominent aircraft and engine lessors. These include Shannon Engine Support (SES), a GE-affiliated company specialized in the leasing of CFM56 and Leap family engines with a 50-50 split.

Tadhg Dillon, chief commercial officer (CCO) at SES, expects high demand for Leap 1A spare engines next year. "Most of this demand is forecasted to be driven by environmental issues; however, the first batch schedule removals should also start next year, driven more by staggering programs versus engine condition," he says. "MROs continue to struggle with supply chain issues, lack of resources and capacity, all of which directly impact on turnaround time, which increases the demand for spare engines."

Another major Shannon-based lessor is Engine Lease Finance Corp., which owns and manages 360 engines, of which 90% are for narrowbodies. CCO Richard Hough identifies the latest-technology narrowbody engines—the Leap and GTF—as driving the narrowbody engine segment forward, despite well-documented technical issues.

"The unprecedented ramp-up in delivery rates from both Airbus and Boeing, combined with the well-publicized technical issues, has resulted in an unanticipated level of early demand for MRO support, with a knock-on effect of increased demand for spare engines," he says. "This increased spare engine demand has accelerated growth of the independent leasing market . . . we expect the Leap and GTF markets will mature into bigger and even more independently supported MRO and leasing markets than any of the preceding technologies."

Hough says the widebody segment has lagged behind narrowbodies in terms of post-pandemic recovery. "But while it is recovering more slowly, it is doing so at a steady rate," he adds.

Green Gains and Growing Pains

Will aviation sustainability initiatives create headaches for MRO providers?

Tom Pleasant London

The MRO industry's commitment to sustainability is encouraging but varied, while airlines see feedstock sustainable aviation fuels as the path of least resistance for reducing their carbon emissions. These fuels are green and compatible with existing technologies, but their use may leave MROs with new problems.

Sustainability has become a defining issue for aviation, with rising public and regulatory pressures demanding action to curb the industry's impact on the climate. Airlines are responding by setting ambitious carbon-reduction goals, publicizing their eco initiatives both large and small, and adding sustainability sections to annual reports. But how are their MRO partners responding to airlines' bold sustainability commitments?

Sustainability adoption across the segment appears mixed. Larger MROs with in-house airline customers have implemented a variety of environmental initiatives ranging from facility energy efficiency upgrades to optimized repair processes that reduce waste.

Derk Nieuwenhuijze, head of strategy, marketing and communication at AFI KLM E&M, says the company is making solid progress on achieving zero emissions by 2030, with a major chunk of forecast cuts to come from more efficient heating and electricity for the company's facilities and better engine and auxiliary power unit testing.

However, some initiatives are taking longer than others. "We really have to be careful about balancing grid capacity, generating solutions and power-saving options," he says. "Not all technologies are ready to be decommissioned straight away. Replacing gas power equipment with electrical isn't always possible, no matter how much we may want to [do so]. Also, engine testing is still restricted to 50% as we're waiting for OEMs and legislators to increase that threshold."

Smaller independent MROs, however, seem slower on the uptake. Off the record, they say they are not seeing large-scale demand from their customers that would justify the investment, possibly because MRO is not considered a good source of low-hanging wins for reducing emissions.

AFI KLM E&M

They may not be wrong. In a recently published strategy guide on how aviation can reduce its climate impact, "Roadmap to True Zero," global consultancy Roland Berger identifies

ENVIRONMENTAL ASSESSMENT CERTIFICATION

The International Air Transport Association's (IATA) Environmental Assessment (IEnvA) certification is a voluntary program that aims to help aviation stakeholders improve their environmental and sustainability performance.

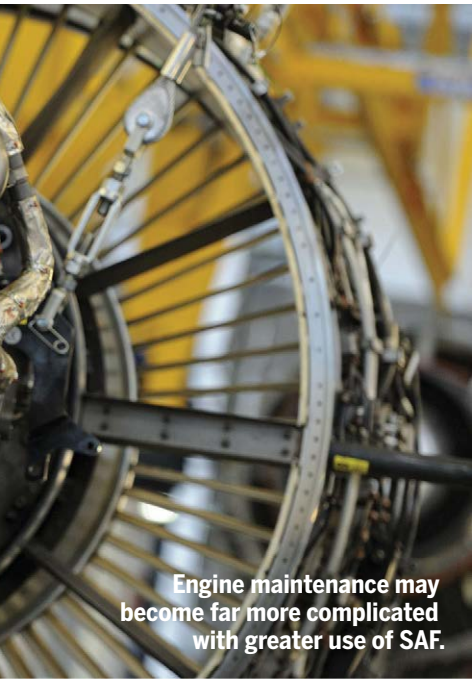
Certification has two stages: Stage 1 represents an intermediary step to full compliance; Stage 2 represents the highest level of compliance and requires an organization to demonstrate ongoing environmental performance improvement. The certification covers different scopes of activities, such as flight operations, corporate activities, catering, ground handling and, increasingly, MRO.

According to the IEnvA Registry, as of September, 28 stakeholders had achieved Stage 1 or Stage 2 certification under IEnvA, and these 18 included MRO as part of their scope of certification:

AAR
Air Canada
Air Canada Rouge
Air New Zealand
Emirates
Etihad Airways
GOL Aerotech
HAECO
LATAM Airlines Brasil
LATAM Airlines Colombia
LATAM Airlines Ecuador
LATAM Airlines Group
LATAM Airlines Paraguay
LATAM Airlines Peru
LATAM Cargo
LATAM Cargo Brasil
LATAM Express
MTU Aero Engines

Their MRO sustainability initiatives include using renewable energy sources, reducing waste and emissions, recycling materials, enhancing employee well-being and supporting social causes.

IATA has also expanded the IEnvA certification to aviation stakeholders beyond airlines, such as airports and ground service providers. In November 2022, Qatar Aviation Services became the world's first ground service provider to achieve IEnvA Stage 1 certification for its core activities and maintenance.



Engine maintenance may become far more complicated with greater use of SAF.

seven distinct groups of "levers" to tackle CO_2 and non-CO_2 aviation emissions. Of those seven, the one with the least impact is the entirety of ground operations, while contrail avoidance, sustainable aviation fuel (SAF) and switching to next-generation—ideally supersonic—aircraft are jointly first.

However, carriers that have publicly committed to bold carbon pledges will increasingly expect their in-house and outsourced MRO providers to demonstrate similar commitments. This is especially the case with increased awareness of Scope 3 emissions.

SCOPING OUT THE ENEMY

Scope 3 includes emissions a company does not create or control directly but which result indirectly throughout its value chain—from buying to usage and then disposal. For aviation, this is largely comprised of aircraft, which account for the majority of the industry's carbon footprint. Scope 3 emissions are therefore a key challenge for the industry's sustainability goals—and with aircraft age comes reduced efficiency.

That puts the spotlight squarely on MROs and how efficient they can make older aircraft. This also means MROs will need to reduce their emissions, even if proportionally they are not in the same league as those top-three industry causes.

"In an activity as ours, Scope 3 emissions are significantly higher than Scope 1 or 2 due to the vast impact of parts production and its supply chain," Nieuwenhuijze says. "We're currently finalizing a huge study to quantify that impact, which means getting more information from our suppliers on the supply chain further upstream, but we're actively working with them to get more clarity on that."

CARBON COLD TURKEY

One of those top-three levers will become a hot topic for MROs in the coming years. The UK's Sustainable Aviation Fuels Roadmap projects a requirement for 4.5 million tons of SAF per year by 2035, driving the global market to reach $27.4 billion by 2032 from the current $430.6 million.

There is a multitude of different

MRO SUSTAINABILITY ACHIEVEMENTS

Here is a sampling of steps MRO providers have taken to reduce their impact on the environment:

AAR has reduced energy usage 10%, emissions 15% and water use 20%, and increased recycling materials 25%. It has also invested in Boeing 737 drag-reduction kits that can save up to $200,000 per aircraft per year.

AFI KLM E&M has installed solar panels in Norwich, England, and Amsterdam, reducing electricity emissions. It also has modernized real estate and added electric vehicles. It performed an engine test with 100% sustainable aviation fuel (SAF), enabling more than 50% SAF for certification.

Aircraft End-of-Life Solutions offers green seats made by refurbishing and reusing aircraft seats instead of discarding them, saving up to 80% of materials and costs.

AJW Group aims to achieve net-zero carbon emissions by 2050, reduce waste and water consumption 20% by 2025 and collaborate with stakeholders to advance sustainability in the aviation industry.

GOL Aerotech uses digital tools to become more sustainable, such as software that optimizes the use of paint and reduces waste 40%. It has also installed solar panels on its hangar roof that generate enough energy to power 300 homes and save $50,000 per year.

HAECO has installed LED lighting that uses 60% less electricity and water-saving devices that cut water consumption 50%, recycles waste oil and metal that reduces landfill waste 70% and conducts regular energy audits that save $100,000 per year.

Lufthansa Technik has developed AeroShark, a surface film that reduces frictional resistance and saves up to 1% of fuel and carbon-dioxide emissions. It also launched the Clean Tech Hub, a team that is developing methods to reduce waste 30%, make aircraft lighter and 5% more aerodynamic, and test maintenance and ground processes for future hydrogen-powered aircraft that can reduce emissions up to 50%.

Magnetic MRO uses water-based paints that reduce solvent consumption as much as 95%. It also has reduced energy usage up to 30% with smart lighting systems, optimized inventory management that lowers storage costs up to 40%, moved toward recycling aircraft parts and materials that recover as much as 90% of their value and worked to offset its carbon emissions.

MTU Aero Engines is developing low-emission engine technologies to reduce fuel burn and emissions by up to 15%, uses renewable energy sources that account for 50% of its electricity consumption and is aiming to reduce hazardous substances and waste by 10% by 2025.

SR Technics aims to cut its emissions by 25% by 2030 and to increase energy efficiency by 15% and minimize waste generation by 10%, both by 2025. It also participates in industrywide efforts to promote sustainable aviation, such as supporting research on SAF and hydrogen propulsion systems, facilitating the drafting of new global emission standards for various engine types and partnering with Kuehne+Nagel and Atlas Air to form the Sustainable Engine Alliance, which aims to set new standards for low-carbon aircraft engine supply chains.

ST Engineering offers modifications that can save fuel and emissions by up to 3% and has adopted eco-friendly practices, such as using biodegradable cleaning agents that reduce chemical usage by up to 80%, minimizing packaging materials that save up to $500,000 per year and recycling waste that generates up to $1 million of revenue per year.

Hydrogen-powered aircraft will require special considerations for MRO providers, such as specialized facilities, procedures and training.

SAFs, each with slightly different performance rates and long-term effects on jet engines—some good, some bad. For example, studies show SAF can reduce engine wear and tear, which can lower maintenance costs and extend the engine life cycle. This is because some SAF has lower levels of sulfur, aromatics and particulates than regular jet fuel, reducing deposits and corrosion in the engine components.

SAF from hydroprocessed esters and fatty acids can have up to 90% less sulfur and 50% less aromatics, which can improve the lubricity and cleanliness of the fuel. Again, this means SAF can help reduce maintenance expenses and increase their asset utilization by extending the time between overhauls and inspections.

However, SAF can also have different freezing points, densities or viscosities than regular jet fuel. For example, SAF derived from Fischer-Tropsch synthesis has a lower freezing point, which improves its cold flow properties, but it also has a lower density and higher viscosity, which affects the fuel injection and combustion processes in the engine.

These factors mean comprehensive safety testing is needed. Some estimates suggest certifying a new type of SAF can cost $5-15 million per engine model.

For MROs, the investment will also be high for this influx of SAF types. Not only must they ensure compliance with

LUFTHANSA TECHNIK

emerging SAF quality and safety standards and stay up to date with new regulations, but they also must provide additional training and certification for technicians and ensure all components and materials meet the necessary standards for use with the new fuels.

ONE SAF TO RULE THEM

While still only relegated to test flights on smaller regional aircraft, hydrogen as a jet fuel has the potential to force MRO companies to transform far more than SAF will.

Hydrogen propulsion systems offer zero CO_2 emissions, as well as a gravimetric and volumetric energy density that surpasses that of batteries. The global hydrogen aircraft market was $143 million in 2021 and is expected to reach $1.7 billion in 2030.

While SAF can be treated almost exactly the same as conventional jet fuel, hydrogen poses more challenges for MRO providers. First, hydrogen-powered aircraft require cryogenic tanks and hydrogen distribution systems. Second, MROs need specialized facilities for handling hydrogen fuel cells along with new maintenance and safety procedures, standards and training. And third, hydrogen requires a completely new supply chain for production, storage and distribution, since the fuel needs to be scalable and cost-effective to justify its adoption.

"Scaling hydrogen to make aviation sustainable is a significant infrastructure challenge," says Shashank Nigam, CEO of consultancy SimpliFlying. "From storage and transportation to ensuring safety, hydrogen-powered aircraft will require a rethink for MRO players serving airlines. Therein lies the opportunity—MRO companies that are able to adapt to and enable the transition to hydrogen to power greener flying will have an edge ahead of the competition looking to maintain the status quo."

Sustainability has become a defining and urgent priority across aviation. While MROs may generate few direct emissions, they will need to become far more aware of their Scope 3 contribution—and especially their need to invest in training in, infrastructure for and handling of SAF, whether biofuel or hydrogen.

Developing Doors

Aircraft cabin door OEMs are improving designs with structural, material and digital innovations

Paul Seidenman and **David Spanovich** San Francisco

With weight savings at the top of the list for any aircraft clean-sheet design or modification, cabin doors present yet another opportunity.

Lighter cabin doors can be achieved starting at the subcomponent level, says Satish Narayanan, vice president for engineering and technology for advanced structures at Collins Aerospace. He reports that while Collins has produced a limited number of passenger, cargo and auxiliary doors over the years, its current focus is on door subsystems such as emergency passenger assistance, flight lock actuation, sensors, lights, the electronic control module and evacuation slides.

Narayanan says Collins is incorporating weight savings into all of its design decisions, with a 20% weight-reduction goal for future door systems. "For example, by designing the evacuation slide, structure and mechanism together, it's possible to achieve compact and efficient designs that weigh less and open more space in the fuselage," he explains. "By optimizing the overall system architecture and subsystems at the same time, duplicate features can be eliminated."

Reducing the weight of the subcomponents has a ripple effect. "When the door is lighter, the mechanisms and hinges can also be lighter since they don't have to support the weight of a heavier door," Narayanan says.

AIRBUS HELICOPTERS

Airbus Helicopters has achieved a door part reduction of 50% using 3D/ additive-layer manufacturing of metallic door operational assemblies.

MANUFACTURING TRENDS

At the same time, he notes that significant weight savings are also being realized by using thermoset or thermoplastic composites. Collins sees these as "a trend for structural applications," he says, specifically to the door skins and stiffening frames.

"This is a trend which is on the rise," Narayanan says. "The Boeing 787 and Airbus A350 already use composites in their structure, and going forward, we see the use of thermoplastic composites increasing because of their improved toughness. This makes them more durable in an environment where impact from luggage handling or other airport operations can be frequent." He adds that parts of the internal door mechanism could be fabricated from composites, citing the moving shafts that facilitate locking and unlocking.

Using fewer parts also reduces weight; employing thermoplastic welding in the manufacturing process would reduce the number of fasteners required, Narayanan says. "Alternatively, by using thermosets, more of the structure could be manufactured as one piece, cutting the number of parts and fasteners required for assembly," he notes. "We are looking at simplifying the mechanism by reducing gears, cams and shafts. By balancing trade-offs between subsystems, we've come up with an approach that reduces the requirements for those parts."

Asked about some of the areas where new door designs are likely to trend, Narayanan says opportunity exists for new variants where additional emergency egress doors might be added, as well as in the freighter conversion realm. "There will be more model-based systems, engineering-based design and development to optimize the system as a whole and more integrated components, embedded intelligence and composite structures," he says.

Although composite doors do not have a maintenance advantage over doors fabricated from metal, according to Narayanan, he reports that there are other approaches to reducing maintenance. "We are looking at ways to connect the multiple systems, as well as a common health monitoring approach that can relay information digitally to the operators," he ex-

LATECOERE/MOTION PALACE

plains. "This way there is no need to disassemble portions of the door." Narayanan cites the pressure check of the evacuation slide pressure bottle as an example that in many cases requires partial disassembly of the door.

"Our team is also looking at ways to combine multiple sources of data from the door, the aircraft and the flight environment to add predictive health and optimize maintenance schedules to reduce aircraft downtime," he adds.

THE COMPOSITES FACTOR

While composites may be no more durable than metal, Dirk Trott, chief engineer of passenger doors at Airbus Helicopters, says composite materials for the primary structure represent the most significant change to the current generation of cabin doors. Airbus Helicopters manufacturers most of the doors for Airbus commercial airliners, in addition to the OEM's helicopters.

"The application of composites [to the cabin doors] was driven by weight-improvement targets compared to metallic structures," Trott says. "Composites have a favorable ratio of high strength at low weight, which is why primary structural elements of the cabin door that carry flight and pressure loads are being manufactured from composites. These include the outer skin as well as the internal stiffening framework of frames and beams. In addition, composite material has proven to be a weight-effective material for the production of the main hinges for doors that are swiveled to open."

Trott says improvements aimed at sustainability as well as operator and passenger comfort were achieved for thermal and acoustic insulation, along with maintenance reduction for systems integrated into the door. "Maintenance intervals for composite doors are comparable to—or longer—compared with the metallic doors," he says. "But this has been a design target from the conception of the product and is achieved by application of respective sizing and corrosion protection principles."

Trott says a key factor with cabin doors is the design of parts with a high integration level in tandem with reduction of single parts and related connections and fasteners.

"Parts reduction and higher parts-integration levels are design goals that are always pursued," he stresses. "Recently, the most significant improvements for this were achieved by the use of 3D-printing/additive-layer manufacturing (3D/ALM) for metallic door operating mechanism assemblies, which

Latecoere's Elcocos project for aircraft doors targets faster manufacturing and the use of fewer raw materials.

allowed a reduction of single parts by almost 50%. In terms of production technology, 3D/ALM, especially with titanium, contributes to the improvement of weight, and is also a very important measure for the future."

Trott says Airbus Helicopters has also addressed the risk of damage to cabin doors. "By far, most of the reported damage to cabin doors originates from support equipment such as passenger bridges and catering trucks colliding with door edges," he notes. To increase door damage tolerance, the OEM has introduced "metallic protection profiles" around the outer perimeter of the composite door skin that deform when struck but prevent damage to the composite skin up to a defined load or impact level.

Looking ahead, Trott says the focus on low weight will continue to prevail. "Cabin doors have to fulfill two very opposite functions: staying safely closed and locked [while enabling] the operator to open them reliably under all normal and emergency conditions," he notes. "Engineers are considering further weight reduction and use of

composite structures that will allow high-strength designs that are able to accommodate both functions safely."

INNOVATIONS

Along with part-count reductions and higher integration levels with composite structures, Trott says there will be further focus on noise reduction and better thermal insulation of the door.

"Actuation will also be an area of interest, even though hydraulic/pneumatic actuation continues to provide reliable weight and cost-effective performance with long lifetime and low-maintenance efforts," he explains. "However, simplification of door operation by application of electric actuation systems is a further field of development that is expected."

Latecoere, a major supplier of aircraft doors, launched a promising technology applicable to cabin door manufacturing in 2019. A small demonstrator door dubbed Elcocos (enhanced low-cost complex composite structure) was delivered to Airbus in June 2021. According to Stephane Bouzat, Latecoere's head of innovation and research and technology programs, the main innovation in the door's manufacturing process involves the implementation of one single part for the main portion of the door, including the skin and the stiffening edge frame.

"The second main innovation is the capacity to consolidate the whole door structure in one shot with a dedicated curing mold, allowing fast door structure manufacturing and less raw material—composite and all additional film and textile traditionally used for infusion processes," he explains.

Bouzat says Latecoere is using liquid-resin infusing technology for the Elcocos project. "Its advantage is in the competitiveness of the manufacturing, depending on the type of product and program rate," he says. "However, in certain aircraft configurations, this technology allows the aircraft to improve its technical and economic performance, including weight, with the related benefit of CO_2 reduction."

While technology continues to enable innovations in door design, manufacturing and sustainability, Latecoere has also turned its attention to the real-world interface between the cabin doors and airline cabin crew. "A big improvement in door handling has been made possible by better understanding the cabin crew environment and getting their direct feedback," says Thierry Eftymiades, Latecoere's senior vice president for engineering.

For instance, Eftymiades says the door handles are sized by taking into account "ergonomics aspects" as they apply to any sample of the population as well as door interfaces and operating loads. "Based on past experience with mechanism sizing, Latecoere is able to propose better low-handle loads by considering all contributors, including seal effect, weight compensation and mechanism-securing means," he says.

Advancing Mobility

Lindsay Bjerregaard Chicago

1. Developer Collaboration

Company: AFI KLM E&M
Product: MRO provider AFI KLM E&M is working with multiple advanced air mobility (AAM) developers to get in on the ground floor of aftermarket services for the emerging segment. At last year's MRO Europe event, the company signed a memorandum of understanding (MOU) with French electric vertical-takeoff-and-landing (eVTOL) aircraft manufacturer Ascendance Flight Technologies to explore potential collaboration areas for its five-seat Atea aircraft, which is planned to enter service in 2027. AFI KLM E&M also signed an MOU with electric aircraft manufacturer Ampaire to explore collaboration in mutual interest areas such as maintenance training, support and data analytics.
marketplace.aviationweek.com/company/afi-klm-em

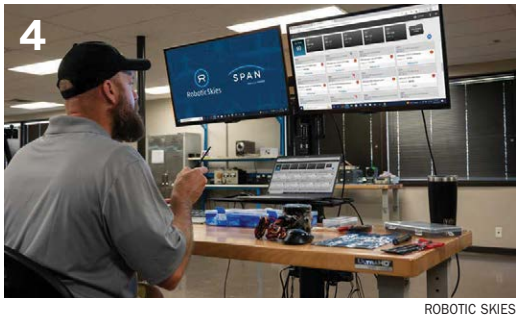
2. Establishing MRO Infrastructure

Company: Eve Air Mobility
Product: Embraer AAM spinoff Eve Air Mobility has made significant headway in developing its MRO infrastructure. Eve says it is establishing a network of maintenance and service providers and leveraging Embraer's service network in the regions from which it plans to launch. The company signed an MOU in August with DHL Supply Chain to study supply chain needs for its eVTOL operations. The study will examine best practices for supplying operators and service centers with spare parts, including requirements around battery transport, storage and disposal. The study will also investigate the distribution of parts and materials required for MRO. In 2021, Eve confirmed plans to use EmbraerX's Beacon maintenance platform for aftermarket coordination of its eVTOLs. The digital platform will be used to connect parts and mechanic needs.
marketplace.aviationweek.com/company/eve-air-mobility

AFI KLM E&M

EVE AIR MOBILITY

HAECO GROUP



ROBOTIC SKIES

3. Chinese eVTOL Support

Company: HAECO Group
Product: Hong Kong-based HAECO Group is partnering with Chinese eVTOL developer EHang to establish after-sales support for its EH216-S aircraft. In October 2022, HAECO signed an MOU with EHang to codevelop maintenance services in preparation for commercial operation of the eVTOL aircraft, which is in the final stages of certification with the Civil Aviation Administration of China. The partnership will include cooperation in areas including aircraft maintenance, continued airworthiness management, personnel training and digital platforms. EHang plans to operate its eVTOL from a variety of locations throughout China. HAECO operates several facilities in Hong Kong and 17 locations in China's mainland.
marketplace.aviationweek.com/company/haeco-group

4. Digital MRO Management

Company: Robotic Skies
Product: Robotic Skies is developing a network of Part 145 repair stations for uncrewed aircraft systems (UAS), including AAM aircraft. It has more than 250 service centers across 50 countries. In August 2022, the company partnered with Continuum Applied Technology to adapt its cloud-based Corridor software for aviation maintenance to the unique requirements of the emerging AAM market. Robotic Skies launched its SPAN software platform, powered by Corridor Go software, in October 2022. SPAN manages and tracks AAM and UAS service and repair projects. Robotic Skies says the platform facilitates scheduled and ad hoc maintenance activity management, and the software can be used to help customers establish optimal maintenance intervals and improve aircraft reliability.
marketplace.aviationweek.com/company/robotic-skies

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AVIATION WEEK

Fleet&MRO FORECASTS

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THAT DRIVES RESULTS

Make informed, strategic decisions with a 10-year outlook of the world's fleets and MRO demand with Aviation Week Intelligence Network's **2024 Commercial Fleet & MRO Forecast**.
Tailor your business strategies and anticipate upcoming market developments with this unique and valuable solution.

91.7%

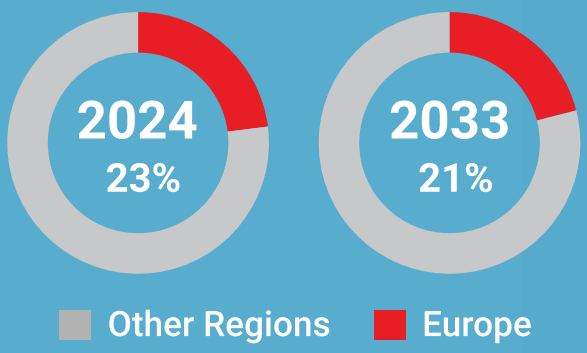
Airbus and **Boeing**, the two largest manufacturers in the world, account for 91.7% of future aircraft deliveries over the 10-year forecast period. See which aircraft dominate markets while other's influence wanes.

10-Year Outlook
Aircraft Storage
Aircraft Family
Retirements
Regions
MRO
Trends
Deliveries
Demand
Engine Family
In-Service Fleets

New this year are emissions projections over the next 10-years.

In-Service Fleet by Region

Europe's share decreases from 23% to 21% despite its fleet strength increasing by over 1,500 aircraft at the end of 2033.



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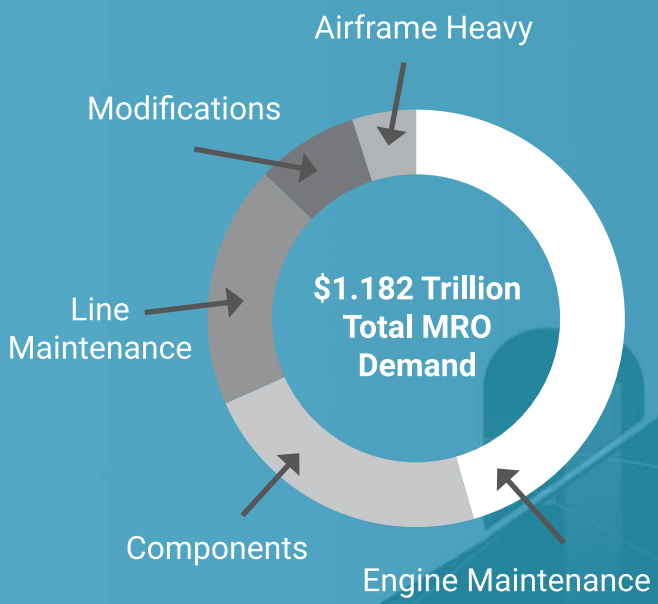
MRO Demand by Expense Category



Pent-up travel demand is driving regions at different rates around the world. With some areas seeing near 2019 levels, others are surpassing those and more. The MRO aftermarket reflects the fleet activities but is facing challenges and headwinds. With new generation engines and aircraft on the scene, see how the shifting dynamics of the nearly $1.2 trillion MRO market makes its mark around the globe.

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AIREXPERT

By ANDY HAKES
Based in Buffalo, New York, Andy Hakes is the founder and CEO of MRO software provider AireXpert.

Digital Divide

How MROs, operators and tech startups can eliminate roadblocks in adopting new technology

Given the extraordinary convergence of labor, performance, regulatory and supply chain challenges for aircraft operators and MROs into the foreseeable future, the appetite for technology-based solutions to alleviate numerous and crippling pain points continues to increase.

While many options and opportunities exist to embrace MRO technology, the digital divide between enablers and enterprise partners persists, often to the detriment of business performance across the globe.

This year's Paris Air Show hosted several aerospace-centric incubators and accelerators, each showcasing dozens of early-stage companies developing, testing or actively deploying innovations that could have a huge impact across the aviation and aerospace MRO landscape. AireXpert was one of the companies exhibiting in conjunction with the previously Boeing-led Aerospace Xelerated accelerator program.

While my many conversations with company founders in Paris and elsewhere are generally optimistic, there is a common thread to the challenges and frustrations voiced by founding teams as well as the leadership teams of airlines and MROs.

With new solutions in various stages of readiness, from prototypes to fully scalable products and technologies, it makes sense for industry stakeholders to collaboratively acknowledge, understand and eliminate the roadblocks that prevent significant advances in MRO technologies.

Many operators and MROs lack a "lab" environment in which new technologies can be validated, vetted and refined. Often there is little or no existing staff dedicated to R&D, but merely teams that tend to be tasked with multiple projects. For obvious reasons, there is usually a low risk tolerance, and enterprise stakeholders are pressed to look for applications that will produce rock-solid, quantitative return on investment (ROI), many times even before an initial engagement. Finance teams often do not have enough visibility into MRO processes and operations to identify and prioritize projects based on impact. Business unit leadership teams might simply have too many competing priorities or too many external demands.

If done correctly, technology adoption in MRO represents an essential opportunity for all of us right now.

By definition, early-stage companies are bringing new value to the table, but they might not have yet figured out how to demonstrate the value to time-constrained leadership teams by telling a convincing story. They might not necessarily speak the language of MRO, as their projects may have spun out of universities or adjacent industries. They are often not sure how to navigate siloed workgroups and do not yet understand the purchasing cycle of an enterprise customer.

Their solutions may require buy-in from multiple stakeholders, and they may not yet have a holistic understanding of how (or if) their solution will play well with the myriad of other systems already in use. Founding teams might not yet have a firm grasp on ROI and/or the practical side of integrations and implementations.

Most important, early-stage companies face the stark reality of running out of funding before these essential questions are answered.

So how do we expedite the journey to where we need to be? It can be difficult to align expectations that deliver meaningful results, but here are several strategies AireXpert has found productive and helpful:

OPERATORS AND MROS

- Proactively partner with aerospace accelerators and incubators, which can provide crucial support during the phase in which companies are building their teams and validating their offerings.
- Recognize that startups value time and money entirely differently than enterprise companies.
- Facilitate 20-min. conversations between early-stage company founders and each of the following roles: business unit (users plus leadership), finance, procurement and legal.
- Iterate together. Your data, inside knowledge and access to people are both essential and priceless for companies that are helping you strategize for the future.
- Keep an open mind and an open door if early-stage companies do not have all the answers right now.

STARTUPS

- It is not a sale, but it is a conversation in which you should be asking a lot of questions.
- If your audience is not understanding your value, you are either not talking to the right people or not telling the right story—or possibly both.
- Think and act holistically. Make it ridiculously easy for your audience to engage with you and understand what you can do for them.
- Come prepared. Use your 20-min. conversation wisely.

In the absence of new technologies, airlines and MROs will continue to purchase from a familiar yet high-cost and dwindling pool of resources. If done correctly, technology adoption in MRO represents an essential opportunity for all of us right now.

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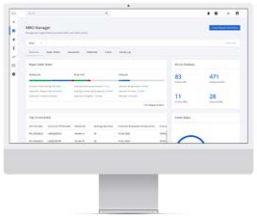

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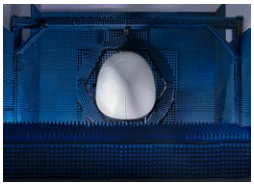

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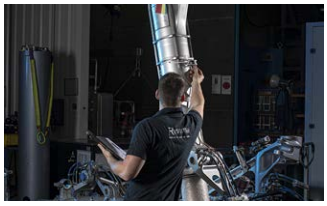

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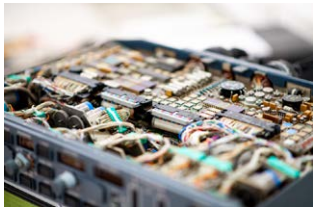

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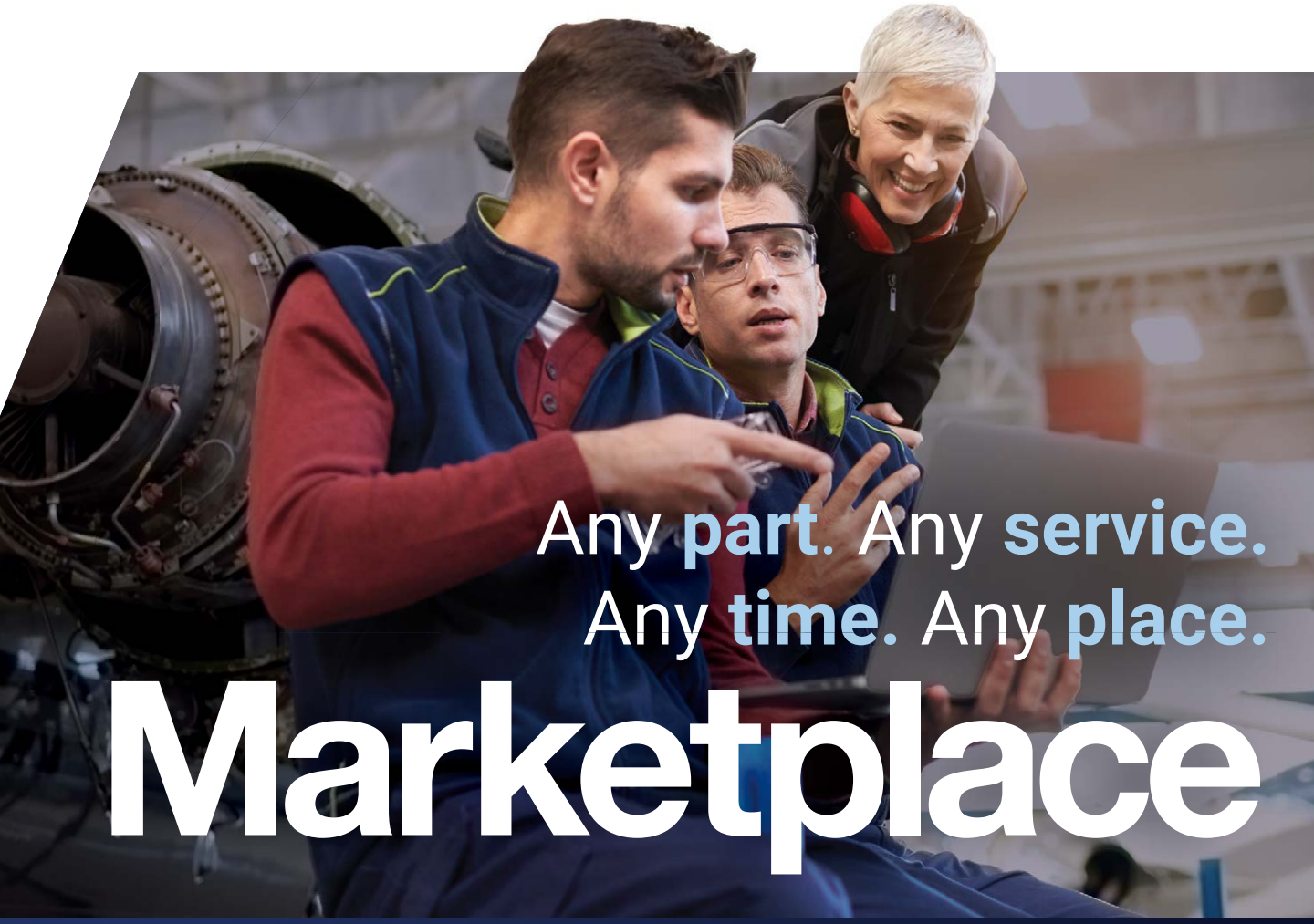

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U.S. Regionals Look Ahead to Innovations and Improvements

> "YOU'LL THRIVE IF YOUR REGIONAL PARTNERS THRIVE," ANALYST TELLS MAINLINE CARRIERS

> OEMs DESCRIBE PRAGMATIC APPROACHES TO NEW TECHNOLOGIES

Christine Boynton Washington

On Sept. 26, Republic Airways was scheduled to operate Delta Air Lines Flight 5692 as its first departure from Boston Logan International Airport to Reagan Washington National Airport at 6 a.m. EDT. But the flight departed Boston 2 hr. late—at the time of boarding, the captain was still en route to Boston from Washington, after having been called in on reserve.

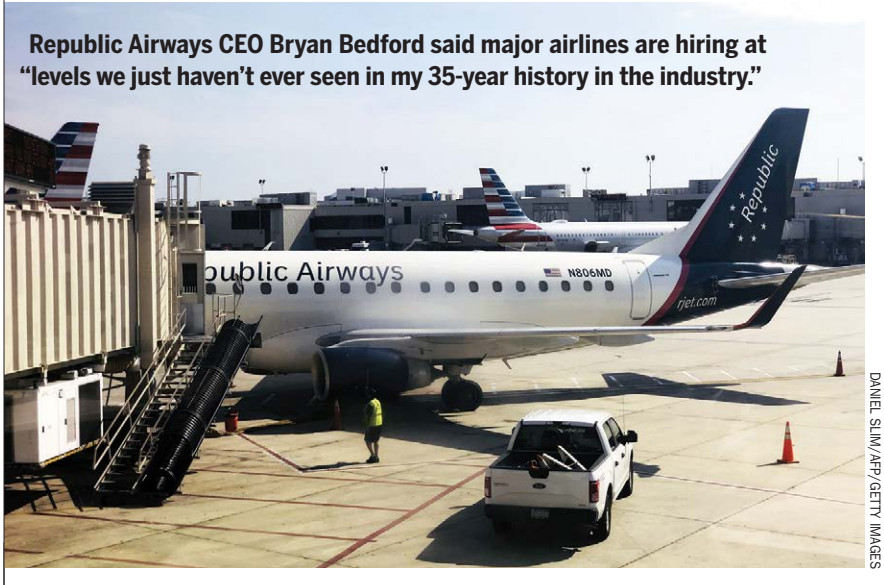
An untimely coincidence, the delay illustrates the biggest problem the U.S. regional airline industry says it is facing: a shortage of pilots. The topic was discussed intensely later that morning at the Regional Airline Association Leaders Conference in Washington.

"We're hiring and the industry is growing even faster," Republic CEO Bryan Bedford said at the conference. Contending with the workforce constraint as a regional airline is nothing new, he told Aviation Week Network's Window Seat Podcast at the event, but it has been compounded by recently accelerated hiring. "The biggest change that we've seen in the last 18 months as we've been recovering from COVID is that the major airlines are hiring at unprecedented levels," Bedford said. "I mean levels we just haven't ever seen in my 35-year history in the industry."

By 2032, the North American industry is expected be short 13,305 pilots, according to an updated forecast from consultancy Oliver Wyman, down 23% from its previous expectations of 17,286. Were pre-pandemic levels of activity from regional airlines factored in, the number would be higher. "You could also think about this shortage as being 19,000 pilots, if the regional industry was back where it was at the beginning of 2020," Oliver Wyman partner Geoff Murray said.

In its update, the consultancy cites lower demand—with about three-quarters of the difference purely associated with the regionals—as well as a smaller post-pandemic fleet due to OEM production delays moderating long-term growth and modest increases in pilot supply. It says enrollments at many flight schools are "up materially." The report also points to recent pay raises as "influencing the supply element of the equation."

"In the regional space, we've seen that pay go up by 86%," Murray said. "It's up around 46% from a mainline basis. This is important because individuals pay attention to this."



Republic Airways CEO Bryan Bedford said major airlines are hiring at "levels we just haven't ever seen in my 35-year history in the industry."

DANIEL SLIM/AFP/GETTY IMAGES

As industry has climbed up and away from pandemic lows, regional airlines were among the first to recover, as they were well suited for the initial demand pockets, said Raymond James analyst Savanthi Syth—until a captain shortage "turned that on its head." In examining performance now, "we're a lot more positive on the regional space," she said at the Leaders Conference. "It's going to take a while, but there are definitely airlines that are doing creative things to come out of this." Something that portends well for both regionals and mainlines, she noted, is partnership.

"The enlightened mainline realizes that they have to support the regionals," Syth said. "The airlines that really work in partnership are the ones that succeed more."

Quantifying those effects were numbers pulled from the September quarter by Deutsche Bank analyst Michael Linenberg. Examining what regional airlines contributed to the Big Three U.S. airlines, he found that they represented "40% of flights, 20% of seats and 10-11% of [available seat miles]." The numbers, Linenberg said, make a strong case for that kind of partnership, describing the difference between success and failure as being about 3-4 load factor points.

"I remember asking American [Airlines] this question a few years back: How much of your load factor is derived from regional feed? And they were about 10-12 points, and then [for] some of the international flights it was about 15 percentage points of load factor," Linenberg said. "If you're getting 10-15 points from your regional partner, you certainly don't want to poison the well or destabilize that relationship. . . . It's a symbiotic relationship. You'll thrive if your regional partners thrive."

Another challenge faced by regionals is fleet replacements. Unlike their mainline counterparts, regional airlines have limited choices in new aircraft due to a lack of options in the 50-seat category and scope-clause considerations with higher-capacity models. While both traditional and startups explore new technologies that are likely to emerge in the regional market first, including hydrogen and electric propulsion, Embraer and ATR

contend that sustainable options for the market are already available—albeit constrained by various factors.

"We have solutions today," Nigel Patterson, vice president for sales and marketing at Embraer Commercial Aviation in North America, said at the Leaders Conference. "For example, we have the [E175-E2]. Unfortunately, with the scope clauses and because it's a heavier aircraft, we can't put it into service. But that aircraft today can deliver real savings, much better than we have with the [E175-E1]. We have aircraft that are available today to deliver real-life economics and better options for the environment."

Patterson described Embraer as pragmatic and realistic about timelines and technologies. For its Energia family concept, with 9-50 seats, the Brazilian manufacturer is examining a variety of options and working with an advisory group, which most recently expanded to include American Airlines. "We're not focused on any one technology going forward," he said. "We're looking at hybrid. We're looking at fully electric, we're looking at hydrogen. . . . As these technologies mature and get better, we see a pathway for us to deliver to our customers the regional aircraft flyers that are here today."

Also characterizing itself as taking a "realistic approach" to future technologies is airframer ATR, which aims to have its EVO family enter service by 2030. The aircraft are expected to offer 20% lower fuel burn and 100% compatibility with sustainable aviation fuel (SAF). Although turboprops have largely fallen out of favor in the

Large Aircraft Lessors Expect Fleets To Double in Coming Years

> AS AIRLINES CHASE CAPACITY, LESSORS ENJOY HIGHER RATES

> FEWER PLAYERS ARE CONTROLLING BIGGER FLEETS

Jens Flottau London

Wouldn't it be nice to own many aircraft and let them fly around the world without having to deal with airport and air traffic control delays, the operational nightmares of more demand than you can handle, pilot strikes or unruly passengers and problems such as faulty engine parts that ground some of your narrowbodies for the next six months for inspections and repairs?

Under such circumstances, a company could focus on reaping the benefits of the strong return of air travel demand and watch profits come back as part of the industry's COVID-19 recovery. Although it might sound unrealistic, those are basically the circumstances in which aircraft lessors are operating now.

It is no big surprise that most of the big leasing companies cannot believe their luck—and have little reason to expect that anything will change to cause them any major concern about the future of their businesses. It is true that interest rates have jumped in a short period of time, but they also may be close to their peaks. Sure, aircraft delivery delays are affecting not just airlines but also lessors. However, there is another way to access increased capacity: buy portfolios or finance aircraft through sale-and-lease-back transactions. It is only when airlines get in serious financial trouble that lessors become nervous, but so far their customers have been scraping by.

"I don't think anyone has ever seen a recovery in lease rentals or market values as strong as we've seen over the past 18 months," Avolon CEO Andy Cronin said on the sidelines of the International Society of Transport Aircraft Trading (ISTAT) Europe, Middle East and Africa conference here. "Airlines are day by day increasing the price they're prepared to pay to secure lift. Based on appraiser data, narrowbodies are now 25-30% above their pre-COVID level."

Cronin's lessor colleagues at ISTAT could not agree more. "We are enjoying an enormous lift in lease rates," Dubai Aerospace Enterprise (DAE) CEO Firoz Tarapore said. "Real lease rates are jumping significantly and continue to do so" with the imbalance of demand and supply here to stay, Aviation Capital Group CEO Thomas Baker said. "We see lease rates accelerating. Demand is really going through the roof," Air Lease Corp. (ALC) CEO John Plueger added. The increases are great enough to compensate for the higher interest rates that will make borrowing more expensive for them, lessors predict.

The lease rate hikes are not only for new deliveries coming through the orderbooks of major players such as Avolon, AerCap and ALC. Rates for older leased aircraft have risen, too, but most airlines are eager to extend leases on older aircraft they already operate nonetheless. As some carriers have seen, if they are not quick enough to renew, lessors may place aircraft elsewhere at better terms—leaving the carriers struggling to find capacity.

"Everybody is extending leases," Plueger said. "I can count on one hand the number of leases that are not extended."

The business models of most lessors are not just limited to leasing. Many also are very active aircraft traders, constantly adjusting their portfolios to increase or decrease exposure to certain aircraft types or geographies.

Much of that trading was put on hold during the pandemic, simply because there were far fewer buyers, leading to depressed values. Those that could afford to hold onto their fleets—which was true for the vast majority of the

U.S., ATR still sees potential for its current offerings on a replacement wave in the regional market.

"We don't need to wait 10-15 years for new technology, with 45% less CO_2 emissions on our aircraft," Zuzana Hrnkova, ATR vice president for marketing, said at the conference. "Already today we have 50% SAF capability. Some operators in Europe are already using this capability for their operations. . . . [Our target is] to have 100% SAF capability in two years' time. We can act now; we don't need to wait."

ATR says it is also making inroads in the Japanese market, which it describes as having had a similar resistance to turboprops. "The U.S. was the country where we have observed the most important impact of the 'jet mania' for the past 20 years," Hrnkova said. "We have also faced a similar phenomenon in other regions, like in Japan. . . . We understood that there were some misunderstandings on the technology." But she said a concerted effort in cooperation with airlines to educate the traveling public about the technology and benefits of turboprops is paying off.

"Now we have 200 operators around the world. In Japan, we have 20 aircraft flying around, and the airlines are ordering every year. There is a huge potential to raise that number to 100," Hrnkova said. "So passenger perception is something we can overcome."

Window Seat *Republic Airways' Bryan Bedford and Aviation Week's Karen Walker discuss challenges facing U.S. regionals:* **AviationWeek.com/Window-Seat**

Airlines are scrambling to find enough aircraft, so lessors are enjoying a steep hike in lease rates.

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larger lessors—did so. Now the situation has changed once again.

"We have really enhanced our aircraft sales," Plueger said. "We hit pause during the pandemic. Now we are selling more than we ever have. A bit of making up for lost time, but we are achieving gains we are happy with."

ALC is not the only lessor selling aircraft. Avolon sold 14 in the third quarter and has agreed to sell 15 more. DAE bought seven aircraft but sold 16 in the first half.

"The market is a bit different at the moment," Cronin said. "You've got this raw demand from airlines, and they are providing quite a convincing bid to own aircraft, to buy them outright now as well."

While there are always new entrants—few of them as financially powerful as AviLease, Saudi Arabia's new venture—the delivery stream of new aircraft into the lessor channel is more focused on big players than it used to be several years ago. And with the planned production increases at Boeing and Airbus between now and the second half of the decade, the top lessors are likely to be able to grow their fleets faster than the rest of the industry. "All large lessors will double their fleets over the coming years," Orix Aviation CEO James Meyler predicted.

The growth is expected to come through direct orders and sale-and-leaseback deals financing orders placed by the airlines themselves. The barriers to entry are also "higher than five years ago, [as] the size to be relevant is bigger," Cronin noted.

In his view, the concentration is not a coincidence. "I think it's a strategy from the manufacturers. Last time around, there were people printing business cards, creating a [special-purpose company] and going to place an order," Cronin said. "That's not happening now because the manufacturers have been more thoughtful. They've seen what happens when you've got too many irrational players, destroying the market. They want five, six or seven large-scale lessor partners who will behave rationally rather than having 25 lessor orders on the orderbook program."

It is no surprise, then, that those with large orderbooks are more confident than ever. "I have never felt better about an orderbook," Plueger said. "I feel excited about the organic growth ahead," Cronin added.

Both ALC and Avolon have more than 300 aircraft on firm order. DAE, a lessor that has not had an orderbook with manufacturers before, recently acquired a 64-unit Boeing 737 MAX yet-to-be-delivered portfolio from China Aircraft Leasing Group for delivery in 2023-26 and is looking for more direct orders, prices permitting.

While the performance of low-cost carriers in the U.S. and Europe shows some signs of weakness (see page 38), lessors agree that demand will stay strong for the foreseeable future, both from airline passengers and in terms of

aircraft capacity. For lessors as for their airline customers, "the biggest concern is how many aircraft you have to park," Plueger said, referring to Pratt & Whitney's PW1100G inspection and repair program (*AW&ST* Sept. 18-Oct. 1, p. 18).

Baker warned that smaller airlines may not be able to sustain the damage inflicted on them by the delays and groundings. "This becomes a credit issue for smaller carriers," he said—and as a consequence lessors would also have to deal with the fallout. Indian low-cost carrier Go First blamed Pratt for its insolvency as it was forced to ground a large part of its Airbus A320neo fleet because of the persistent reliability issues. However, the airline has had financial issues for some time unrelated to the Pratt engines.

In one regard, airlines and lessors are in the same boat. They are competing for scarce aircraft coming off the Airbus and Boeing production lines and the even scarcer engines to power them. Because of the engine and other supplier constraints, Plueger forecasts that Boeing and Airbus production ramp-ups will be "slower than expected." ALC has had "routine creeping delays at Airbus, less so at Boeing," he noted. "We have been told to expect more delays in 2024.

In particular, Plueger expects that the additional large-scale engine inspections and repairs of powder metal contamination in the PW1100G program will "take even more engines out of the delivery supply chain to Airbus than what we know today."

With engines in such short supply and nearly 600 aircraft expected to be grounded in the first half of 2024, Pratt will have to decide who will get the few new engines that will be available. "There is a tremendous amount of very active dialog between Airbus and [Pratt] these days," Plueger said. In his view, the engine-maker is now stepping up to face the issues.

Conflicts among airlines, lessors and OEMs are all but certain. Nonetheless, Plueger said, "What are you going to do when you are Pratt and you [have] big airline CEOs screaming at you for engines for aircraft that are currently parked or that you know will be parked? . . . We all say: Give it to us and forget these other smaller airlines. Look who is your biggest mouth-feeder."

The big lessors clearly propose that it is them.

Despite its lowered third-quarter guidance, Frontier remains bullish in its outlook.

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U.S. ULCCs Battle Financial Headwinds as Legacies See Upside

> ULTRA-LOW-COST OPERATORS ARE FACING A NEGATIVE THIRD-QUARTER MARGIN PERFORMANCE

> LEGACY AIRLINES ARE FORECASTING POSITIVE MARGINS

Christine Boynton Boston and **Lori Ranson** Washington

U.S. legacy airlines are enjoying a financial upswing while their ultra-low-cost peers are battling margin pressure. It is a role reversal from the recent past, and begs the question of whether the switch is a fleeting trend or a permanent shift in market dynamics.

Ultra-low-cost carriers (ULCC) Frontier Airlines and Spirit Airlines recently lowered their margin expectations for the third quarter. Frontier's third-quarter margin guidance flipped. The ULCC initially estimated a positive range of 4-7%, but lowered its adjusted pretax margin for the third quarter to between -4 and -7%. Spirit now expects an adjusted operating margin between -14.5 and -15.5% compared with previous expectations of in the range of -5.5 to -7.5%.

Both airlines described sales trending below historical seasonality patterns and heightened promotional activity with steep discounting. Legacy carriers that also adjusted guidance mainly raised expected fuel costs while their margins remained positive.

United Airlines' previous guidance projecting revenue growth of 10-13% year over year remains intact, while Delta Air Lines refined its operating margin guidance from the midteens to 13%, and American Airlines revised its adjusted operating margin expectations from 8-10% to 4-5%.

"You've got fuel, capacity and demand all heading in the wrong direction," Frontier CEO Barry Biffle said Sept. 13 at the Morgan Stanley Laguna Conference. The carrier adjusted its capacity guidance for the third quarter to 20-21% growth year over year from an increase of 21-23%.

Delta President Glen Hauenstein said at the conference that the company was surprised to see the demand commentary from other U.S. airlines. He added that budget airlines tended to be some of the fastest growing airlines, "so maybe they're a little bit over their skis in terms of allowing the demand sets to catch up."

The shift in legacy airline and ULCC performance is a "fundamental change," Michael Leskinen, United chief financial officer and executive vice president, said at the Laguna Conference. He attributed the airline's performance to a focus on areas of competitive advantage, including segmenting the cabin and driving costs down by focusing on hub connectivity and upgauging aircraft rather than adding frequencies, while "not trying to add new points to the map."

He also pointed to shared constraints. "Air traffic control is going to be a constraint, OEMs are going to be a constraint, pilots are going to be a constraint," Leskinen said. "There are all these constraints that the whole industry faces. Those have all contributed to this flipping of the industry dynamic around margin."

The constraints are something United CEO Scott Kirby has previously described as contributing to a "cost convergence," narrowing a gap between low-cost and legacy airlines. "Historically, before 2020, everyone could grow as much as they wanted

with no constraints," Kirby said at the JP Morgan Industrials Conference in March. "There are now constraints. Your models need to include the constraints. And that's not something people in the airline [industry] have ever done."

Pre-pandemic, "ULCCs would trade at two times the multiple of the legacy carriers," Leskinen noted. Today's now familiar challenges are contributing, he said, to a "complete inversion of the industry structure" around margins.

All of this comes against the backdrop of an uncertain economy, rising costs of living and shifts away from flexible virtual work arrangements, factors which recent analysis from TD Cowen noted has likely contributed to the "more dire warnings" from the ULCCs with their "outsized exposure" to more price-sensitive customers.

"We think those consumers are being affected by higher food and energy prices, as well as by higher rent expenses, looming increases in childcare costs and the resumption of student loan repayments," TD Cowen analyst Helane Becker wrote in her Sept. 15 Takeoffs and Landings report. "Add to this more employers requiring workers to return to the office as many as four or five days a week, and you get a decline in travel."

The question is whether this will precipitate a long-term shift for ULCCs accustomed to aggressive growth while taking advantage of high costs faced by larger mainline carriers, or an anomaly following a challenging couple of years with post-pandemic preferences trending toward premium experiences. Analysis by the Swelbar-Zhong Consultancy proposes that change is—and was already—in the wind.

"For some time, we have suggested that a reversal in fortunes was underway," writes the consultancy in a Sept. 15 update. "Leading up to and through the pandemic, the best profit margins would be found within the ULCC group. As the international markets opened, it is the Big Three network carriers that are reporting, and will continue to report, the better profit margins. Our eyes are all on carrier financial performance as capacity growth for many airlines is exceeding their ability to fill those seats without price discounting."

Frontier remains bullish in its outlook. In addition to focusing on out-and-back flying and doubling down on costs, the airline plans to push to grow subscription loyalty businesses such as its credit card, as well as high-margin ancillary offerings. "You can buy a [mini drink] for $0.50 and sell it for $7," Biffle told investors at the Laguna Conference. "You don't have any kind of margin on a bag or a seat like that, right? So we're looking at the products that you can get high margin on."

Amid the current headwinds, Frontier sees opportunity, contesting any long-term implications. "We've seen this movie before," Biffle said, noting a focus on simplifying the business and doubling down on costs. "Our business models aren't broken. This time isn't different, and the world is not flat. The lowest cost will win, and we're doubling down on it."

ITP AERO PHOTOS

ITP Unveils Ambitious Expansion Goals, Including AAM and MRO Sectors

> NEW CIVIL AND MILITARY ENGINE PARTNERSHIPS EXPECTED

> CIVIL AFTERMARKET GROWTH IS IN ITP AERO'S SIGHTS

Guy Norris Bilbao, Spain

ITP Aero, a Spanish Tier 1 propulsion provider that was until a year ago part of Rolls-Royce, is gearing up for significant growth.

Separated from its UK parent, the Basque-region company is on the hunt for new partnerships, engine programs and commercial maintenance, repair and overhaul (MRO) business as part of ambitious plans to expand its commercial portfolio.

"Rolls remains a key customer for us and very important, but for us the fact we are independent gives us the opportunity to pursue further growth with the other original equipment makers [OEM]," says Mikel Lantero, executive director of ITP Aero's civil business unit. "Maybe in the past it was a limitation being owned by one of the competitors, so we think the fact we are now independent gives us a better chance of increasing collaboration with Pratt & Whitney and GE Aerospace and others."

ITP Aero's entry into the commercial engine world started 30 years ago with the low-pressure (LP) turbine for the Rolls-Royce Trent 700. Since then, its expertise, experience, and know-how have grown to encompass engine parts and systems from the fan module to the turbine rear frame and many parts in between. The company also supplies combustors for business jet and military engines, as well as engine external systems—much of which are made at its facility in Queretaro, Mexico.

"Now we have capabilities across the entire engine, and we have tried to combine this with diversification with customers as well," Lantero says. Partnerships were forged with

ITP's growth plan is mostly focused on its large engines, including the Rolls-Royce Trent XWB.

GE on industrial turbines and with Honeywell on LP turbines for the HTF7000 engine family. In 2012, having already partnered with Pratt & Whitney Canada on the PW800, ITP also joined Pratt's PW1000G geared turbofan (GTF) program on compressor elements.

ITP Aero is on a growth path for two reasons, Lantero says. "First, our products—such as the GTF, PW800 and Trent XWB—are all young programs at the start of their lives and growing very fast. Then second, we are actively looking for new growth opportunities. We are already in discussions with the different OEMs to increase collaboration," he says.

Sustainability is also a key driver for the company, says Lantero. "For us, whether you're talking about the industry as a whole or the planet in general, sustainability is vital—so we are investing in new technologies such as the UltraFan," he adds, referring to the ultra-high-bypass engine recently developed by Rolls-Royce. ITP was responsible for the design of the intermediate-pressure turbine

that has been running in the demonstrator engine since April.

Although the UltraFan has yet to secure a launch application, ITP—like Rolls-Royce—expects that the engine's higher efficiency will win its way onto a program in due course. "For us, that's a technology path we are growing. So more efficient engines, probably in combination with sustainable aviation fuels—we are working those in line with the whole industry," Lantero adds.

The company's expansion push also comes amid a wave of new technology development programs supported with investment from the Spanish government—all with direct and indirect relevance for its future civil propulsion vision. ITP has started work on all-electric propulsion technology for the urban and regional air mobility markets under two newly announced national research programs. "These are what I call game-changer technologies," says Lantero. "We are investing around €25 million ($26.4 million) in both of them."

Between the two programs, ITP and its partners will cover the 60-600-kW power range with five demonstrators, says Erlantz Cristobal, ITP's executive director of engineering and technology. Tests are expected to run through 2026-27 and culminate in the development of integrated electric propulsion systems to a preproduction technology readiness level 6.

"We believe that the urban and regional mobility sector is going to be a growth market for the next decade, and we need to prepare ourselves," Cristobal says. The initial target is all-electric, "but we can hybridize later as necessary," Cristobal adds.

Involving Spanish industrial and academic partners, the Aperturas program includes the design and development of two demonstrator vehicles with different power levels: the smaller one for typical urban air mobility applications and the larger targeted at regional projects. The project is funded by the Spanish Center for Technological Development and Innovation under the Spanish Ministry of Science and Innovation through the national Aeronautical Technology Program (ATP).

The Preludio program, which is subsidized by a Basque government business R&D support initiative, is aimed at the design and development of a scalable and certifiable electric propulsion system usable at higher altitudes.

ITP Aero is also leading a national consortium targeting testing and development of the first hydrogen-powered commercial aircraft engine developed in-country under the €12 million Cryogenics, Fuel Cells and Hydrogen Combustion in Air Transport project. Cosponsored by European Union Next Generation strategic investment funding, the project forms part of the ATP.

The consortium includes hydrogen-powered high-speed aircraft developer Destinus, fuel cell specialist Ajusa, and aerospace systems and structures company Aerotecnic. The consortium is also supported by a network of Spanish technology centers and universities, including the country's National Hydrogen Center and the National Institute for Aerospace Technology (INTA).

ITP aims to expand its long-running defense and regional MRO work into the commercial market.

A crucial target of the project is the production of a sophisticated open-air test bench facility at INTA's Torrejon de Ardoz facility near Madrid. Design of the test site is underway, with construction expected to begin in 2024. Initial tests on the site will begin in 2025 using a Eurojet EJ200 modified for hydrogen combustion—representing the first time a modern combat engine has been tested with the fuel.

"Hydrogen needs transformational action—not only the technology involved at a system level but also from an infrastructure perspective, so that's why it is a longer-term option," Lantero says. "But we need to start somewhere, and so part of this new program is focused on how to transition from liquid to gas stages and how to use heat exchangers. That's one of the areas we are focusing on."

The company is also playing a key role in developing a new military engine for the European Future Combat Air System (FCAS). To support the effort, it is investing in a new research and development facility at its Zamudio headquarters. "FCAS is very important from a technology point of view for the future," Lantero says. "ITP is responsible for the low-pressure turbine as well as the exhaust system and heat exchangers. These will be important technology drivers for dual-use applications which will read across to the civil market."

ITP also has ambitions to grow its MRO business. Although its Ajalvir, Madrid and Malta facilities already provide MRO services for regional, business and defense markets covering engines ranging from GE CT7s and F414s to PW500s and EJ200s, ITP is eager to grow into the commercial sector. "It isn't an area where we are currently playing at any scale, so it's a market we are considering growing into," Lantero says. "Flight hours are growing, so we are looking to position ourselves for the future, particularly at our Madrid site, where we have a lot of capability and expertise and many years of operations."

"We just want to do more—it's part of the ITP DNA," Lantero says.

UH2 Hydrogen-Electric Dash 8 Flight Tests Move to Phase 2

> PHASE MOTION CONTROL IS DEVELOPING PRODUCTION MOTORS

> SUPPLEMENTAL TYPE CERTIFICATE PROCESS IS UNDERWAY

Guy Norris Mojave, California

Backlit by the rising Sun for its dawn takeoff, Universal Hydrogen's De Havilland Canada Dash 8-300 hydrogen-electric demonstrator seemed to be kicking up dust as it accelerated down Runway 30 at the Mojave Air & Space Port.

But while dust is hardly surprising at a desert runway, the faint swirls in the morning light here were made up of water vapor—the only emission and visible exhaust from the hydrogen fuel-cell propulsion system mounted in place of the standard Pratt & Whitney PW123 turboprop on the Dash 8's right wing.

Developed by startup zero-emission-propulsion developer Universal Hydrogen (UH2), the 1-megawatt hydrogen-electric propulsion system is designed to pave the way for a 2-megawatt hydrogen-electric powertrain. The system is intended to replace the PW127-series turboprops powering the ATR 72 regional airliner and has to date attracted about 250 conversion orders.

For Phase 1, the Dash 8 has been undergoing maturation tests since its first flight at Moses Lake, Washington, in March. The switch to the second phase—which came with its 10th flight on Sept. 26—was marked by tests of new powertrain control software. It was "the inaugural flight of our flight-test campaign, where we start upgrading parts of the powertrain to ultimately morph it into the final product," UH2 CEO Paul Eremenko says.

The powertrain air-cooling system has performed better than expected, UH2 says.

"From here on out, we have a pretty aggressive agenda," he adds. "The next big thing is we're upgrading the turbo-compressor." The new device, custom-made for UH2 by Connecticut-based R&D Dynamics, will replace two smaller existing turbo-compressors and pump a higher volume of air through the heat exchanger. The bigger unit is designed to produce a 5:1 pressure ratio compared with 3:1 for the current devices, extending the flight envelope from the current limit of 10,000 ft.

The second flight-test phase "comprises a lot of technology maturation, data collection and envelope expansion, where we're targeting 25,000 ft. with some hardware and software upgrades," UH2 Chief Test Pilot Alex Kroll says.

"We've taken delivery of the turbo-compressor hardware at our Hawthorne, California, headquarters, and we're integrating it first onto the iron bird. After ground testing, it will go into the airplane," Eremenko says.

Beyond this, the next major milestone is targeted for mid-2024, when the Dash 8 is expected to begin flight tests with UH2's custom-designed liquid-hydrogen modules in place of the current gaseous-hydrogen tanks.

"Our major modification is going to be the liquid-hydrogen storage modules, which will increase the range performance and endurance of the aircraft, and we're targeting the next year approximately to accomplish all those objectives," Kroll notes.

Development of the liquid-hydrogen module, which is palletized for loading on and off the aircraft, is underway at the company's Toulouse facility, where an engineless ATR 72 is being used for systems and fit checks. "The teams are running in parallel for speed, so we intentionally decoupled them," Eremenko says. "Then we bring the two streams together in the middle of next year when we fly our powertrain with our module here in Mojave."

Development of the module itself is "in good shape," he adds. "We have demonstrated we've met our target of thermal flux and exceeded it. The test house we use in Germany that does all the liquid-hydrogen work in Europe, mostly for automotive stuff, said that it's the best in class, and they have

The new flight-test phase will incorporate an upgraded turbo-compressor to allow envelope expansion up to altitudes of 25,000 ft.

MATT HARTMAN PHOTOS

never seen a thermal flux that low." The dual-wall, insulated dewar-style tank design is also meeting pressurization targets, Eremenko says. "It's not a very high pressure, but it does have to confine the boil-off to our design target of 100 hr., or four days."

Two modules, each containing 180 kg (397 lb.) of liquid hydrogen, will be installed in the aircraft. The entire system will also be ground-tested using the iron bird rig prior to flight tests. "That will be by the end of this year. So that's what we're working on right now," Eremenko says.

Although initial tests have shown that performance data matches the prediction "surprisingly well," he adds that the current microtube radiator design—located in the distinctive side-mounted scoop inlets—provides more cooling capacity than required. "It is a good problem to have, but we actually had to put some speed tape over a portion of that radiator to cover up part of it," Eremenko explains. "Now, there'll be some degradation with bugs and debris and things like that over its life, but in general, the performance has met the modeled expectations."

Flight tests so far show the powertrain is "behaving as expected," notes Loris Gliner, director of powertrain engineering and flight testing at UH2. "We also validated our buffer-free battery architecture," she adds. "We really do believe that the direct-fuel-cell-to-electric motor is the way to go for aerospace applications. Designing the radiator and heat rejection system is probably the single hardest technical challenge with a fuel-cell powertrain, so it's been nice to validate our models."

Design work for a production electric motor for the ATR 72 is also underway with Genoa, Italy-based Phase Motion Control. Similar to the MagniX 560-640-kW Magni650 electric propulsion unit used in the Dash 8 testbed, the Phase-developed motor will be direct drive. "We thought it was impossible for a while, and they convinced us that it was possible, and so we're all in on the direct drive now," Eremenko says. "When you go up in power, typically you go up in rpm, and then you need reduction gear, and they have some clever approaches for doing a much bigger-motor direct drive.

"The relationship has gone well," he continues. "We've gone through a couple of design reviews and iterations, but I think we have a product architecture, and it's off to the races." He adds that the initial motor is due to be tested on the iron bird at Hawthorne in 2024. The MagniX motor directly drives a 91-in. Hartzell propeller on the testbed, but the larger Phase unit is slated to enable flight tests with a standard PW123-size propeller.

The transition to the active flight-test campaign comes just weeks after the FAA accepted the company's application for supplemental type certification (STC) of the retrofit. Marking a step toward establishing the certification basis, the move represents a first in the industry for hydrogen-electric propulsion and could help set the standard for future certification programs.

"It's a precedent, and it means there is alignment within the regulatory community on what the concerns are with hydrogen that are different to jet fuel," Eremenko says. "So we're there in terms of the regulators being comfortable with understanding hydrogen and all of the issues that are involved for us and for others in the nascent hydrogen aviation world."

The release of the FAA Stage 2 G-1 issue paper establishes the regulator's position on certifying the modified ATR 72 under Part 25 transport category airworthiness regulations. UH2 is now preparing to respond with Stage 3, which proposes special conditions, and to establish its position as the applicant for certification. This will lead to a final Stage 4 G-1 that establishes the certification basis, including any special conditions.

"We now understand in a much more fine-grained way what the flight-test campaign is going to look like to actually get to the STC in the end," Eremenko says. "And so our current best estimate [for gaining certification] is probably 2026. We've previously sometimes said 2025, sometimes 2026, but the error bars have significantly shrunk."

CHINA OUTLOOK > Exclusive survey results show Western suppliers diversifying away from China **p. 46**

SEPARATION

- **AEROSPACE AND DEFENSE COMPANIES GRAPPLE WITH U.S.-CHINA TENSIONS**
- **EUROPEAN COMPANIES CAN SEPARATE POLITICS FROM ECONOMICS MORE EASILY THAN U.S. ONES**
- **EFFECTS OF CHINA'S RARE-EARTH EXPORT RESTRICTIONS WILL NOT BE DRAMATIC AT FIRST**

Matthew Fulco Washington

RTX CEO GREG HAYES RAISED EYEBROWS in June when he told the *Financial Times* that "decoupling [from China] is impossible," given his company's several thousand suppliers in the country.

While Hayes did say that it was possible to "de-risk" from China, the difference between the two terms can be lost on many observers—including Beijing. In an Aug. 4 commentary, Chinese Communist Party-owned newspaper the *Global Times* contended that "from decoupling to de-risking, there has been no change to the U.S. moves of sanctioning Chinese companies, causing disruption in global supply chains."

"To shut out China in the name of de-risking is to throw away opportunities, cooperation, stability and development," a government spokesperson was quoted as saying in *The South China Morning Post* on Sept. 30.

RTX's relationship with China well encapsulates the increasingly fine line that aerospace and defense companies must walk. Because Raytheon is a key arms supplier to Taiwan, RTX—including Hayes himself—has been sanctioned by China several times in recent years. In September 2022, China announced unspecified sanctions on the RTX chief executive as well as Boeing Defense, Space and Security CEO Ted Colbert.

Yet China did not attempt to sanction the commercial divisions of RTX and Boeing—and it has not done so to date. If China did turn the screws on large U.S. aerospace suppliers, "they would penalize their own civil aviation industry," given its dependence on foreign components, Richard Aboulafia, managing director of consultancy AeroDynamic Advisory, tells Aviation Week.

A December 2020 analysis by the Center for Strategic and International Studies in Washington found that U.S. companies account for almost 60% of the Comac C919 narrowbody's top suppliers. Almost 32% are European. Only 14 key suppliers are from China, seven of which are Chinese-foreign joint ventures.

Even if such a move seems unlikely for now, Beijing is still trying to leverage its massive market, the world's second-largest for commercial aviation, to pursue its geopolitical interests. Boeing can attest to that: It has not received a large aircraft order for China since 2017, the year before the U.S.-China trade war began. "That's China in a nutshell," Aboulafia says.

FREDERIC LANCELOT/AIRBUS

Given the tension fomented by U.S.-China decoupling as well as China's slowing economic growth and increasingly unpredictable regulatory environment, "if you had to put a new [aerospace] investment in Asia now, you might put it in India or Southeast Asia, but not in China," Joshua Ng, Singapore-based managing director of Alton Aviation Consultancy, tells Aviation Week.

However, foreign aerospace companies that already have a large presence in China might add to their existing investments. "It depends on risk appetite," he says.

For its part, Airbus seems unworried about risk in China. In April, the European aerospace giant announced that it would add a second final assembly line to its plant in Tianjin, which has been in operation since 2008, doubling capacity there. Airbus made the

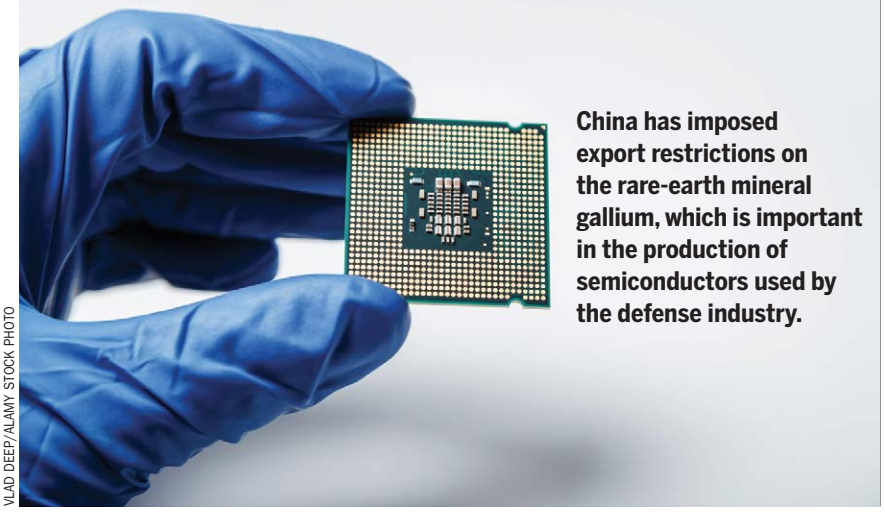
Read all the articles in our series on the future of Chinese aerospace and aviation

Oct. 2-15: Airlines, aircraft leasing and manufacturing, and the advanced air mobility market.
This issue: The supply chain. **Oct. 30-Nov. 12:** Military platforms.

ANXIETY

announcement during the state visit of French President Emmanuel Macron to China, whose delegation included Airbus CEO Guillaume Faury.

The Airbus CEO lauded China's business environment. "What always strikes me in China is the energy, the speed, the optimism and the ability to go fast," Chinese state media quoted him as saying.



VLAD DEEP/ALAMY STOCK PHOTO

China has imposed export restrictions on the rare-earth mineral gallium, which is important in the production of semiconductors used by the defense industry.

Airbus made its commitment to the China market—and by extension its aversion to decoupling—evident and underscored a chasm between Washington and Brussels on how to deal with Beijing.

"Airbus is happy with this situation because it's no longer 50-50 in terms of market share—they are very much ahead of Boeing in China," Shukor Yusof, Malaysia-based founder of the Endau Analytics consultancy, tells Aviation Week. Given the European company's growing advantage, it "would not want to appear disagreeable to the way China is behaving"—and possibly jeopardize its market position.

When this Airbus A350-900 for China Southern Airlines was on the final assembly line in Toulouse in 2019, industry still expected to enjoy big growth in China.

Noting that Rolls-Royce and Air China broke ground on a maintenance, repair and overhaul joint venture near Beijing Capital International Airport in August—a deal that was announced a year ago—Yusof says: "The Europeans are very happy to divide the politics and economics of it. Jobs are very important to the UK, France and Germany."

For U.S. companies, however, there is no escaping the geopolitical rivalry between Washington and Beijing. That point was driven home on Aug. 1, when China began requiring export licenses for the rare-earth minerals gallium and germanium, both of which are critical to aerospace and defense manufacturing and both dominated by Beijing. China produces about 80% of the world's gallium and 60% of its germanium, according to the Critical Raw Materials Alliance, a European industry association.

China's commerce ministry on July 3 announced the restrictions on the raw materials, citing "national security interests" in a statement. Exporters of the rare-earth metals must apply for "special permission from the state" to ship them overseas, the statement says.

Only a few companies—most of them in China and Japan—can produce gallium at the required purity.

Gallium nitride (GaN) semiconductors, known for their superior switching speed and thermal conduc-

tivity, are used in active, electronically scanned array radars and electronic-warfare systems such as RTX's GhostEye product group, Northrop Grumman's TPY-5 and Lockheed Martin's Q-53. GaN also is used in European radars made by Leonardo, Saab and Thales. Germanium is used in semiconductors, infrared sensors and fiber-optic devices.

Because China has not formally banned exports of the rare-earth minerals, the effect of the restrictions will not be dramatic, "but they will spur more efforts to develop alternative sources of these metals," Capital Alpha Partners Managing Director Byron Callan writes in a July 4 research note. The note poses a provocative query: "Why would China continue to buy commercial products from companies if those companies use cash flow and technology to develop defense products aimed at deterring and defeating China's military?"

The answer could be that China has no choice—both because the aerospace and defense sector is highly consolidated and because Western companies control the highest-value parts of the supply chain. Indeed, although China has often been called "the world's factory," that description does not hold true for production of commercial or military aircraft.

Beijing does have control at the commodities level, but analysts do not expect its rare-earths gambit to bear fruit.

"They're doing a great job of putting the rest of the world on notice that it would be wise to cultivate second sources [of gallium and germanium]. Let's start a mine in Australia or Nevada," Aboulafia says.

To that end, Netherlands-based metals provider Nyrstar told Reuters in July that it was exploring germa-

How To Say Goodbye in Chinese: Western Industry Eyes the Exit

> SURVEY SHOWS WESTERN SUPPLIERS SHIFTING AWAY FROM CHINA

> MORE DOMESTIC COMPETITION, IP CHALLENGES AND LESS FROTH PUSH AWAY SUPPLIERS

Michael Bruno Washington

Businesses love few things as much as they love new markets to exploit. And for at least one generation of executives in the Western aerospace and defense manufacturing sector, China was the promised land.

The combination of serving the largest commercial aviation passenger marketplace by country, riding the rise of a new OEM in Comac and enjoying a so-called labor arbitrage of lower-cost factory workers seemed almost too good to be true. Apparently, it was.

Today's new realities of diverging national, economic and social interests seem to have turned around industry's outlook on China, according to the results of an Aviation Week and Bank of America survey. Escalating trade tensions between China and other countries, including the U.S., have forced many suppliers to diversify their supply chains away from China in recent years.

Poll results from the spring survey indicated the majority of respondents (58%) are diversifying away from China, and many (51%) anticipate reshoring operations or suppliers to the U.S. "I think if you asked that question three or four years ago, [the percentage] wouldn't have been quite as big," Bank of America analyst Ron Epstein tells Aviation Week.

To be sure, survey respondents did not foresee the end of work and revenue in China, just the sobering of marketwide expectations. The now-certified Comac C919 uses parts extensively from Western suppliers, and many still see market growth ahead—just not for them.

"It is striking that 79% of respondents do not see an opportunity for growth in Chinese OEM programs," Epstein's team writes in their report. "However, for those that do see a growth opportunity in China, 72% believe Chinese OEM programs will experience growth in the latter half of this decade."

Nonetheless, the narrative clearly is one of throttling back in China, albeit gradually. Many respondents see the process taking a long time to unwind their ties, with 43% expecting the process to take 6-18 months, 32% longer than 18 months and 27% expecting only six months needed.

That begs the next question: Where to next? The majority of those surveyed said they were expecting to reshore production or look to a U.S. supplier to fill the void. Meanwhile, 21% eyed other Asia-Pacific countries, and another 21% said they would look at places other than the Asia-Pacific or North America.

"We do find the 21% to [Asia-Pacific] surprising given the increased manufacturing presences from larger OEMs in countries like India and Vietnam," Epstein's team writes.

The majority of survey respondents (59%) were based in the U.S. Those participating were primarily (51%) lower-tier suppliers at companies with annual revenues of less than $25 million.

Other financial analysts and industry consultants confirm the sentiment. At a recent subtier supply chain conference in the U.S., where comments were made under Chatham House rules, a panel of analysts was asked whether it was time to get out of China. They agreed that China will remain a meaningful market, but it was resetting lower in general—and more so for Americans.

"What you're going to see is clearly—and certainly from Boeing and out of the U.S. side—a disengagement of China as a supply base. That's going to accelerate," said one analyst who regularly surveys aerospace suppliers on his own. "Does that ultimately hurt Boeing in terms of its market share in China relative to Airbus, for instance? Possibly. But certainly you're going to see more capital moving out of China into countries like India or into other emerging markets where it makes sense.

"That's something the industry's going to have to really struggle with because I think we're in the very early innings of that migration," he added.

Still, the analysts on the panel, and

nium and gallium projects in Australia, Europe and the U.S. Nyrstar noted it was planning to expand operations at its Clarksville, Tennessee, zinc plant by adding a $90 million gallium and germanium processing facility that could provide up to 80% of U.S. needs for the critical metals.

On Sept. 21, China's commerce ministry said "a number of applications" to export gallium and germanium had been approved, without naming the companies that had received export licenses. "[The ministry] will continue to examine other export applications in accordance with required procedures and make licensing decisions," He Yadong, a ministry spokesperson, said at a press conference.

Data from China's General Administration of Customs shows that the country exported no gallium- or germanium-related items in August, but that exports surged in July ahead of the restrictions coming into effect.

Looking ahead, the extent to which aerospace and defense supply chains pivot away from China will be significantly affected by the ruling Communist Party's politics. To be sure, the party has long sought to turn China into an advanced manufacturing powerhouse and strengthen domestic supply chains. But under the nationalistic rule of Xi Jinping—which began in late 2012—China has begun to turn inward and reassert Communist Party control over the economy and society after several decades of uninterrupted opening.

Should Xi remain in power another decade—a strong possibility, provided he remains in good health—a gradual, partial separation of Western and Chinese aerospace and defense supply chains seems likely, although comprehensive decoupling does not.

Epstein separately, also are certain that Chinese companies and the country eventually will figure out how to make, support and sell large commercial aircraft of their own. "When you have an entire country throwing all the resources on it, it's a matter of time," another analyst said.

IMAGINECHINA LIMITED/ALAMY STOCK PHOTO

Industry once saw several benefits to being in China, including less expensive labor such as these workers making barcode scanners at a Honeywell plant in Suzhou in 2013.

The rise of China's domestic aerospace capability likely will crowd out Western suppliers. "China as a market, as it becomes less impactful maybe over the next five or 10 years—relative to where it was 10 years ago—you are much less likely to see the McDonnell Douglasses and the other investments [made] out of necessity to play in this market as you saw in the prior cycle," one analyst told the conference. "You will see a natural migration of suppliers and capabilities out of the country somewhat, just because [Western industry] doesn't have as much weight to throw around as it maybe did 10 years ago."

Last but not least, longstanding issues with doing business in China could serve as a further disincentive for Western companies. In a July report, advisors Alvarez & Marsal said recent events have highlighted the need for companies to reexamine supply chains and identify weaknesses.

"China's dominance in the industry's supply chain—from electronic components to raw materials—is just one of the risks for international aerospace and defense companies," they write. "Geopolitical uncertainty, the country's focus on investing in satellite technology and the difficulty companies have protecting intellectual property rights necessitate rigorous due diligence for aviation and defense companies investing in the Chinese market or relying on its supply chain capabilities."

There are also "black swan" events such as the COVID-19 pandemic, the war in Ukraine and even a much-discussed U.S.-China conflict over Taiwan. In turn, companies should run risk scenario planning that includes everything from mundane trade war effects to unexpected crises.

The Alvarez & Marsal consultancy is finding new business in industry's reexamination of China. They said they were advising a $2 billion-revenue, lower-tier raw material provider to aerospace and defense when Russia invaded Ukraine in February 2022. That and simmering U.S.-China concerns prompted a scope increase in their planning to include potential disruptions to rare-earth elements supply. The results were more predictable 13-week cash flow visibility and renegotiated customer contracts while maintaining program performance and throughput targets.

In another case, Alvarez & Marsal helped one $20 billion-revenue aerospace propulsion provider create a new operating model and cut costs in sales and operations planning, which allowed the unidentified company to cut 15% of its workforce and focus more on inventory delivery. "This allowed the client to proactively reduce risk from China's rising aerospace prowess and prepare for future competition," they said.

NASA Eyeing Joby eVTOL for Lunar Lander Trainer

> NASA IS CONSIDERING MOTION AND INFLIGHT LUNAR LANDER TRAINERS

> JOBY DELIVERS FIRST S4 TO EDWARDS AFB

JOBY AVIATION

Joby Experimental Test Pilot Zach Reeder conducted flight tests onboard the Joby aircraft in Marina, California.

Irene Klotz Cape Canaveral

When NASA awarded contracts to SpaceX and Blue Origin to fly astronauts between lunar orbit and the surface of the Moon, it decided to retain pilot landing flight-simulation training for itself.

One option would be to design and procure motion simulators and training aircraft, such as NASA did under the Apollo program, which landed six crews on the Moon from 1969 to 1972. To analyze and practice lunar landing techniques—the force of gravity on the Moon is one-sixth of Earth's—NASA purchased two Lunar Landing Research Vehicles (LLRV) and three follow-on Lunar Landing Training Vehicles (LLTV) from Bell Aerosystems for Apollo pilot training. (Parent company Bell Aircraft built the famed Bell X-1, which Chuck Yeager flew in 1947, becoming the first person to break the sound barrier.)

One LLRV and two LLTVs were destroyed in crashes, with the pilots safely ejecting. A 2005 NASA History Office monograph on the LLRV called them "unconventional, contrary and ugly." Apollo 8 astronaut Bill Anders wrote that they were "a much unsung hero of the Apollo Program."

For NASA to go that route today would be expensive and time-consuming. The first lunar landing under the Artemis program is targeted for late 2025 or 2026. NASA's proposed fiscal 2024 budget includes nearly $8 billion for deep space exploration, with $1.9 billion earmarked to support SpaceX's and Blue Origin's lunar landing systems development.

Another option comes from NASA's aeronautics portfolio. NASA has an interagency agreement with the Air Force Research Laboratory's AFWerx technology directorate to test Joby Aviation's S4 electric vertical-takeoff-and-landing (eVTOL) aircraft.

NASA/HUMAN LANDING SYSTEM PROGRAM

Everett Bolduc, co-chair of the NASA Human Landing System Manual Piloting Working Group, inside the Lunar Flight Deck Simulator at NASA Langley.

Joby delivered the first of nine eVTOLs under a $131 million AFWerx Agility Prime contract to Edwards AFB, California, on Sept. 25 (*AW&ST* Oct. 2-15, p. 56).

Initially, NASA's S4 testing is planned to focus on exploring ways to integrate air taxis and other new types of aircraft into the national airspace through its Advanced Air Mobility mission.

"Starting in 2024, NASA pilots and researchers will be working with the Joby aircraft to test how this type of aircraft could be integrated into a representative city environment," the agency stated in an email to Aviation Week.

Informally, the S4 may still loom large in NASA's Artemis program. In the summer of 2020, NASA's Human Landing System (HLS) program, headed by Lisa Watson-Morgan at Marshall Space Flight Center, formed a Joint Test Panel (JTP) to figure out how to train crews to return to the Moon safely.

NASA also solicited industry for potential motion simulators and inflight trainers that could be used to prepare Artemis astronauts to land multiple types of vehicles on the lunar surface. SpaceX is under contract to provide the first two Artemis Moon landings. The company is developing a version of its Starship spacecraft to land astronauts on the Moon and return them to awaiting NASA spacecraft in lunar orbit. Blue Origin was contracted for the third Artemis landing.

California-based Joby Aircraft was among the respondents to the request for information NASA issued in the summer of 2020. After collaborations with the Armstrong, Glenn, Langley, Johnson and Marshall field centers, the JTP in December 2020 recommended that NASA's HLS program track two platforms.

The U.S. Navy's GL-6000 disorientation research device—better known as "The Kraken"—located at the Naval Medical Research Unit's Capt. Ashton Graybiel Acceleration Research Facil-

ity at Wright-Patterson AFB, Ohio. The Kraken provides six degrees of freedom and up to 3g of force. The JTP plans to assess The Kraken as a motion-based simulator for lunar landings and make a recommendation to NASA's HLS program in mid-2024 on whether it provides the required motion control and simulation. Veteran astronaut Doug Wheelock, who co-chairs the JTP, kicked off Kraken testing in March, using visuals from the 1971 Apollo 15 approach.

"It was steeper [than previous approaches], coming in over the mountain range and landing just short of the canyon," Wheelock tells Aviation Week. "They landed on a slope, which is what we're concerned with as well.

"We flew that approach under lunar landing simulation in The Kraken. It was all open-loop, so there was no manual control in it, but we did a landing zone redesignation, and it worked out beautifully," he says.

The Kraken is being developed to support closed-loop, manual-control lunar landing simulation runs as soon as late October, he says.

The Joby Aviation S4 eVTOL "popped out" as the leading candidate to pursue for a possible inflight trainer platform, Wheelock says. "We do not have a contract on it," he notes.

"Our first S4 data points for HLS are going to be purely [of the computational fluid dynamics] type," Wheelock notes. "The NASA Joint Test Team, which is working directly with Joby and the Air Force Agility Prime program, gave Joby the data points in low gate—essentially from 1,500 ft. to surface with about 2 km (1.2 mi.) distance. They're going to run simulated lunar trajectories . . . just to make sure that the vehicle could support the rates of descent and the maneuvering requirements."

The initial runs will take place in simulators, followed by remotely piloted S4 runs at Edwards to prove simulation fidelity. "If those points prove to be good—or we'll see if we need to expand or tighten those boundaries—then we launch the flight test in 2024 and fly those same simulated lunar runs with a pilot on board as well," Wheelock says.

"We intend to exploit the all-electric vehicle and the fully reprogrammable flight control system on it," Wheelock says, noting the S4's six electric motors—four on the wings and two on the V-tail—can be controlled independently.

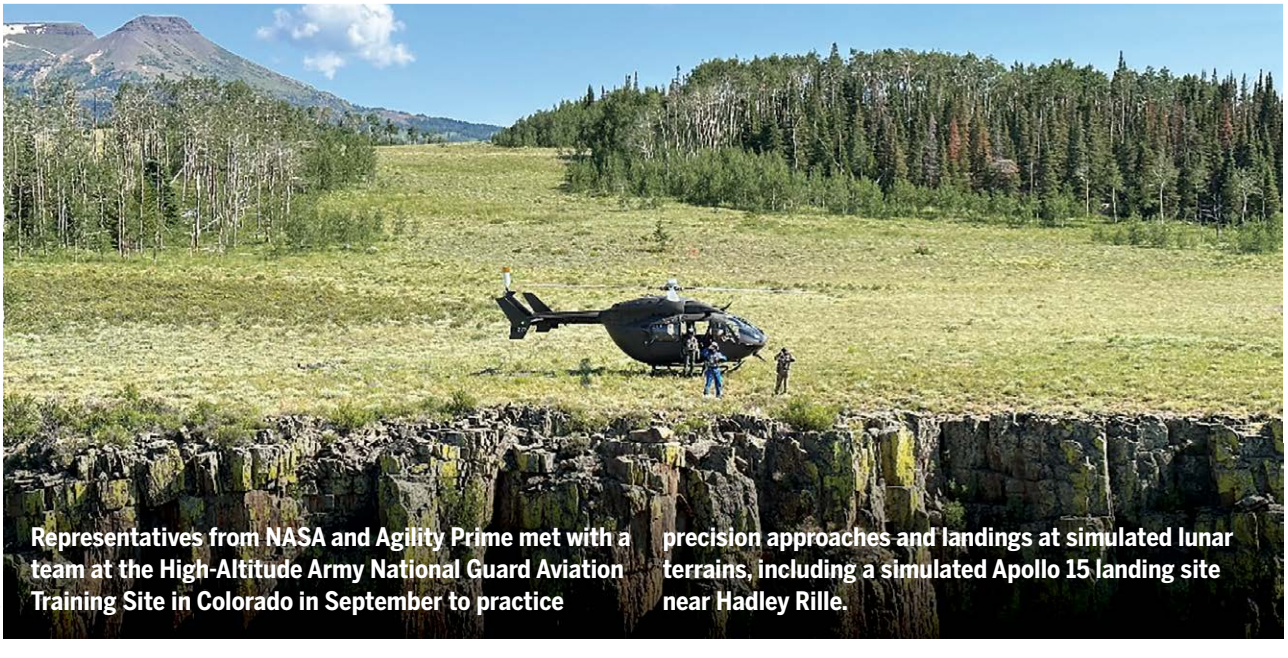
"You can turn it into a craft that can mimic, certainly in pitch, any kind of lunar dynamics," he points out. "That's going to be essential because the first lander is the SpaceX Starship, which is like a 10-story building."

Based on Apollo landing trajectories, the Artemis HLS vehicles likely will dampen out early lateral or yaw motions, essentially leaving just pitch modulations. "At the end, we can do a little bit of yaw, just to avoid putting one of the legs on top of a rock or down into a crater or something like that," Wheelock says.

After assessing the S4's dynamics in simulated lunar space, Wheelock says he will make a clear recommendation to NASA headquarters whether to acquire the system. NASA adds it has begun to explore options for software and aircraft to train astronauts for piloting a human landing system and that it has not taken steps to acquire such an aircraft from Joby to date.

NASA used Lunar Landing Training Vehicles to prepare the Apollo pilots to land on the Moon. Pictured is astronaut Charles "Pete" Conrad, Jr., Apollo 12 commander, during a lunar simulation flight at Ellington AFB, Texas, in October 1969.

NASA



Representatives from NASA and Agility Prime met with a team at the High-Altitude Army National Guard Aviation Training Site in Colorado in September to practice precision approaches and landings at simulated lunar terrains, including a simulated Apollo 15 landing site near Hadley Rille.

NASA/HUMAN LANDING SYSTEM PROGRAM

PRAGMATIC ELEC

> BETA TECHNOLOGIES OPENS MANUFACTURING FACILITY AND LAUNCHES PRODUCTION

> THE PLANT CAN PRODUCE 300 ELECTRIC AIRCRAFT PER YEAR

> TYPE-DESIGN MOTORS ARE FLYING ON DEMONSTRATORS

Graham Warwick South Burlington, Vermont

While publicly traded electric aircraft startups trumpet every financial and technical milestone to reassure shareholders, Beta Technologies has made substantial progress within the relative sanctuary of private ownership.

Two piloted, full-scale demonstrators have logged more than 500 flights, with both conventional and vertical takeoffs and landings. Hundreds of electric motors have completed more than 10,000 hr. of ground testing. And on Oct. 2, Beta opened its manufacturing facility at Patrick Leahy Burlington International Airport in Vermont.

A visit by Aviation Week to South Burlington in August underlined Beta's quiet progress, from the aircraft on routine test flights, motors undergoing endurance runs and battery packs being built to the wing-assembly fixture already in position in the nearly complete manufacturing facility.

TRIC

This is not a pilot production facility like those where Joby Aviation and Archer Aviation are assembling their first aircraft. The first prototypes of Beta's electric aircraft will be manufactured on the same tooling and in the same building where certified production aircraft are scheduled to begin rolling off the line in 2025.

Those first aircraft will be the CX300 electric conventional-takeoff-and-landing (eCTOL) version of Beta's Alia design. The startup decided in 2022 that customer demand for an electric aircraft justified moving ahead first with a fixed-wing version that would be easier to certify. FAA certification is targeted for 2025.

CX300 deliveries to customers such as Bristow Group and United Therapeutics will bring in revenue while Beta continues development of the A250 electric vertical-takeoff-and-landing (eVTOL) version of the Alia, planned for certification in 2026. Both versions are 80% common and will be built on the same tooling.

INDUSTRIALIZING ALIA

Founded in 2017, Beta has raised more than $800 million from private investors, ranking it fourth in the advanced air mobility (AAM) industry in total funding secured behind Joby, Archer and Lilium. Beta says it has invested more than $150 million in capital facilities, including the manufacturing plant.

Rather than integrate vertically like Joby or outsource major aerostructures like Archer, Beta has elected to buy parts and assemble aircraft in-house. This will allow the startup to keep control of process changes as production ramps up and to decide when and where to invest and automate.

Albany Engineered Composites (AEC), a supplier to Boeing and Airbus, is providing the "big bones" of the Alia's composite primary structure. Automated tape-laying of the first wing skin was completed in late August at AEC in Salt Lake City. Brussels-based Solvay is supplying the carbon-fiber prepreg material system.

Other supplier partners announced by Beta include Garmin for the integrated flight deck, Triumph for the landing gear and Hartzell for the pusher propeller, which is fitted to both the eCTOL and eVTOL versions. Sensata Technologies is providing the pilot inceptors and Volz Servos the electromechanical rotary actuators for the flight control surfaces.

Advanced Integration Technology is providing the assembly tooling and equipment as well as supplying tooling to Beta's composite parts suppliers. There are assembly positions for the wing, booms, empennage, fuselage and final assembly. Built on a 60-ft. tool, the one-piece wing is common to both Alia versions, although the eCTOL version does not have high-voltage wiring for the lift motors on the eVTOL variant.

Built on a 40-acre site and entirely powered by solar and geothermal

Beta's first Alia proof-of-concept demonstrator has been flying in eCTOL configuration since June 2022.

BRIAN JENKINS/BETA TECHNOLOGIES

energy, the 188,500-ft.² facility is designed for a production rate of up to 300 aircraft a year but could double its size in a Phase 2 expansion.

Beta also has locations in Montreal; Plattsburgh, New York; Raleigh, North Carolina; Springfield, Ohio; and Washington. A former Strategic Air Command airbase and a short flight from South Burlington across Lake Champlain, Plattsburgh International Airport is home to Beta's flight-test center, where two hangars house the demonstrators, telemetry system, pilot briefing facilities and test control room.

Expected to roll off the assembly line before year-end, the first prototypes will be used to prove out the manufacturing process and then go into testing with customers rather than straight into for-credit tests for FAA certification.

"Those first three or four aircraft are really line-commissioning aircraft," says Kyle Clark, Beta's founder and CEO. "We could put them straight into for-credit tests. We aren't going to for two reasons. One, there is a bit of a mind shift in aerospace around electrification, where we're finding the ability to sell precertified aircraft. The other is that the learning curve is still really steep on not so much the design, but the process. And we will have a faster type and production certification if we tighten up that process."

"In this refinement of commissioning the line, we're really testing all the elements of industrialization not talked about publicly," he says. "That includes the business systems, the quality management systems, the employee training handbooks and the billing mechanisms."

The first structure that will go into conforming-article structural testing will come before the first fully conforming aircraft rolls off the line. "The reason is because we want to learn as much as we can about the airframe," Clark says. "If there's a problem, we want to know it soon. So we'll actually break our first wing before we build our first airplane."

VISIBLE PROGRESS

Beyond the manufacturing facility, evidence of Beta's substantial progress is visible also in the test rigs, motor testing, battery assembly, aircraft charger and flight-training activities underway in other buildings around the Burlington airport.

An array of test rigs is visible through the fireproof glass that lines the office level looking into Beta's research and development hangar. This openness is deliberate. "Teamwork, empathy and innovation don't happen by email," says Blain Newton, Beta chief operating officer. "Here you can see clear across the hangar, go talk to someone and create unintentional collisions."

In the hangar itself is the final assembly line test rig or "FAL Bird." This is a full-scale mockup of the vehicle, made from wood and 3D-printed parts, used to understand the integration of systems and sequencing of assembly and provide feedback into design for manufacturing and maintenance.

The focus is on areas where there is overlap, with the objective of derisking the design before assembly of the actual vehicle begins. One example is access to the environmental control system in the nose with the correct tool, which required a redesign of the installation.

Beta is deploying its own network of charging stations across the U.S. to support Alia and other electric aircraft.

BETA TECHNOLOGIES

Across the hangar is the ergonomic test rig, or "Ergo Buck," another full-scale partial mockup dedicated to crew ingress and egress. "Human factors is one of the most subjective certification areas of aircraft," Clark says. If how the pilot exits the aircraft in an emergency is an afterthought, "you're going to be upside-down in certification" because it can affect structures, pilot visibility and other issues.

Also in the R&D hangar are the iron bird systems test rig and the proof-of-concept mockup for the flight simulator, which Beta is developing with training partner CAE. The center in which they will provide pilot and maintainer training for customers is adjacent to the manufacturing facility and home to a diverse fleet of aircraft Beta uses for flight testing, transport and training—including for its own employees.

While the Alia is designed for single-pilot, instrument-flight-rules operation, Beta plans to build a two-seat trainer version as well. This complies with the FAA's proposed operating rule that would require powered-lift pilots to undergo training in a dual-control aircraft. As proposed, the rule is a major

Beta's eCTOL demonstrator completed the first cross-border electric aircraft flight into Montreal on Sept. 27.

BETA TECHNOLOGIES

obstacle to most other eVTOL developers, as they have designed their aircraft with a single-pilot cockpit.

PROPULSION PIONEER

Beta has focused its in-house development on the electric propulsion system—the pusher motor, lift motors, power electronics and batteries. The startup has also brought the fly-by-wire flight control system in-house after acquiring an experienced development team from a major defense contractor.

Both demonstrator aircraft are now flying with the type-design pusher motors planned for certification, Beta's sixth generation over four years of development. From Day One, the startup says, the goal was to develop a motor configuration and technology based on manufacturing at a scale beyond what is traditional in aerospace.

"What makes a high-performance motor good for aviation? The least complexity. So we remove things that fail," says Manon Belzile, motors team leader. Beta's motors are direct-drive and air-cooled, eliminating gearboxes and liquid cooling. Two motors power the pusher propeller and each of the four lift props on the eVTOL version. Each motor is itself dual-redundant, with two three-phase windings. Each half of the motor has its own air-cooled silicon-carbide inverter/controller.

With the type-design pusher motor installed, the Alia demonstrator's climb rate outperforms a Cessna Caravan, Beta test pilot Chris Caputo says. If the motor loses half its power during takeoff, the aircraft can still climb out and safely make the turn back to the departure runway and a downwind landing.

Beta's motor design has an outer stator and inner rotor, which is easier to stabilize with bearings on a shaft, Belzile says. To date, the company has built 250 motors. The pusher motor has demonstrated 97.5% efficiency in cruise flight, Beta says. The lift motor has the same architecture but is wider and shallower, and cooling air flows differently through the stator. Power density is higher but efficiency slightly lower.

The production eVTOL A250 will have two dual-redundant motors on each lift rotor, with a sprag clutch making them mechanically independent.

"It's not just four motors tied to a shaft; it's four motors tied in an elegant way," Clark says. "They're mechanically decoupled and electrically decoupled, and they have different control systems."

Where other eVTOL developers have gone with six, 12 or even 18 lift props, Beta has stayed with its four-post design, choosing to put redundancy into motors rather than rotors. "Where you put reliability is in places where there is a propensity to fail," Clark says. "You do not tolerate the separation of a propeller. That's a prime reliable component. It can't separate. But it does happen that engines shut down.

"It is inconceivable to me that a singular motor would ever be prime-reliable," he continues. "So putting four on a post, all capable of safely landing the aircraft, separated so there's no galvanic connection between the stators and no mechanical connection in a way that one can fail the other, you end up with a higher redundancy numerically than you do with six single systems."

PUNISHING TESTING

Beta has multiple pusher and lift motors running endurance tests on dynamometer stands in South Burlington and also continuously driving propellers at a "prop farm" across the lake in Plattsburgh. "The ratio of motors built to motors flown is roughly 40 to 1. The motors that we put into containers and heat up and cool down, they'll never get flown," Clark says.

So far more than 10,000 hr. of accelerated-life testing has been conducted with motors at elevated operating temperatures to gather reliability data. Endurance dynamometer testing equivalent to years of operation has been completed with no degradation seen on the motors, Beta says.

The pusher motor is the first product the startup plans to certify—by the end of 2024, well ahead of the eCTOL aircraft. The FAA has established the special conditions for Part 33 type certification of an electric engine, and Beta expects to be the first in the U.S. to achieve certification.

The certified pusher motor will then be incorporated into the type certificate for the eCTOL version, which is planned to be certified as a Part 23 general aviation aircraft. The lift motors are scheduled to be approved as part of the eVTOL aircraft's Part 21.17(b) powered-lift type certificate.

Data collected from all the motor

and battery testing, as well as from simulation runs and flight tests, goes into a central repository. This enables the company to understand how variability in manufacturing leads to variations in performance. "The data backbone that we're aggregating is a phenomenal asset," Clark says. "The fact that it's parsable, searchable and operable on is an important part, so that anybody can take that historical data, make a good decision and show the FAA that we have a statistically relevant dataset that informs that decision."

BATTERY EVOLUTION

Beta has also developed its own battery packs, and the fifth generation is flying in the first demonstrator aircraft. The company has built up a manufacturing capability focused on building these packs to support the experimental aircraft while also acting as a sandbox in which to gain experience for production. This includes building to a released design, tracking to the pack serial number and cell production lot, and conforming all the way back to the lithium-ion cell supplier.

The fifth-generation pack uses commercially available cylindrical cells for which the supply chain is mature. The Alia flies with between two and five of the 40-65-kW modular packs in a belly fairing; the number of packs is a trade-off between range and payload. The pack is air-cooled, so cells with low internal resistance are used that generate less heat. At its advanced battery research center in St. Albans, north of Burlington, Beta is testing pouch cells and advanced chemistries that could become available later this decade.

For the production aircraft, Beta has switched to a battery system that is liquid-cooled on the ground while it is being charged and the cells heat up. The production-intent battery now has subpacks with the cylindrical cells on either side of a cold plate. Other design and process improvements have been made for battery production, which is being set up in an area within the new manufacturing facility.

BETA TECHNOLOGIES

Aircraft charging is a key leg of Beta's business plan, and the company now has 13 operational sites, mostly in the Eastern U.S. but extending as far as Arkansas. The network is being expanded continuously to support early customers such as Bristow, UPS Flight Forward and the U.S. Air Force's Agility Prime program. Beta is installing a charging station at Duke Field on Eglin AFB in Florida to support eCTOL flight tests planned to begin this year.

The company's latest ground support equipment configuration has three modules, or "cubes," for fast charging, battery conditioning and cabin conditioning. The temperature rise in the batteries during flight is minimized by the aircraft's efficient design and architecture, Beta says, and any accumulated heat plus heat generated by fast charging is removed through a liquid-cooling loop when on the ground. This is a simpler and lighter solution than providing active cooling in flight.

The charging station uses the Combined Charging System (CCS) standard developed for electric vehicles. Under an initiative led by the General Aviation Manufacturers Association and chaired by Beta, most electric aircraft OEMs and several vertiport developers have agreed to adopt the CCS standard.

Beta's station provides DC fast charging up to 350 kW, enabling a full recharge in 50 min. The cable motors out and back to prevent the connector from being dropped. And there is no display: A software app keeps track of the operator, aircraft, battery and how much charge is needed for the mission, Newton says.

Bristow Group is among early customers whose test pilots have already flown Beta's eCTOL demonstrator.

INTO EXECUTION

The manufacturing facility, training center, R&D hangar, and battery and charger shops in South Burlington are all clear signs of the progress Beta has made and evidence that the startup is one of a small handful of electric aircraft developers ready to move into certification and production.

"That's an indicator to me that the next phase of the business is very much an execution phase built on that plateau of capital that we've put down. And so as we work into the execution phase, the question is: What's our strategy to execute?" Clark says.

"A saying that I learned from Martine Rothblatt in the pharmaceutical world was: 'Approve, then improve.' We are well aware that our best aircraft, best design, best software is our next aircraft, next design, next software," he says. Rothblatt is CEO of United Therapeutics and an early Beta investor and launch customer.

With lift rotors attached, Beta's second Alia demonstrator has been conducting piloted eVTOL tests.

BRIAN JENKINS/BETA TECHNOLOGIES

"And so being intensely pragmatic—some may accuse me of being dogmatic—we know what our next step is," Clark says. "We need to focus on a technology that can be understood and certified today, a market that is willing and able to accept it, in a regulatory framework that works today."

This is the thinking behind Beta's decision in 2022 to complete design of the eVTOL Alia and then determine what could be removed to produce a viable eCTOL aircraft that could be brought to market sooner and with less certification risk—in response to a demand signal from customers keen to gain early operating experience with an electric aircraft.

"It seems so clear to me that this market is begging for a stepwise pragmatic entry into service," Clark says. "So we completed our design on the A250 and submitted our proposed means of compliance to the FAA. And the CTOL aircraft is the A250 minus a bunch of stuff. And that's really important in that the entire certification basis of the CX300 is portable into 21.17(b)."

That pragmatism is evident across Beta's activities. The full-scale demonstrators have been piloted from the outset, while other OEMs have flown only remotely piloted. "It drives the thinking," Clark says. "If we're going to fly into Class B airfields like Montreal or Louisville, [Kentucky,] on a motor, it better be a motor that has seen that times 10 in every stressful dimension, voltage, current, temperature, salt fog, humidity—all the things that we have to be really comfortable with before we put ourselves and our customers in the aircraft."

Aviation Week saw this approach in action during a visit to Beta's flight-test center in Plattsburgh. In the meticulous preparation for an eCTOL test flight, the test director, test pilots and flight-test engineers methodically ran through the procedures that would be required to respond safely to a potential failure unique to an aircraft with electric propulsion and therefore new to the industry.

The demonstrators have gone through multiple incremental improvements in motors and batteries. The eCTOL aircraft now has slimline booms where the eVTOL aircraft has large fairings over the lift motors. The booms will be removed ahead of the wing for the production CX300. Other design changes are tricycle landing gear, a bulkhead between the cockpit and cabin, gull-wing cockpit doors and a larger cargo door.

The eVTOL demonstrator has been flown along the long Plattsburgh runway at up to 62 kt. to begin exploring the transition between thrustborne and wingborne flight. The full transition corridor is expected to be cleared by year-end. Beta has been refining the design of its lift rotors in stages. "I think that the more refined system that will go into the production vehicle . . . will be a transition that the FAA will consider an average pilot can't break," Clark says.

PRACTICAL MAGIC

Beta's no-nonsense, stepwise approach to introducing electric aviation has resonated with industry analysts. SMG Consulting ranks privately held Beta second to publicly traded Joby in its influential Advanced Air Mobility Reality Index. "I would say that the first AAM vehicle going into service is going to be a two-horse race between Joby and Beta, each more advanced than the other in some areas," says Sergio Cecutta, founder and partner at SMG.

"The strategy of Beta to go eCTOL before eVTOL is a winner, as it allows for the regulations to stabilize while they de-risk certification with an aircraft almost identical to the eVTOL," he says. CX300 deliveries will also generate revenues to help de-risk investment in certification of the eVTOL A250.

Finally, Cecutta says, Beta's cargo-first approach to putting electric aircraft into operational service "allows them to sign up customers that are eagerly waiting for the aircraft, have put deposits down, and that do not have to worry about infrastructure and customer adoption."

A PRACTICAL OPTION

> AAM STARTUPS SEEK MODULAR, SCALABLE VERTIPORTS

> EARLY-STAGE AAM REQUIRES AFFORDABLE, LIGHT INFRASTRUCTURE

> MORE INVESTMENT IS NEEDED TO ENABLE AIR TAXI LAUNCH

Ben Goldstein Boston

When people think of vertiports capable of facilitating advanced air mobility services, they often imagine expansive, futuristic complexes that can handle large numbers of passengers and aircraft at one time.

The reality, however, may look more modest. Conversations with startups looking to enter the fast-growing market for vertiport construction and operation reveal that the first generation of dedicated infrastructure for advanced air mobility (AAM) likely will be designed around a handful of practical considerations—chief among them, affordability and scalability.

Larger, more expansive facilities of the kind seen in investor decks may eventually come, but not without sufficient operational density to justify investment in them. At least in the near future, services are likely to center on existing helicopter infrastructure, augmented by smaller, simpler vertiports that do not require significant upfront investment.

KOOKIEJAR

Based in Stockholm, Kookiejar is an AAM startup with aspirations to build out networks of infrastructure-light vertiports that can be leased to third-party operators to facilitate drone delivery and air taxi services.

Kookiejar's vertiport concept uses modular, aluminum platforms that connect together to create different shapes and configurations, like LEGO blocks. A single 2 X 2-m (6.6-ft.) module suffices as a takeoff and landing area for a single delivery drone, while three or four modules combined can accommodate an electric vertical-take-off-and-landing (eVTOL) vehicle.

The startup aspires to build out its drone and air taxi platforms either on top of existing buildings like gas stations or parking garages, or at ground level. Its underlying philosophy is to build out a large, distributed network of small and affordable droneports and vertiports rather than concentrate operations at large, complex facilities that require a good deal of upfront investment.

The company can also outfit its modules with a "cookie layer" of technology, including positioning systems, light systems, power systems and more, says CEO Michael Pettersson Markman.

"To be able to do a full-scale business at the end of the day, you need to have a flexible, light vertiport," Markman tells Aviation Week. "We don't believe in these infrastructure-heavy buildings like airports do. We think that anything we build has to be something that is movable and scalable at the same time—not these elaborate designs that others are talking about."

For its initial operations, Kookiejar is concerned mainly with facilitating drone deliveries, including through a last-mile pilot program with Swedish fast food company MAX Burgers. Kim Silander, Kookiejar's co-founder, says he views drone delivery as a stepping-stone to air taxi services, which he expects will require greater investment and more time for viable business models to evolve.

"Once it's developed, we're likely talking about hundreds of these modules spread out across a city the size of Stockholm," Silander says. "That sounds like a lot, but we're not talking about a €1 million investment—they will be affordable. And in that way, we believe that some customers who want our module for drone services initially will also cater to the electric vehicle market when it becomes mature."

SKYPORTZ

Australian startup Skyportz is taking a similar approach with its "vertiport-

in-a-box" concept for modular vertiports, which are 3-10 m (10-33 ft.) long and can be joined together in various configurations. The aluminum-monocoque vertiport shells would cost about €100,000-250,000 ($105,000-262,000), according to CEO Clem Newton-Brown, although the price would rise with additional features such as charging stations or passenger amenities.

The modular vertiports are to be fabricated in a factory offsite and can be transported to vertiport locations using a standard shipping container. To further derisk the proposition for property owners and developers—whose participation Newton-Brown says will be crucial to building out the AAM ecosystem—he suggests the modular buildings could be repurposed as cafes or bars until they are ready to be activated for AAM.

"What we envisage is a beautiful little building that will still present a really cool image for the beginning of this new industry but be at a price that the property owners will feel comfortable with," Newton-Brown tells Aviation Week. "Even if they don't have approval yet, they can still set up their vertiport-in-a-box building and use it as a meeting room or something else for now."

The idea behind Skyportz is to offer a low-cost, mass-producible product that enables property developers to explore AAM without risking an uncomfortable amount of capital upfront while helping to break the "nexus" between aviation and existing airports, Newton-Brown says.

"For practical aviation reasons and cost reasons, I've come to the conclusion that we need to make vertiports as affordable as possible," he adds.

"Everybody is talking about $3-per-mi. ticket prices, so for a short hop it's really not much money," Newton-Brown says. "The size of the pie is actually very small. We can't have vertiport operators or owners expecting huge payments for each landing—and we have to make sure each component of the process is as lean and efficient as possible."

VOLATUS INFRASTRUCTURE & ENERGY SOLUTIONS

Wisconsin-based AAM startup Volatus Infrastructure & Energy Solutions also has taken a pragmatic approach to vertiport development. The company's vertiports come in three main design configurations: 500 ft.^{2}, 1,000 ft.^{2} and 2,000 ft.^{2}. Because of their modular design, they can be quickly constructed "in a matter of days," with the flexibility for owners to scale them up in size easily to accommodate growth, says company co-founder Grant Fisk.

The vast majority of vertiports to be built in the coming years will likely be modest facilities with just a small passenger terminal and one or two vehicle landing pads and charging stations, Fisk adds.

"It's a huge ask for a community or an individual or a private enterprise to spend $10-20 million dollars upfront on infrastructure, especially when it may be a decade before we really see operational density," he says. "We need to be able to offer a solution that can handle a dozen or 20 flights per day. This is all you need, and you don't even have to spend a million bucks."

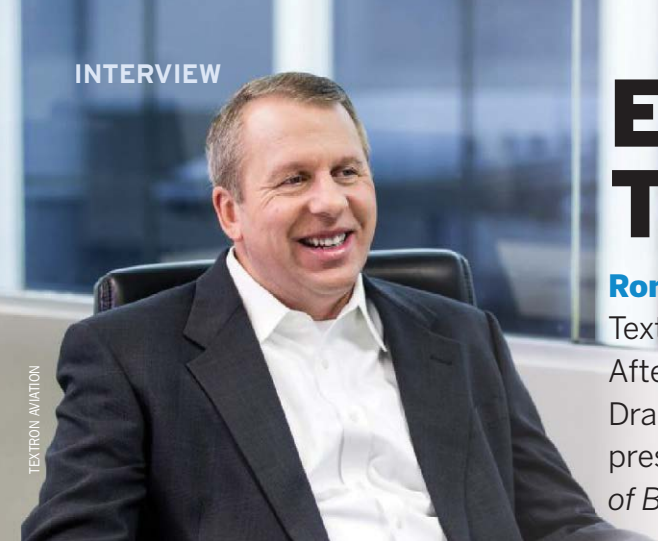
Volatus has so far committed to building three vertiports at rural and general aviation airports: Greenport International Airport near Austin, Texas; Bellefonte Airport in rural Central Pennsylvania; and Wittman Regional Airport in Oshkosh. Those projects will begin with a single landing pad and charging station, although the company plans to scale them up eventually.

With the first eVTOL air taxis expected to launch service in 2025 in the U.S., Fisk says he "cannot overemphasize" how underfunded the infrastructure component is and estimates it will "require a multitrillion-dollar" investment to support services in the coming years. He also points to Japanese government estimates for 100,000 vertiports in the country by 2030 to illustrate the scale of the challenge facing the industry.

"If you take that figure for just Japan and expand it, what does it mean for the world? We're talking tens of millions of vertiports to support this technology properly," Fisk says. "Even if it's only half that amount, we're still talking about an extraordinary number that will require investment on a scale that hasn't been seen before—and it's going to have to come from the private sector."

VOLATUS INFRASTRUCTURE & ENERGY

Volatus is building vertiports at airports in Pennsylvania, Texas and Wisconsin.



TEXTRON AVIATION

Evolving Technology

Ron Draper joined Wichita's Cessna Aircraft Co., now Textron Aviation, in 1999 as director of supply chain. After stints at Bell and Textron Specialized Vehicles, Draper returned in 2011 and was named Textron Aviation president and CEO in 2018. He talked with *The Weekly of Business Aviation* Editor-in-Chief **Molly McMillin**.

AW&ST: **A good number of new entrants came to the business aviation market since the pandemic started. Where are you finding the market today?** Those new customers have come to the industry and have stayed, and that's increased the market for us. The market for selling airplanes is strong. A year ago, it was white-hot-strong. Now it's cooled off to a strong market—if you notice, everybody's backlogs have grown. Three years ago, we had $1.5 billion or $1.8 billion in backlog, and now we have $6.8 billion in backlog. For the first half of the year, book-to-bill has been greater than 1.

What are your strongest regions today? North America—no change there—is our strongest market. Latin America has really been a strong market for us. It has creeped up into probably second place for us. Mexico and Brazil are the two strongest elements within that entire region.

Have corporate buyers returned? In this cycle of a strong market, initially it was individuals and leisure travelers, and the corporate buyers waited a little longer, and now they've been back for some time.

At the European Business Aviation Convention & Exhibition (EBACE) in Geneva in May, protesters disrupted the static display. What are you expecting at the National Business Aviation Association Convention & Exhibition (NBAA-BACE) in Las Vegas? We did training even before we got to EBACE. We just prepped employees on what to do. I was very happy with our employees. We didn't want to engage with [the protesters]. We just locked the airplanes and kept folks safe, and it ended up not being that big of an event for us. But it made a lot of news, which is exactly what the protesters wanted. I suppose some people may try that [at NBAA]. They're trying stuff all over the world: blocking roads, tarnishing monuments, trying to handcuff themselves to airplanes. NBAA is assuring us that security is going to be very high and that they're doing whatever they can to prevent that. But if somebody wants to do something, then we'll be prepared to just keep our folks safe and keep our airplanes safe and not engage with them.

What are your biggest challenges? We're still all pushing through some supply issues. The capacity of the aerospace supply chain needs to grow, raw materials on up. The whole country is facing a shortage of skilled labor. And that's good for workers. That will push wages up. We will go out and compete. We hired 2,000 people this year. We'll be doing that every year and training lots of folks.

The regulatory process to certify products has slowed. Is European Union Aviation Safety Agency (EASA) validation moving at a faster pace than the FAA, or what is the case there? Validations are too slow, and we continue to discuss that with EASA and the FAA. They're working on it, and the folks in Washington are all telling us they're working on it. I believe they are. I was really upset over our [Citation] Longitude validation. It took almost two years. Now, in EASA's defense, it was in the middle of COVID, and it was hard to get pilots to fly the airplane, and they were short of people. We missed sales in Europe because of that. Compared to what we expect, it's still too slow.

How do you see business aircraft technology evolving until 2035? Technology is evolving at a rapid rate. A whole part of this industry is looking at alternate propulsion sources. Textron is investing in that with eAviation. We've got Pipistrel looking at electric and hydrogen. I think you're going to see more of that come to market in that 12-year timespan. There are limits to that technology, but it's going to continue to evolve.

The technology that is evolving around situational awareness in the cockpit is incredible. You get in brand-new aircraft that we deliver—the avionics, it's better than what airliners have: They avoid; they can land themselves. That's going to continue. It's making the job of the pilot so much easier when the plane nearly flies itself. The technology we're putting in cabin comfort . . . technology is going throughout the product line from nose to tail.

Given the slow ramp-up in sustainable aviation fuel (SAF) production, is it reasonable for business aviation to bet on heavily using SAF? Production is going to be the constraint on SAF, but SAF is the biggest answer to the sustainability challenge of jet aircraft. We are going to bet on it as an industry. Production and adoption have to continue to grow. There are other technology bets that we'll make—alternate sources of propulsion, hydrogen, electric—and all that will evolve separately. I see those technologies first evolving in shorter-use, smaller airplanes. But to go across the ocean with even 10 people in a business aircraft, it's going to be hard to beat the energy density that's in jet fuel.

Sustainable Investment


PILATUS

Markus Bucher joined Switzerland's Pilatus Aircraft more than 30 years ago. He was appointed to manage aircraft assembly and maintenance operations in 2008, became chief operating officer in 2011 and was promoted to CEO in 2013. He talked with *ShowNews* Editor-in-Chief **Thierry Dubois**.

AW&ST: **In March, you reported supply chain problems. Has the situation improved?** It was more of a shortage of raw materials, and that improved considerably. We still have supply chain challenges, and we are not producing the number of aircraft we had planned in 2023. At stake are on-time delivery and quality. It is too early to tell if we are seeing the light at the end of the tunnel.

On the PC-24 [business jet], the robustness of the supply chain has improved, and the production rate is close to our objective. On the PC-12 [turboprop], however, the output is up to 10% below target.

In 2023, we will deliver more than 40 PC-24s and close to a record of 100 PC-12s. Demand for the PC-12 was high, and it is even higher now.

The aerospace industry in Europe is struggling with recruitment. Are you easily filling open positions? We find enough candidates to fill open positions in general. We hire 2% of the applicants. Nevertheless, certain skill sets are difficult to find, such as in cybersecurity, specialized engineering and supply chain management. But Pilatus does not suffer from a general labor shortage.

Among your markets, where are the growth regions? With the PC-12, the typical geographical breakdown is unchanged, with two-thirds the Americas and one-third Europe and the rest of the world.

With the PC-24, the situation is slightly different. During the first five years, we sold aircraft in our typical areas. Then buyers in areas where single-engine aircraft get less traction expressed interest. In the Middle East and Asian countries such as India and Japan where flying over water is a requirement, we have found customers. The share of the Americas in the PC-24's market is around 50%.

What's next for the PC-24? What our customers tell us since the introduction of the Super Versatile Jet is they want more payload, range and cabin comfort. Over the past four years, we have worked on the next model. From the beginning of 2024 and Serial No. 501, the new model will offer more payload at an additional 600 lb. or more range at an extra 200-250 nm. We changed over 1,000 parts and saved a lot of weight. The new standard cannot be retrofitted.

When you enter the cabin, you will enjoy a new welcome center, a large divan where a tall person can lie flat and a new inflight entertainment system. We upgraded the overall cabin design.

Maintenance engineers will enjoy our predictive maintenance program. Because aircraft systems are fully digital, we can use a large quantity of data. Customers will be aware of unscheduled maintenance actions in advance.

Could you consider a stretched version of the PC-24? No. Pilatus builds aircraft that are fit for purpose. If we think of a longer fuselage, we design a new aircraft. We do not stretch aircraft.

How do you see business aircraft technology evolving until 2035? There is a lot of goodwill and capital spent on research for new propulsion systems. In reality, an electrical powertrain or a hydrogen aircraft have a long way to go. At Pilatus, as a first priority, we are trying to reduce fuel burn until new technologies arrive.

We believe in sustainable aviation fuel (SAF), not so much from biomass but rather synthetic fuels. A drop-in fuel is the best solution that our industry can find.

Given the slow ramp-up in SAF production, and the fact that several industries compete for such fuels, is it reasonable for business aviation to bet on heavily using SAF in the future? Absolutely. If we want to be carbon-neutral by 2050, the only way is SAF. Keep in mind, only 2% of the business aircraft fleet is replaced every year. Going electrical, hydrogen, etc. is mission impossible.

As an industry, we need to invest more in SAF, especially to produce synthetic fuel. We have to invest our own money, along with partners who are in the SAF business and countries that are in a favorable position to mass-produce SAF.

Why not make more publicity about the PC-12's significantly lower CO_2 emissions? The Swiss are humble people. We have a sustainability strategy based upon environmental, social and governance principles. We have been ISO14001-certified for more than 20 years.

As for CO_2 emissions, customers do the comparison themselves. And this is part of the most recent success of the PC-12. People who would never have considered a turboprop are considering it now. We are not promoting that attribute further because we already cannot meet the demand for the PC-12. But customers do have a requirement for lower emissions and they let us to know.

TECH TAKE

By **Graham Warwick**

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

Deutsche Aircraft Readies Fuel-Cell Demonstrator

Deutsche Aircraft has completed wind tunnel testing of the 328Alpha hydrogen-electric powertrain flight demonstrator, a planned modification of the D328 regional turboprop.

DEUTSCHE AIRCRAFT

The 328Alpha hydrogen fuel-cell propulsion demonstrator has two electric engines in outboard nacelles.

The wind tunnel tests involved a powered model of the 328Alpha, which has a pair of electrically driven propellers added outboard of the aircraft's standard turboprop engines. Deutsche Aircraft is aiming to fly the propulsion testbed in 2025.

The nine-week wind tunnel test campaign investigated propulsive power, stability and control, and performance over the expected flight envelope and confirmed computational fluid dynamics analysis, the company says.

The objective of the German government-supported 328Alpha program is to demonstrate emissions-free cruise flight using liquid-hydrogen fuel and a megawatt-class fuel-cell powertrain.

The project is partially funded by the German Federal Ministry of Economic Affairs and Climate Action under the LuFo VI-1 national aeronautics research program.

Deutsche Aircraft is working with German hydrogen-electric propulsion pioneer H2Fly to develop the liquid-hydrogen fuel system and fuel-cell power system and with GE Aerospace for the hybrid-electric propulsion system.

The megawatt-class powertrain will be based on H2Fly's 175-kW H2F-175 fuel-cell system, which is planned to begin flight tests this year on a yet-to-be-revealed testbed aircraft. H2Fly flew its HY4 fuel-cell technology demonstrator on liquid hydrogen for the first time in September.

GE says it is working with Deutsche Aircraft to "mature hybrid-electric technology through a system test" on the 328Alpha demonstrator, building on a multiyear partnership with the German government. "We're supporting propulsion integration," the engine manufacturer says.

GE also says the project does not involve development of the powertrain it is already developing with Boeing for NASA's Electrified Powertrain Flight Demonstration program. Under the NASA program, GE plans to fly a megawatt-class hybrid-electric propulsion system on a modified Saab 340B regional turboprop later this decade.

United Invests in Green Hydrogen

United Airlines has invested in Electric Hydrogen, a U.S. startup manufacturing and deploying electrolyzer plants to produce green hydrogen that could be used in the production of sustainable aviation fuel.

The airline participated in Electric Hydrogen's (EH2) $380 million Series C funding round, which takes the total raised since the Natick, Massachusetts-based startup's founding in 2020 to more than $600 million.

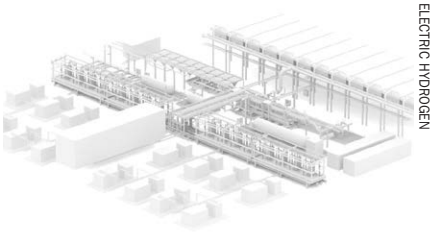
Green hydrogen produced by the electrolysis of water using renewable electricity is a key ingredient in producing synthetic power-to-liquid sustainable aviation fuel (SAF) using captured carbon dioxide.

EH2 plans to manufacture 100-megawatt electrolyzer systems, each capable of producing almost 50 tons of green hydrogen per day. The first customer system is planned to be installed and commissioned in Texas in 2024 for New Fortress Energy.

The startup is scaling up and improving the performance of proton exchange membrane electrolyzer technology with the goal of driving the cost of green hydrogen, when produced using low-cost renewable energy, down to around $1.50 per kilogram by 2030.

Most hydrogen produced today is gray hydrogen generated from natural gas or methane by steam reforming. At $1.50/kg, it makes sense to switch from natural gas

ELECTRIC HYDROGEN



Electric Hydrogen plans to build 100-megawatt electrolyzer plants to reduce the cost of green hydrogen.

to green hydrogen, says Jason Mortimer, EH2 senior vice president for global sales.

"We are closer than anyone else [to that price], irrespective of any incentives," he says, referring to the $3/kg tax credit for green hydrogen included in the Biden administration's 2022 Inflation Reduction Act.

EH2 is installing manufacturing equipment in its 1.2-gigawatt factory in Devens, Massachusetts, and plans to begin producing commercial electrolyzer systems in the first quarter of 2024. The company has reservations for systems totaling 5 gigawatts, Mortimer says.

A typical plant producing e-fuel SAF using green hydrogen could require around a gigawatt of electrolyzer capacity, or 10 of EH2's plants, he says.

EH2 is a spinout from Bill Gates' Breakthrough Energy organization and is led by the same team that led First Solar, the only U.S.-headquartered manufacturer to still rank among the world's 10 largest solar panel producers.

Initially, Mortimer expects the electrolyzer systems to go to greenfield sites. "The infrastructure to manage hydrogen gas is still early in its evolution, so it makes sense to locate production close to where the hydrogen is consumed," he says.

As the hydrogen pipeline infrastructure is built out, "we see a shift to production hubs near where the renewable energy is," Mortimer says. Areas with abundant solar and wind energy such as the Gulf, Morocco and Western Australia are expected to become hubs for green hydrogen production.

The Series C funding round was led by Australian energy and metals company Fortescue with investment companies Fifth Wall and Energy Impact Partners. The round included new investors bp Ventures, Oman Investment Authority, Temasek, Microsoft's Climate Innovation Fund, United Airlines' Sustainable Flight Fund, New Legacy, Kajima Ventures and Fatima Holdings USA.

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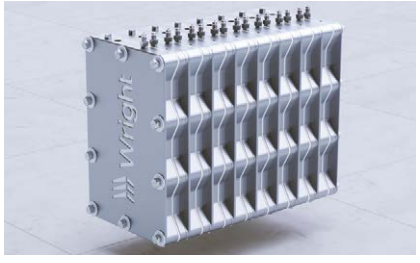
AVIATION WEEK NETWORK

TECH TAKE

Wright Targets 1,000-Wh/kg Batteries

Electric propulsion startup Wright Electric has launched an initiative to develop power-dense batteries to power regional airliners. The company's goal is a pack-level energy density of 1,000 Wh/kg—four times that of current electric vehicle batteries and sufficient to power a 100-seat aircraft for 700 mi.

WRIGHT ELECTRIC



Wright's planned energy-dense battery would be swapped after flight and mechanically recharged by refilling.

Founded in 2017, Wright has been focused on developing a 2-megawatt electric motor for regional aircraft. The motor has produced 1 megawatt of peak power in ground tests, and the company plans to test the motor at simulated altitude in the NASA Electric Aircraft Testbed in Sandusky, Ohio.

"When I founded Wright Electric, the best vehicle batteries had an energy density well below 250 kW/kg," CEO Jeff Engler says. "Now several large manufacturers are advertising cells at double that capacity, and we have visibility into new battery chemistries that could get us to our target of 1,000 Wh/kg."

Wright is focused on electrifying aircraft with at least 100 passengers and ranges of 700-800 mi., which would cover about 25% of the aviation industry's carbon emissions and about 75% of its noise footprint, Engler says.

"Batteries are not at the level needed for large commercial aircraft. For that, we want to get above 500 Wh/kg at the pack level, but really the goal would be to get above 1,000," he says. "If you can get 1,000 Wh/kg, then you can do 100 passengers, 700-800 mi. with reserves."

In 2018-19, Wright began small internal experiments on different battery chemistries beyond today's lithium-ion cells. "We now think that the industry is at a turning point where there are a couple of approaches that could meaningfully get to 1,000 Wh/kg," Engler says.

The U.S. Energy Department's Advanced Research Projects Agency-Energy (ARPA-E) thinks similarly and has launched the Propel-1K program to develop high-energy, high-power energy storage solutions for aircraft, trains and ships with the goal of 1,000 Wh/kg at the pack level at end of life.

Wright is focusing on high-temperature battery chemistries and has launched a program to evaluate three approaches, with the goal of making a final decision in two years. The company is targeting the release of initial packs for laboratory testing in 2025 and first commercial deliveries in 2027. The first applications of the battery are expected to be ground-based, Engler says.

"High temperature isn't new," Engler adds. He notes that Ambri, a spin-off of the Massachusetts Institute of Technology, is commercializing a calcium-antimony liquid-metal battery for electrical grid storage. ARPA-E says molten-salt chemistries such as sodium-sulfur and sodium-nickel chloride also have potential.

"What's new is our company has expertise in complex high-temperature systems for motors, and the packaging that goes into these batteries will have some overlap," he says. "We're going to be taking our expertise in thermal management and installation of large motor systems and applying it to batteries."

Molten-salt and liquid-metal batteries are solid and stable at ambient temperature but become liquid and active at temperatures above 350C (660F)—temperatures with which the aerospace industry has ample experience managing within jet engines, ARPA-E notes.

"At high temperature, the ions inside these batteries have a lot more freedom of movement," he says. "So you can increase the ratio of materials that store energy versus others that essentially play a supporting role. Our goal in these experiments is to prove that out at a scale that's meaningful for the aerospace, maritime and trucking industries."

For aircraft, high-temperature batteries would be swapped out after flight and mechanically recharged by refilling "like a big box of chemicals," Engler says. In form factor, they would be closer to conventional lead-acid batteries than lithium-ion cylindrical and pouch cells. Swapping the batteries would enable 30-min. aircraft turnarounds.

Diamond Aircraft Flies Trainer on SAF

A Diamond DA42 training aircraft has flown for the first time on SAF at the European Flight Academy, part of Lufthansa Aviation Training. The circuit flights were conducted at Bremen Airport in Germany using fuel produced by Neste and supplied by World Fuel Services.

The project partners had to overcome a lack of SAF available for testing to clear the DA42-VI's kerosene-fueled piston engines—produced by Diamond subsidiary Austro Engine—to operate on SAF. Bremen was selected for the flight tests because it is one of the first airports in Germany to stock SAF for its airline customers.

BREMEN AIRPORT

A Diamond DA42-VI trainer operated by Lufthansa's European Flight Academy flew on a 33% blend of SAF.

"Kerosene-fueled piston engines play only a minor role in aviation due to their low volumes globally and their low emissions in general," says Felix Zahradnik, chief technology officer at Austro Engine. "As a result, it was very difficult for us to procure these 'new' fuels for analysis and testing, let alone to participate in their certification in order to address the specific requirements of a compression-ignition piston engine."

But working with customer Lufthansa Aviation Training, Bremen Airport and World Fuel Services, the company procured enough fuel for engine bench and flight tests in preparation for certification of the fuels, Zahradnik says. The Bremen flight was conducted on a 33% blend of SAF and fossil jet fuel.

An extensive series of flight tests is planned to determine whether SAF can serve as the sole fuel for the European Flight Academy fleet in the future, Diamond says. Working with Austro Engine, Diamond plans to approve its entire range of kerosene-fueled aircraft to use SAF blends of up to 50% by 2025; 100% SAF use is expected to come later.

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CONSULTING SERVICES

Municipality of Ramat-Hasharon

Call for proposals

Price quotes for a paper on the examination and presentation of the influence of nuisances caused by flights passing above the city of Ramat Hasharon.

Ramat Hasharon Municipality is hereby announcing a call for proposals to locate entities with experience, ability, and specialization for the examination and presentation of nuisances influence caused by flights passing above Ramat Hasharon City, as well as a presentation of alternative flight routes, incorporating specialization between the field of aviation and the field of examination and presenting the influences of flights and the environment quality, quality of life, residents' health and the resulting economical impact.

Companies with proven experience in this field of activity are invited to participate in the call for proposals.

To obtain details, additional information, and the submission documents, please apply to the Municipality's site at www.ramat-hasharon.muni.il under the link "Tenders" and "Call for Proposals."

The last date for proposal submission is Monday, 30th of October 2023, at 12:00 noon.

The proposal should be submitted by E-mail: Nitzan_p@ramat-hasharon.Muni.il attention, Nitzan Perel, Assistant to the Municipality's Director General, telephone: +972-3-5483807.

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Postmaster: Send address changes to *Aviation Week & Space Technology*, Attention: Subscription Services, 22701 W. 68th Terrace, Ste. 100, Shawnee, KS 66226-3583.

Aviation Week & Space Technology
Oct. 16-29, 2023
VOL. 185, NO. 20 (ISSN 0005-2175)

Aerospace Calendar

To submit Aerospace Calendar Listings
email: aero.calendar@aviationweek.com

Oct. 23-25—AMTC23 (Air Medical Transport Conference). Greater Columbus Convention Center. Columbus, Ohio. See theamtc23.eventscribe.net

Oct. 24-25—Spaceport Norway 2023 Conference & Expo. Vulkan Arena. Oslo. See spaceport-norway.no

Oct. 25-26—2nd Africa Air Force Forum. Hangar Heugene Demba/Leopold Sedar Senghor. Dakar, Senegal. See airforceafrica.com

Oct. 27-Nov. 2—The Ninety-Nines 2023 International Conference. Dead Sea Marriott Resort & Spa. Sweimeh, Jordan. See ninety-nines.org/conference.htm

Nov. 6-8—CyberSatGov. Hyatt Regency Reston. Reston, Virginia. See cybersatsummit.com/cybersatgov

Nov. 6-9—Defense & Security 2023. Impact Exhibition and Convention Center. Bangkok. See asiandefense.com/2023/en

Nov. 7-9—International Air Transport Association Aviation Energy Forum. Conrad Abu Dhabi Etihad Towers. Abu Dhabi. See iata.org/en/events/all/iata-aviation-energy-forum

Nov. 13-17—Dubai Airshow. Dubai World Central at Al Maktoum International Airport. Dubai. See dubaiairshow.aero

Nov. 14-16—Space Tech Expo Europe. Messe Bremen. Bremen, Germany. See spacetechexpo-europe.com

Nov. 16-18—Global Summit and Expo on Aerospace and Mechanical Engineering (Gseame2023). Rome. See thescientistt.com/2023/aerospace-mechanical-engineering

Aviation Week Network Events

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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.

Nov. 7-9—GAD World. Barcelona, Spain.

Nov. 8—Aviation Week Network's Program Excellence Awards. Washington.

Nov. 23-24—CTC Sydney Corporate Travel Summit & Awards 2023. Sydney.

Nov. 28-29—CAPA World Aviation Summit & Awards for Excellence. Abu Dhabi.

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VIEWPOINT

Why Harmonization Matters

By **Jim Harris**

Charles Darwin famously devised his theory of evolution on the Galapagos Islands, observing that finches on different islands had developed variations across beak shape, size and diet. They had adapted to thrive in their different surroundings.

By contrast, after nearly a century of responding to increasing harmonization, modern aviation has led to convergence and standardization. Since the Chicago Convention of 1944, the aviation industry has worked toward alignment on common standards including physical infrastructure, air traffic management and flight safety.

This has led to efficiency in aircraft production and operations, promoting economies of scale that have allowed the real cost of travel to decline and passenger traffic growth to flourish. The global market for aircraft manufacturing, leasing and maintenance today centers on a handful of platforms that handle more than 80% of all commercial air traffic.

MALCOLM PARK/ALAMY STOCK PHOTO

However, the global, unified frameworks that have defined nearly eight decades of commercial air travel and fed industry profit pools are at risk of unraveling. While the International Civil Aviation Organization member states last year agreed to adopt net-zero emissions as their 2050 Aspirational Goal, a rapid evolution of ecosystems specific to regions and countries with their own policies around carbon reduction has come to life.

Competing decarbonization approaches are just beginning to emerge. The European Union's recent agreement on ReFuel EU favors prescriptive solutions for required fuel blends, and policymakers have explored mandating specific future propulsion technologies. Meanwhile, the U.S. has chosen to subsidize sustainable aviation fuel (SAF) production and invest in hydrogen through the Inflation Reduction Act. Other countries are developing and deploying a regulatory mix of carrots and sticks for the aviation industry. These differing approaches fundamentally skew the economics for airline operations as well as the investment decisions by the OEMs.

Airlines will have to respond by tailoring their fleets with fit-for-purpose aircraft with propulsion technologies that vary by region, eliminating efficiencies around having large numbers of common aircraft types. For instance, could we see hydrogen-powered aircraft in Europe, more traditional aircraft burning SAF in the U.S. and Asia and countries in between, such as Norway, adopting all-battery-electric aircraft by 2040? These subscale, specialized fleets would be more expensive to operate and require a costly, redundant fuel supply chain infrastructure, further raising the cost to airline operators and ultimately to passengers.

Policy divergence and fragmentation across regions threaten to disturb the harmony that has allowed a global aviation industry to grow and could create islands of regional aviation that arise from adoption of competing technologies. This could then lead to several disruptions across the value chain.

> **"UNIFIED FRAMEWORKS THAT HAVE DEFINED EIGHT DECADES OF COMMERCIAL AIR TRAVEL ARE AT RISK OF UNRAVELING."**

For instance, airframe and engine OEMs and their suppliers could see smaller production runs on individual aircraft programs yet face the same very large development costs, resulting in an unsustainable erosion of life-of-program profitability. Meanwhile, lessors could see values for the same aircraft differ considerably across different parts of the world, fracturing the global market lessors enjoy amid a rise of subscale, more costly region-focused specialists. Finally, the aftermarket-centric business models in which products are sold at low or no margin in exchange for lucrative aftermarket parts sales would rapidly degrade with subscale volumes.

Competing standards and approaches risk running aviation through an evolutionary experiment in survival of the fittest against differing regional requirements. This would threaten a global industry that has invested in new products that have reliably improved fuel efficiency by 1-2% per year on average with ever-increasing safety and reliability.

The aviation industry needs global policy harmonization and coordination to ensure green technologies can scale, not a future in which a variety of finches evolve to fly in different environments.

Jim Harris is a senior partner in the Washington office of Bain & Co.

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