STARTS AFTER **PAGE 34**

InsideMRO™

Boeing's 787 Quality Misses

Aircraft Production Is It Still Too High?

RICH MEDIA EXCLUSIVE

Building a Hydrogen Infrastructure

$14.95 SEPTEMBER 14-27, 2020

AVIATION WEEK & SPACE TECHNOLOGY

BEYOND THE MQ-9

AVIATION WEEK NETWORK

INTERNATIONAL FLIGHT TRAINING SCHOOL

IFTS

AERONAUTICA MILITARE

Powered By LEONARDO

Training
Next Generation Fighter Pilots

Experience, Excellence and Effectiveness

The Italian Air Force's world-renowned excellence in flight training and Leonardo's leadership in delivering proven integrated training solutions, come together to create the International Flight Training School (IFTS).

Based on the Italian Air Force training syllabus, the IFTS offers to each Air Force Training Partner, customized teaching modules further optimizing the download of flight hours from frontline fighters in the Operation Conversion Unit.

The Italian Air Force brings to the new IFTS its long-standing expertise, while Leonardo brings its proven M-346 advanced jet trainer and Ground Based Training System (GBTS) with Live, Virtual and Constructive capabilities.

JESSE H. NEAL AWARDS
Est. 1956
2020 Winner
66 WINNER

AVIATIONWEEK & SPACE TECHNOLOGY

September 14-27, 2020 · Volume 182 · Number 18

60 | *NOAA's GOES-East satellite captured this image of a hurricane off the coast of Florida.*

DEPARTMENTS

FEATURES

ON THE COVER

To target the looming threat of mobile missile launchers in Russia and China, Northrop Grumman is developing an SG-2 next-generation hunter-killer UAS that could swarm behind enemy lines or neutralize electronic threats. Defense Editor Steve Trimble's report on this and Lockheed Martin's concept for an MQ-9 replacement begins on page 50. Northrop Grumman concept image.
Aviation Week publishes a digital edition every week. Read it at **AviationWeek.com/AWST**

DIGITAL EXTRAS *Access exclusive online features from articles accompanied by this icon.*

AVIATIONWEEK & SPACE TECHNOLOGY

Editor-In-Chief Joseph C. Anselmo joe.anselmo@aviationweek.com

Executive Editors
Jen DiMascio (Defense and Space) jen.dimascio@aviationweek.com
Jens Flottau (Commercial Aviation) jens.flottau@aviationweek.co.uk
Graham Warwick (Technology) warwick@aviationweek.com

Editors Lindsay Bjerregaard, Sean Broderick, Michael Bruno, Bill Carey, Thierry Dubois, William Garvey, Ben Goldstein, Lee Hudson, Irene Klotz, Helen Massy-Beresford, Jefferson Morris, Guy Norris, Tony Osborne, Bradley Perrett, James Pozzi, Adrian Schofield, Lee Ann Shay, Steve Trimble

Chief Aircraft Evaluation Editor Fred George

Director, Editorial and Online Production Michael O. Lavitt

Associate Managing Editor Andrea Hollowell

Art Director Lisa Caputo

Artists Thomas De Pierro, Rosa Pineda, Colin Throm

Copy Editors Jack Freifelder, Arturo Mora, Natalia Pelayo, Andy Savoie

Production Editors Audra Avizienis, Theresa Petruso

Contributing Photographer Joseph Pries

Director, Digital Content Strategy Rupa Haria

Content Marketing Manager Rija Tariq

Data & Analytics

Director, Forecasts and Aerospace Insights Brian Kough

Senior Manager, Data Operations/Production Terra Deskins

Manager, Military Data Operations Michael Tint

Editorial Offices

2121 K Street, NW, Suite 210, Washington, D.C. 20037
Phone: +1 (202) 517-1100

605 Third Avenue, New York, N.Y. 10158
Phone: +1 (212) 204-4200

Bureau Chiefs

Auckland
Adrian Schofield avweekscho@gmail.com

Beijing
Bradley Perrett bradley.perrett@aviationweek.co.uk

Cape Canaveral
Irene Klotz irene.klotz@aviationweek.com

Chicago
Lee Ann Shay leeann.shay@aviationweek.com

Frankfurt
Jens Flottau jens.flottau@aviationweek.co.uk

Houston
Mark Carreau mark.carreau@gmail.com

London
Tony Osborne tony.osborne@aviationweek.co.uk

Los Angeles
Guy Norris guy.norris@aviationweek.com

Lyon
Thierry Dubois thierry.dubois@aviationweek.com

Moscow
Maxim Pyadushkin mpyadushkin@gmail.com

Paris
Helen Massy-Beresford helen.massy-beresford@aviationweek.co.uk

Washington
Jen DiMascio jen.dimascio@aviationweek.com

Wichita
Molly McMillin molly.mcmillin@aviationweek.com

President, Aviation Week Network Gregory Hamilton

Managing Director, Intelligence & Data Services Anne McMahon

AVIATION WEEK NETWORK
By Informa Markets

FEEDBACK

FIDDLING WHILE ROME BURNS

My July viewpoint *(July 13-26, p. 74)* about the systemic mismanagement of GPS and how perennial GPS managers wield enough power to resist accountability points out that this has caused GPS to fall behind the Chinese and European systems while remaining vulnerable to adversary attacks for decades, with resolution still a decade away.

Three great Americans in their fields—Adm. (ret.) Thad Allen, Prof. Brad Parkinson and Capt. "Sully" Sullenberger—coauthored a "rebuttal," "LightSquared Fiasco 2.0" *(Aug. 17-30, p. 66)*, that did not address my assertions head-on. Instead, they restated the argument that Ligado's use of L-band causes harmful GPS interference, which has been soundly debunked by extensive world-class testing, internal Defense Department-National Telecommunications and Information Administration documentation and the world's foremost spectrum management organization, the FCC.

This is deeply troubling because it confirms the worst: GPS is a national security and economic vulnerability. It is time for a reckoning of this mismanagement before a GPS "9/11" takes place in America. The L-band's value to U.S. 5G is clear, as Nokia, Ericsson, Samsung, MITRE and others have confirmed.

Congress must eliminate debilitating amendments in the National Defense Authorization Act—notably the contracting amendment by House Armed Services Committee Ranking Member Michael Turner (R-Ohio) that, disastrously, would give the Pentagon a "veto" over the FCC and punish private companies for freely and legally choosing to build out the L-band 5G network.

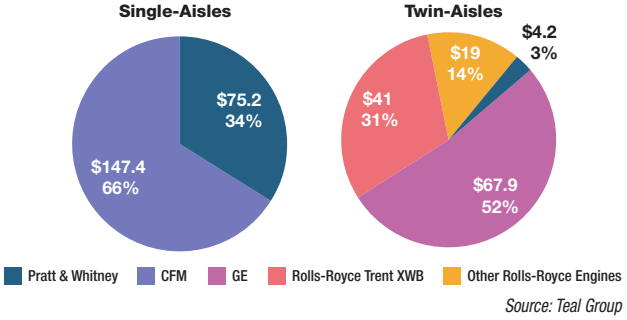
We have a 5G race to win. As FCC Chairman Ajit Pai testified to the Senate in June 2020: "This process has gone on long enough. . . . We made a decision based solely on the facts and the law. I will defend this decision before any forum in this Congress or around the country."

Continuing to oppose the FCC's unanimous, legal and accurate finding—that Ligado bolsters U.S. 5G without harming GPS—is fiddling while Rome burns.

Daniel S. Goldin, Malibu, California

COMMERCIAL JET ENGINES

Expected Revenues and Market Share, 2020-29 (U.S. $ billion)



Source: Teal Group

CORRECTIONS

The slices in the "Twin-Aisles" pie chart accompanying the article "'The Golden Age Is Over'" *(Aug. 31-Sept. 13, p. 16)* were misidentified. The corrected pie chart appears above. The scale for "Growing Military Engine Repair, 2020-29" *(Aug. 31-Sept. 13, p. 9)* should have been "(U.S. $ billion)."

'INFINITE WING'

On behalf of my husband, Roger Read, a long-time subscriber to your magazine who died Dec. 24, 2019, I would like to thank your editorial team for the very excellent tool Aviation Week provided him. In his retirement years—after a long career in aerial survey and aerial photography and as a lecturer and author—he and aviation friend John J. A. Smith endeavored to bring the Infinite Wing, a cutting-edge invention to eliminate wingtip vortices, to the attention of the aeronautics world. In this, *Aviation Week & Space Technology* proved an important source of information.

Since the passing of my husband, Mr. Smith has continued the scientific association started in 2014 with the College of Engineering at Swansea University.

Milton Friedman said: "Only a crisis—actual or perceived—produces real change." Will COVID-19 prove to be such a crisis? The Infinite Wing could offer:

Climb fuel saving >15%
Cruise fuel saving >10%
Descent fuel saving >5%
Simple "bolt-on" wingtips
No spar strengthening needed
Reduced noise footprint
Reduced CO_2 and NOx emissions
No moving parts.

Aviators, take note!

Tuula Read, Enschede, The Netherlands

'UNLOADING' CAVEAT

Regarding "Signs of a Shift" *(July 13-26, p. 18)*, the "Roller-Coaster" method of unloading the stabilizer when using manual stabilizer trim is described in the 1982 Boeing 737-200 pilot training manual and depended whether nose-up or nose-down trim was required.

If nose-up trim was required because the aircraft was in a dive, the technique recommended by Boeing required the nose to be raised initially well above the horizon. This may require both pilots on the controls to raise the nose. Control column pressure is then relaxed, allowing the nose to start to fall. This is called unloading, and simultaneously one or both pilots rapidly wind the manual trim handles backward.

As the nose passes the horizon (and the aircraft picks up speed), the maneuver is repeated until the stabilizer trim is neutral. If this maneuver is simulated when airborne, the Boeing 737 instructor manual warned that the trim was not to be deliberately set more than 2.5 units of stabilizer trim either side of normal. This was a safety limitation to prevent excessive control forces.

Trials reported in your article showing two pilots could exert enough force to move the trim wheel without dropping the nose would have had to have been conducted at relatively low airspeed to be effective.

John Laming, Tullamarine, Australia

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

Kendall Goodman has been promoted to *AVX Aircraft* president and chief operating officer. Goodman was serving as chief operating officer and also had been senior vice president of the company's Future Vertical Lift effort and program manager of its Future Attack Reconnaissance Aircraft Competitive Prototype. Goodman has been awarded six U.S. patents.

International Airlines Group has named **Luis Gallego** as CEO; he succeeds Willie Walsh, who has retired. Gallego was the head of Iberia and launched Iberia Express; before that, he was chief operating officer at Vueling.

Elizabeth Anderson has been appointed CEO of the *British Interplanetary Society* think tank. She worked at the Confederation of British Industry, The Aldridge Foundation and at the Royal College of Surgeons of England, where she led a major overhaul of governance.

Jean-Paul Alary has been named CEO of *Safran Aircraft Engines*. He succeeds **Olivier Andries**, who has been named Safran executive vice president to succeed Philippe Petitcolin in January 2021. Andries had served with the French finance ministry and the Lagardere group. Alary was head of Safran Power Units (formerly Snecma). Both men are on the executive committee.

Vertical Aerospace has hired **Eric Samson** as head of engineering. He was vice president of engineering and head of design at Jet Aviation.

Gulfstream has appointed **Josh Thompson** as chief financial officer. He had been with General Dynamics Ordnance and Tactical Systems. He succeeds Dan Clare, who has retired.

Lisa Campbell has been appointed president of the *Canadian Space Agency*. Campbell was associate deputy minister of Veterans Affairs Canada and before that led military and marine procurement for the country. She succeeds Sylvain Laporte, who has retired.

Redwire has hired **Al Tadros** as chief growth officer and executive vice president of space infrastructure. He joins Redwire from Maxar, where he was vice president of space infrastructure and civil space.

Wheels Up has appointed U.S. Air Force Lt. Gen. (ret.) **Thomas W. Bergeson** chief operating officer. He succeeds **Jason Horowitz**, who moves to a new role as chief business officer. Bergeson will oversee company operations; Horowitz will focus on business strategy.

Risk management and mission support services provider *Constellis* has hired **Richard Hozik** as chief financial officer. Hozik held executive positions for government and commercial entities.

Astroscale has hired **Sharon Parker-Lines** as UK operations director. Parker-Lines was director of the Oxford Center for Innovation.

Parker Aerospace has promoted **Michael Portela** to group vice president of operations, airframe and actuation. He was general manager at Advanced Atomization Technologies, a Parker Aerospace-GE Aviation joint venture.

GRSi has promoted **Kelly Baldwin** to vice president of defense programs and general manager of the company's Naval Information Warfare Center operations. He was project manager and leader of the platform integration business unit.

Elliott Aviation has promoted **Lawrence Harting** to vice president of operations from vice president and general manager at Flying Cloud Airport in Eden Prairie, Minnesota. He was director of operations and manager of scheduling and planning at Dassault Aircraft Services.

Bombardier Aviation has appointed **Marc Beaudette** general manager of its Fort Lauderdale, Florida, service center, which is planned to move to a new facility at Miami-Opa Locka Executive Airport. **Michel (Mike) Menard** succeeds Beaudette as general manager of the Tucson, Arizona, service center. Beaudette has 30 years' experience with Bombardier. Menard was vice president and general manager for StandardAero and Dassault Aircraft Services U.S.

NASA has named **Catherine Koerner** manager of the Orion program, overseeing development and operations of NASA's newest spacecraft to carry astronauts to the Moon and back. Koerner has been a flight director, space shuttle manager, deputy manager of the vehicle office and manager of the transportation integration office for the International Space Station program.

Renee Martin-Nagle has joined *Eckert Seamans* as special counsel in the firm's Pittsburgh office. She served for more than 20 years at Airbus Americas, retiring in 2011 as vice president, general counsel, chief compliance officer, head of environmental affairs, corporate secretary and board member. She joins Eckert Seamans from water law and resources consultancy A Ripple Effect, where she was CEO and president.

U.S. Navy Rear Adm. (ret.) and Space Foundation CEO **Thomas Zelibor** has joined the *Defense Innovation Board Space Advisory Committee*.

Aerojet Rocketdyne has appointed **Audrey McNiff** to its board. She worked at Goldman Sachs in the hedge funds and sovereign wealth funds departments.

Maintenance, repair and overhaul provider *Elliott Aviation* has named **Melissa Maddox** to its board. She was vice president and general manager for StandardAero in Houston.

Novaria Group has elected **Bonnie Peat** and **James Riley** to its board. Peat was vice president at Parker Aerospace, and Riley was CEO of Consolidated Precision Products.

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.*

FIRST TAKE

For the latest, go to
AVIATIONWEEK.COM

COMMERCIAL

A quality issue with assembly of horizontal stabilizers is slowing deliveries of the Boeing 787, and follows discovery of unrelated defects in fuselage sections of the widebody twin (page 22).

Ed Dandridge has been named senior vice president and chief communications officer of Boeing. He joins from AIG General Insurance, where he was global chief marketing and communications officer.

Embraer is laying off 900 employees in Brazil, 4.5% of its global workforce, blaming COVID-19 and the termination of the planned commercial-aircraft partnership with Boeing (page 58).

China's three state carriers reported a combined 26.1 billion yuan ($3.8 billion) net loss for the first six months of 2020, even as they worked their way back toward normal capacity.

Embattled aircraft connectivity provider Gogo will sell its commercial aviation unit to bankrupt satellite services provider Intelsat for $400 million.

An Etihad Airways 787-10 has begun a series of test flights as part of Boeing's ecoDemonstrator program aimed at reducing CO_2 emissions and noise.

Contracts totaling $33 million for all-electric power train and fuel-to-electric power conversion technologies for future single-aisle airliners have been awarded by the U.S. Energy Department.

E-commerce giant Amazon has received FAA Part 135 air-carrier certification for its Prime Air drone service but does not plan to begin commercial deliveries imminently.

VIEW FROM LONDON

Brexit Threat Returns

The UK aerospace industry is again warning of the dangers of a "no-deal" Brexit after it emerged that the UK government could renege on elements of the Withdrawal Agreement previously struck with the EU.

"The economic impact of the pandemic makes the cost of failure in negotiations especially severe," says trade association ADS' CEO Paul Everitt. His comments came after media reports the UK could tear up elements of the agreement relating to Northern Ireland.

Reneging on that agreement is seen by many as a nuclear option and could result in UK-EU trade talks collapsing. That would leave the UK without a deal with its largest trading partner, in turn damaging an increasingly fragile aerospace industry already ravaged by COVID-19.

"A no-deal outcome to Brexit negotiations is the worst possible result," Everitt says. "Manufacturers in our sectors rely on complex Pan-European supply chains, international regulatory arrangements and access to the EU market as the largest destination for UK aerospace products."

The UK left the EU in January but remains a part of the single market and customs union for a transition period that ends on Dec. 31. The news emerges as the UK aviation industry awaits government plans for a stimulus package like those in France and Germany.

DEFENSE


DRDO

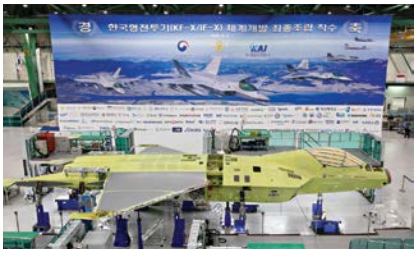
India's defense research organization conducted a 20-sec. scramjet-powered, Mach 6 test flight of the indigenous Hypersonic Technology Demonstration Vehicle on Sept. 7.

The U.S. Air Force has awarded sole bidder Northrop Grumman a $13.3 billion contract for the Ground-Based Strategic Deterrent program to replace the Minuteman III intercontinental ballistic missile.

The U.S. Air Force is to launch a competition between General Electric and Pratt & Whitney to deliver up to 461 engines for its planned Boeing F-15EX fleet.

As a budget debate continues over the helicopter program's fate, Boeing has delivered the first MH-47G Chinook modified to Block II standard to U.S. Special Operations Command.

The UK is investing £317 million ($410 million) in development of an active-array radar for the Royal Air Force's Eurofighter Typhoons (page 28).


KAI

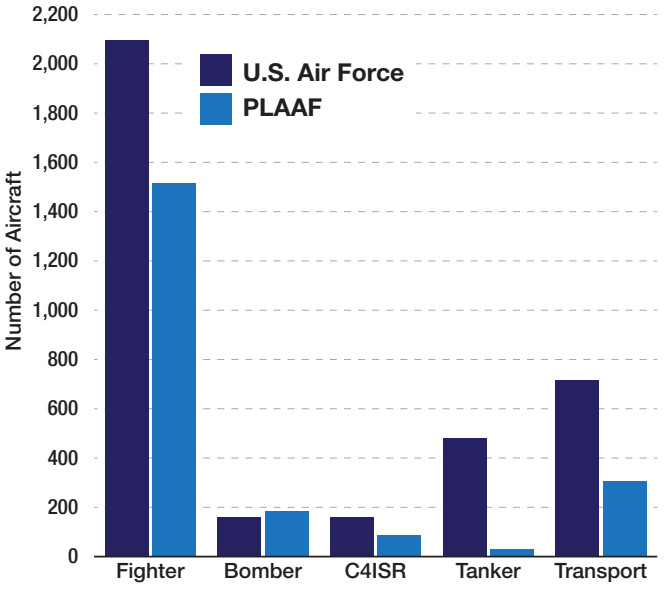
The first Korea Aerospace Industries KF-X fighter prototype has entered final assembly and is scheduled to be rolled out in June 2021.

DARPA and the U.S. Air Force plan to start free-flight tests of Lockheed Martin and Raytheon scramjet-powered missile demonstrators by the end of the year.

Airbus is to deliver 17 uprated, fenestron-tailed UH-72B Lakota helicopters to the U.S. Army and National Guard over the next two years.

SPACE

Launched by a Long March 2F booster, a Chinese "reusable experimental spacecraft" touched down at the scheduled landing site on Sept. 6 after two days in orbit.



Where China's Air Force Still Lags

The latest U.S. Defense Department annual report on China's military notes the People's Liberation Army Air Force (PLAAF) is rapidly catching up with Western capabilities. Aviation Week Network analysis shows that while China has made huge strides in modernizing its fleet, the greatest disparity remains in mobility and power projection: Tankers and transports account for 33% of the U.S. Air Force fleet compared to 15% of the PLAAF's.

To request more information about Aviation Week's Military Fleet & MRO Forecast, go to **pages.AviationWeek.com/Forecasts**

Source: Craig Caffery/Aviation Week Intelligence Network

Arianespace's Vega rocket returned to flight Sept. 3 from Europe's spaceport in Kourou, French Guiana, with a ride-share mission carrying 53 satellites (page 32).

Lockheed Martin and York Space Systems will each build 10 networking satellites for the Tranche 0 Transport Layer of the U.S. National Security Space Architecture, for launch by Sept. 2022.

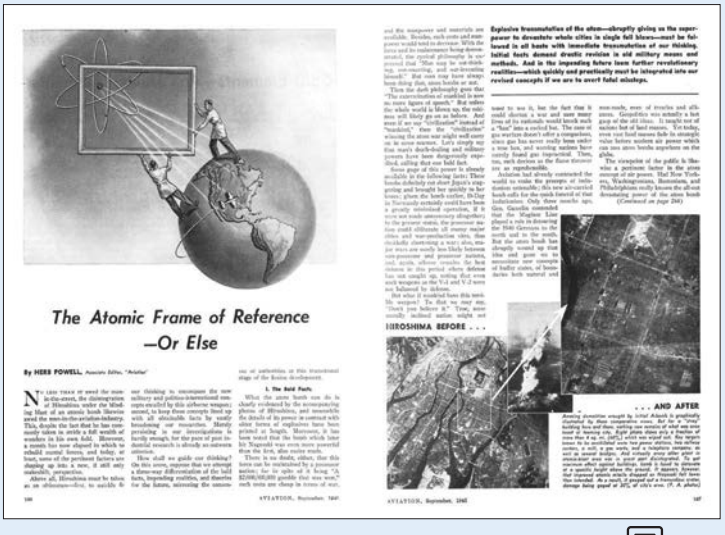
After repeated attempts to sell a solid-propellant, heavy-lift vehicle for U.S. national security launches, Northrop Grumman is discontinuing work on its Omega rocket.

AWARDED

Former NASA Administrator USMC Maj. Gen. (ret.) Charles Bolden is to receive the 2020 Wright Brothers Memorial Trophy for his "public service in aviation and aerospace as an aviator, astronaut and leader," says the U.S. National Aeronautic Association.

75 YEARS AGO IN AVIATION WEEK

Peace came fast in 1945. On Aug. 5, Operation Downfall, the U.S. ground invasion of Japan set for November, was still a "go." One week—and the atomic bombings of Hiroshima and Nagasaki—later, Japan was set for unconditional surrender. Whatever the staff of *Aviation* had planned for the September issue, they pivoted. After an eight-page special feature that meticulously diagrammed the physics of atom splitting, Herb Powell, the associate editor, attempted to grapple with the implications. A survey of Manhattan Project scientists, he wrote, predicted that it would take a decade to harness atomic energy for civilian purposes, which proved eerily precise when the first nuclear power plant opened in the Soviet Union nine years later. In the meantime, the device to look for next, Powell predicted, was the integration of the atom bomb with two other scientific marvels yielded by World War II: Germany's V-2-type missiles precisely guided by "radio-electronic devices." In other words, an intercontinental ballistic missile.


The Atomic Frame of Reference —Or Else

By HERB POWELL, Associate Editor, "Aviation"

HIROSHIMA BEFORE . . .

. . . AND AFTER

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

UP FRONT

RICHARD ABOULAFIA

Forward Planning

A five-part strategy for Airbus

FOR THE TWO BIG COMMERCIAL aircraft OEMs, the next few years will be very tough going. It will be important for them to maintain a strategic plan, a list of goals and directions beyond mere survival. In July, Kevin Michaels' column provided a definitive list of Boeing's priorities *(July 27-Aug. 13, p. 10)*. Here is my equivalent strategic priorities list for Airbus:

❶ **Make a tough twin-aisle choice.** Airbus A350XWB output is falling quickly, probably by at least 50%. Meanwhile, Airbus' other twin-aisle, the A330neo, has an extremely weak orderbook and faces years of two-per-month production rates. The two aircraft are not all that different in terms of capabilities and price point. Airbus must decide whether to bolster A350XWB sales by killing the A330, which would end a profitable long-running program but rationalize production, saving money.

This decision largely comes down to Delta Air Lines, the only truly strategic (and healthy) A330neo customer. Since Delta is also an A350XWB customer, consolidating these orders should not be a problem. Airbus also needs to consult with Rolls-Royce, the engine prime on both programs, since Airbus needs to be mindful of Rolls' health.

❷ **Maintain aircraft design capabilities.** Overall, Airbus' product portfolio is in better shape than Boeing's, since the latter company is heavily dependent on the 737-8 for its single-aisle market standing, while Airbus enjoys a strong presence throughout its narrowbody product line. It will be easy for Airbus to become complacent and coast on this product lineup, though, jeopardizing its strong design capabilities.

So far, unlike Boeing, Airbus has not announced serious R&D budget cuts. Yet it is not really clear what its engineers are doing: Airbus has not had an active new commercial development program since the A350-1000 entered service in February 2018. Factory digitization, green initiatives and ancillary aviation concepts are not the same as designing a new jet. Some kind of new program—even just a stretched A220-500—is essential to keep jet design and integration skills intact.

❸ **Rejuvenate defense.** Two decades ago, Airbus (and predecessor EADS) defense programs were all about to hit their stride. The A400M transport, Eurofighter/Typhoon, Tiger and NH90 helicopters and others had promising futures. Today, these platforms are winding down, with dwindling backlogs.

There are few new European programs, and the most important by far, the Franco-German-Spanish Future Combat Air System, has been given to Dassault. Dassault has a strong fighter culture and is not famous for cooperating with other primes.

For Airbus, the challenge is clear: It must motivate political leaders to create new programs, get more work on existing programs or promote military derivatives of civil platforms such as the KC-30 tanker or H160M helicopter.

❹ **Preserve a global production strategy.** Boeing has six final production lines in three sites: Renton (737) and Everett (777/777X, 767/KC-46, 787, 747) in Washington, and Charleston (787) in South Carolina. The Boeing 747 line is closing, and one 787 line is likely to close, leaving four lines. Airbus has nine lines in five sites: Toulouse (A320, A330, A350, A380); Hamburg, Germany (A320/321); Mobile, Alabama (A220, A320/321); Tianjin, China (A320/321); and Montreal (A220). This line proliferation represents high fixed costs, and in a downturn there will be some temptation to rationalize these sites.

AIRBUS

But in many cases, particularly in China and the U.S., secondary lines have helped to circumvent protectionist trade barriers. While the A330neo may be on the chopping block and the A380 is dying, Airbus would be well-advised to preserve the other seven lines, despite the overhead.

❺ **Leverage better supplier relations.** With Partnering for Success and other initiatives, Boeing has been squeezing its suppliers' margins by demanding price concessions, aftermarket rights and lengthened payment terms. The results are a weakened supply chain and a lot of alienation.

Airbus can take advantage of Boeing's aggressive approach by quietly telling suppliers that it will offer better terms and conditions in exchange for superior and more innovative products. This approach could mean that the next generation of Airbus jets will be more competitive than Boeing's, since Airbus' will be enabled by best-in-class subsystems and technologies that surpass what Boeing's aggrieved suppliers are willing to provide.

The COVID-19 downturn will be brutal. But if Airbus prioritizes long-term outcomes, it will come out of it stronger than ever.

Contributing columnist Richard Aboulafia is vice president of analysis at Teal Group. He is based in Washington.

The Courage to Meet Tomorrow's Challenges Today

IAI draws on innovative solutions and proven technologies to meet today and tomorrow's challenges.
We've been creating exceptional solutions since 1953.
IAI offers tailored interconnected and interoperable solutions within and across domains.
Leap into the future together with us.

www.iai.co.il • corpmkg@iai.co.il

GOING CONCERNS
MICHAEL BRUNO

LEAVE IT TO A SILICON VALLEY software startup to try to puncture the doom and gloom of today's aerospace and defense markets with a ray of hope: Palantir, the big-data cruncher for the U.S. military and intelligence community, expects to go public in a stock offering, according to a recent regulatory filing.

Status Quo

Why the **Old Guard** should not fear the new upstarts

Too bad it means nothing when it comes to changing the sclerotic, government-dependent defense industrial base.

For certain, Palantir is making waves, and not just because it is a rare new entrant to the clubby defense contracting world—where libraries of regulations, decades-long vendor locks and revolving-door relationships make for almost insurmountable barriers against outside competitors. Early last decade, Palantir fought its way onto the U.S. Army's Distributed Common Ground System despite reluctance from service leaders at the time and quiet congressional lobbying from established defense primes.

The company is backed in part by Peter Thiel, who started PayPal with Elon Musk and who has differentiated himself from other tech titans by publicly endorsing President Donald Trump's reelection campaign. In the guise of a prospectus for potential stock investors, Palantir made what amounted to a public oath of allegiance to government customers. The move helped gloss over disclosures that Palantir—with $3 billion in venture capital along with annual revenue—has not been profitable in its 17-year history and lost $590 million last year alone.

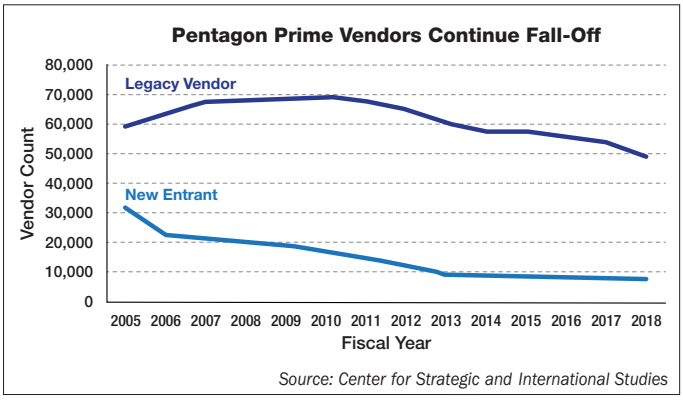
There are other challenges. As AllianceBernstein analysts noted Aug. 25, Palantir still is small relative to the major government information technology contractors such as Leidos and General Dynamics Information Technology. Plus other large defense contractors tend to have operating margins in the high-single-digit range and valuations of just about 1x sales—far below the multiples that investors expect from software companies.

Still, Palantir, Musk's SpaceX and Thiel-supported Anduril—another Silicon Valley startup that aims to marry artificial intelligence, UAVs and sensors for government customers and which in July unveiled a $200 million Series C round of new funding—certainly are attention-getting newcomers to the government contracting arena. But all three have yet to pass the test of time as going concerns—a key feature in a sector where government programs can run half a century, like the B-52—let alone as indicators of new competition in defense acquisition.

Indeed, research continues to show the top tiers of the defense industry to be a nearly impenetrable cadre that is shrinking. Since fiscal 2015, the total number of prime vendors doing business with the Defense Department has fallen 15%, while the number of new prime vendors has dropped 16%, according to a 2019 report from the Center for Strategic and International Studies. At the same time, and despite a multiyear rebound in Pentagon spending, defense contract obligations awarded to the Big Five primes increased 32%.

"These trends, particularly the continued decline in number of new entrants, are troublesome, as the Defense Department and the National Defense Strategy emphasize the National Security Innovation Base and try to attract nontraditional defense companies to do business with the Defense Department," the think tank said.

The COVID-19 crisis is only expected to make it worse. Large pure-plays should come through the pandemic relatively unscathed but may see lower spending growth outlooks, according to Capital Alpha Partners defense analyst Byron Callan. Mergers and acquisitions will become an even more important corporate tool for delivering growth in 2021-25 and will further concentrate the sector.



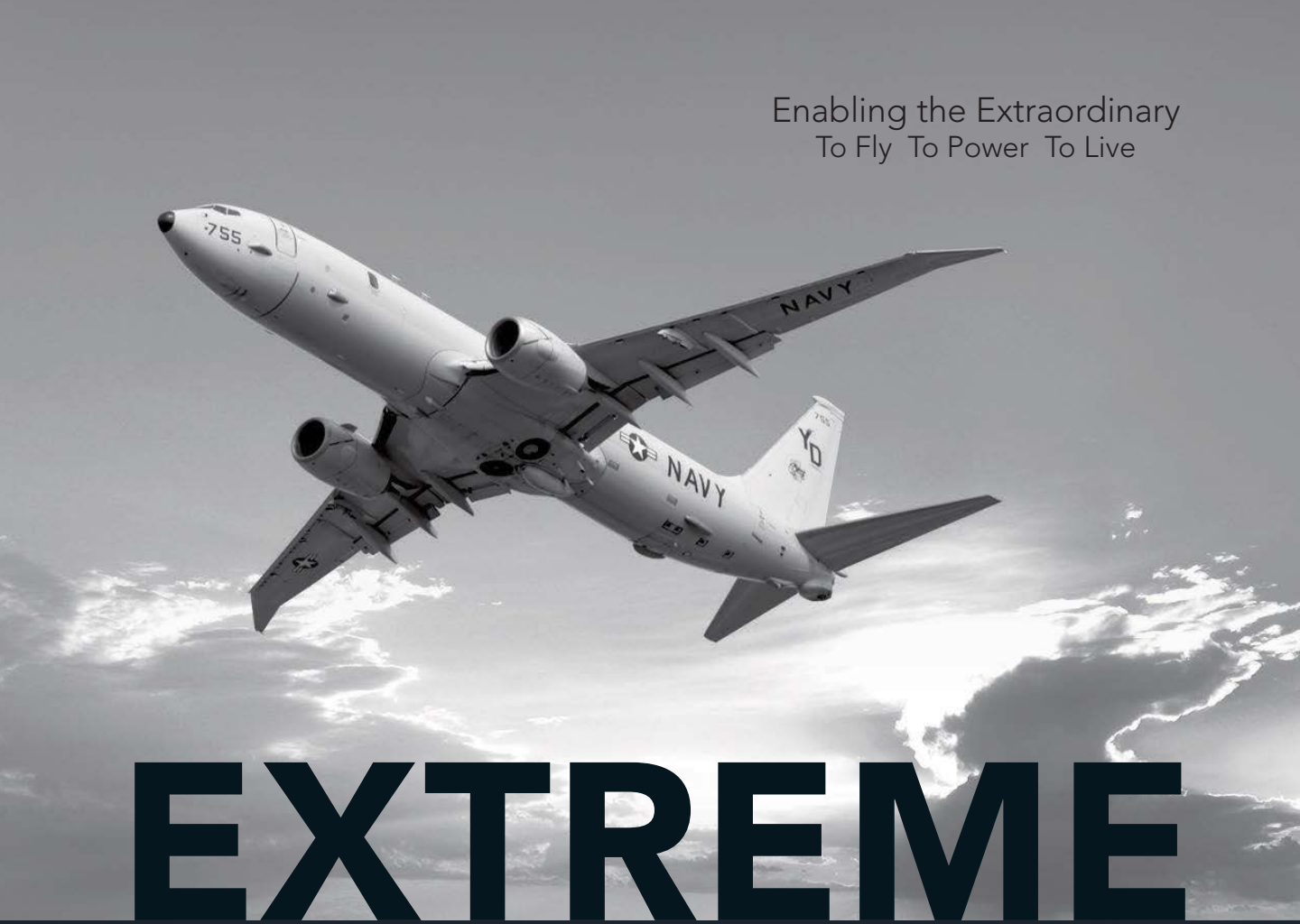
Source: Center for Strategic and International Studies

"One factor that has struck us is the stability among defense contractors over the past 5-10 years," he said in August. "With the exception of SpaceX, there has not been a new entrant that has scaled to multi-hundred million dollars in annual sales."

But do Palantir, SpaceX and Anduril represent a new wave of entrants? Probably not. In a recent letter to defense officials published in *DefenseNews*, several venture capital leaders bemoaned how government, with all its actions to date, seems eager to rally around its legacy primes.

"We need new entrants into the defense industry more than ever, but without government support through crises like this one, the talent and capital simply won't be there," they wrote. "If we see the same old story of the government claiming to support small businesses but prioritizing its old incumbents, those investment dollars will disappear."

Enabling the Extraordinary
To Fly To Power To Live



EXTREME

Advanced thermal management for extreme military environments

Around the globe, military and aerospace systems designers have turned to Meggitt to help them meet thermal and power management challenges with compact, lightweight, and efficient vapor cycle systems, liquid cooling systems and components including fans, pumps and compressors.

Meggitt has developed cooling solutions for the most challenging flight conditions, missions, and extreme environments. From low supersonic flight, to high hot wet hover, to desert and arctic operations, our thermal management solutions are proven and ready to meet the challenge of the more electronic platform and battlefield.

Tel: +1 949 465 7700
E-mail: gerry.janicki@meggitt.com

MEGGITT

www.meggittdefense.com

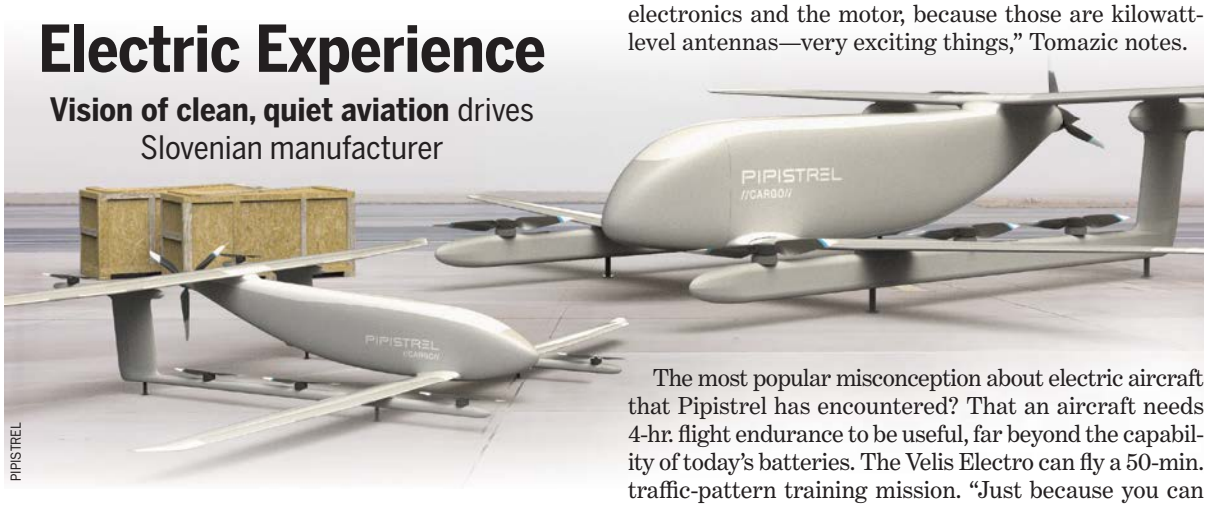
LEADING EDGE
GRAHAM WARWICK

BARELY 20 YEARS AGO, PIPISTREL was a virtual unknown in the aviation industry, a tiny Slovenian manufacturer of small ultralight aircraft. In June, the privately held company entered the history books when it received the first internationally recognized type certificate for an electric aircraft.

European Union Aviation Safety Agency (EASA) certification for the Velis Electro two-seat trainer—and its in-house-developed electric engine and battery system—was not the first aviation milestone for Pipistrel. In 2007, its one-off, dual-fuselage Taurus G4 won NASA's Green Flight Challenge; the battery-powered four-seater exceeded the equivalent of 400 mpg per passenger.

Electric Experience

Vision of clean, quiet aviation drives Slovenian manufacturer



Pipistrel followed up in 2014 with the WattsUp, a proof-of-concept electric trainer that started its journey toward the Velis Electro. Along the way, German aerospace center DLR modified the Taurus G4 into the Hy4, which in 2016 became the first four-seater to fly on hydrogen fuel-cell propulsion. That same year, Pipistrel ground-tested a 200-kW serial hybrid-electric power train.

All this experience proved invaluable in gaining EASA approval for not only the Velis Electro but also a complete licensing, operating and maintenance ecosystem around the aircraft that allows buyers to begin training immediately. "We ship the airplane with the charger as well," notes Tine Tomazic, Pipistrel group chief technology officer.

"Why do we do it?" he asks, referring to electric propulsion. The answer is cost: The energy cost of flying the Velis Electro is just €0.9 ($1.06) per hour. That compares with $40-60 per hour in avgas to fly a popular piston-powered trainer such as the Cessna 172. Factoring in battery replacement takes the Velis Electro to €17 per hour, but even its total operating cost of €33 per hour is a fraction of the $150-200 per hour for a 172.

Pipistrel has learned much by bringing the Velis Electro to market and hopes its EASA certification "will create good precedents for other applicants in the pipeline," Tomazic says. One key has been Pipistrel's electrified flight experience back to the two-seat Taurus Electro of 2007. "How to do it? Fly, fly and fly more," he says.

In ground testing on an iron bird, all elements of the power train operate at the same electrical potential because the system is connected to the Earth. "When you fly, there's no cable to the ground," Tomazic says. "Almost by definition, the components will be floating in voltage. If you don't make sure they all operate at the same potential, you may see interesting things going on."

Other issues relate to electromagnetic interference and cable routing and can range from "some interesting ringing and singing in the radios" to spurious cockpit indications from the air data computers, he says. "You learn a lot about the placement of AC cables between the power electronics and the motor, because those are kilowatt-level antennas—very exciting things," Tomazic notes.

The most popular misconception about electric aircraft that Pipistrel has encountered? That an aircraft needs 4-hr. flight endurance to be useful, far beyond the capability of today's batteries. The Velis Electro can fly a 50-min. traffic-pattern training mission. "Just because you can fly for half an hour or an hour doesn't render this aircraft useless," Tomazic says. "It could be very useful."

Pipistrel is not stopping at the Velis Electro. The company is leading Europe's Mahepa project, which is developing a hybrid-electric propulsion architecture using modular components. This will fly with fuel cells in the Hy4, and batteries and a combustion engine in the Panthera. Under Mahepa, Pipistrel is studying scaling the system up to a 19-seat commuter aircraft.

The company also has announced its next aircraft: It is an electric vertical-takeoff-and-landing (eVTOL) type and a departure from the more than 2,000 light aircraft it has built to date. But it is not an urban air taxi for Uber, as expected. It is the Nuuva family of hybrid-electric unmanned cargo aircraft. With a 1,700-kg (3,750-lb.) maximum takeoff weight and 13.2-m (43.3-ft.) span, the V300 is designed to carry a 300-kg payload 300 km (185 mi.) at 165 kt. The 6-m-span, 100-kg V20 will carry up to 16 kg.

The company slowed work on its Uber design to accelerate development of the unmanned cargo aircraft, arguing regulatory and other constraints could delay entry into service of eVTOL air taxis to 2028. The V300 is planned to enter service in 2023, but deliveries of the V20 could begin as early as 2021. Pipistrel says the simple, reliable Nuuva will be able to operate from standard helipads at a fraction of the cost of a helicopter.


PRATT & WHITNEY
DEPENDABLE ENGINES
GO BEYOND
PW800
A LEGENDARY BOMBER.
AND THE ENGINE THAT TAKES IT FURTHER.
FOR THE USAF AND THE B-52, THE FUTURE BEGINS NOW.
Pratt & Whitney's revolutionary PW800 changes the game for the United States Air Force — and creates new possibilities for what its B-52 can accomplish. With unmatched fuel efficiency — and significantly lower maintenance costs — the PW800 will take the B-52's capabilities to new heights for decades to come.
EXPLORE THE FUTURE OF FLIGHT AT PRATTWHITNEY.COM/B52

THE LAUNCHPAD
IRENE KLOTZ

Jettisoning Racism

MANY OF US HAVE BEEN EXCLUDED—or worse—at some point in our lives due to skin color, gender, sexual orientation, size, religion, family pecking order, etc. We're also, unknowingly or otherwise, part of the problem.

In an effort to raise awareness of discrimination and to stem racist practices and proclivities, ExploreMars.org devoted an opening day panel of its Aug. 31-Sept. 2 Humans To Mars (H2M) summit to the topic of race, an event held virtually this year due to the COVID-19 pandemic.

For many of us, including staff and management of this magazine, our virtual workplaces have become a fruitful ground for new discussions about increasing diversity and combating racism. We all have skin in the game, so to speak.

The takeaway from the H2M panel, moderated by Lockheed Martin's J.R Edwards and planetary scientist Sian Proctor with Arizona's Maricopa Community College District, is that our future on Mars will be determined by who we resolve to be on Earth today, notes ExploreMars President Janet Ivey.

EXPLOREMARS.ORG

Mars exploration advocates **tackle diversity and inclusion**

"I remember when I was in high school I was in the car with my girlfriend, and a police officer rolled up on us," recalled panel member Leland Melvin, a former NASA astronaut and retired National Football League wide receiver. "He took her out of the car and told her that I was raping her because he wanted me to go to jail," Melvin said. "You know, when young black men get into the prison system, they really never get out. They never have a second chance.

"Every father in the black community has a conversation with their son to tell them that if you get stopped by an officer, you assume the position, which is '10 and two' [hands on the wheel]. You're very respectful . . . all these things.

"I've been to space two times. I've ridden this rocket with millions of pounds of thrust, and not once was I afraid going to space," Melvin says. "It's when I've been stopped by police officers I didn't even know that I was starting to sweat and was holding the steering wheel really hard.

"People have to ensure two things," he adds. "Make sure they're not part of the problem . . . and [decide] what are they doing to help—being antiracist versus not a racist."

Panel member Charles Bolden, another former astronaut who served as NASA's administrator from 2009 to 2017, grew up in the segregated South of the 1950s under the specter of lynchings.

Years later at the U.S. Naval Academy, Bolden faced another form of racism. "The assumption was because I was black that I couldn't swim," he says. "I was a competitive swimmer all my life, so I was a damn good swimmer. It was always funny, because the instructors would see [me] get in the pool and they'd go get the shepherd's crook because they thought they were going to have to pull me out."

As his career progressed, Bolden found that "the higher you get in rank, the more subtle" the racism and discrimination became—dogging him all the way into the NASA administrator's office.

Helpfully, panel member Danielle Wood, director of the Space Enabled research group at the Massachusetts Institute of Technology's Media Lab, provided a two-book reading list: *Home* from Nnedi Okorafor's spacefaring science fiction series, *Binti*, and *How To Be An Antiracist* by Boston University's Ibram Kendi.

"I am a space engineer, but my goal is actually to develop research abilities to combine antiracism with our space engineering research so that all of us could then ask ourselves: What am I doing in my job—any job you might have in the space community, anything you're designing or building or leading—to be antiracist while I do it?" Wood says.

"It simply means asking two questions," she continues. "Am I bringing anything from the history of racist ideas and policies in the U.S. and repeating those in my work? And second: When I evaluate the outcomes of my work—whether it's a communications system, a hardware system or an event—who is benefiting, and are people from different racial groups benefiting, equally?"

And the last word goes to NASA's Camille Alleyne, deputy manager of the Commerical Lunar Payload Services program at the Johnson Space Center in Houston, who counsels: Always show up as your most authentic self.

You can view the entire panel discussion, "Celebrating Black Lives in the Space Industry: An Exchange of Leadership Stories and Experiences," on YouTube.

Innovation in Miniature

LEE

WHEN IT COMES TO PERFORMANCE, WE'RE YOUR WINGMAN.

PEACE OF MIND, SINCE 1948.

Count on The Lee Company for relentless support and unsurpassed reliability. That's been our approach for over 70 years, which has placed our field-proven Microhydraulic fluid control components on board every military and commercial aircraft flying today. So, whether you need a standard or custom-engineered solution, choose The Lee Company and relax. We've got your back.

Your Microhydraulics Flight Manual.
The Lee *Technical Hydraulic Handbook* has, for decades, served as the industry-standard engineering reference for hydraulic components. Request your free copy today at www.theleeco.com/new-hydraulic-handbook

The Lee Company **860-399-6281 • www.TheLeeCo.com**

WESTBROOK • LONDON • PARIS • FRANKFURT • MILAN • STOCKHOLM

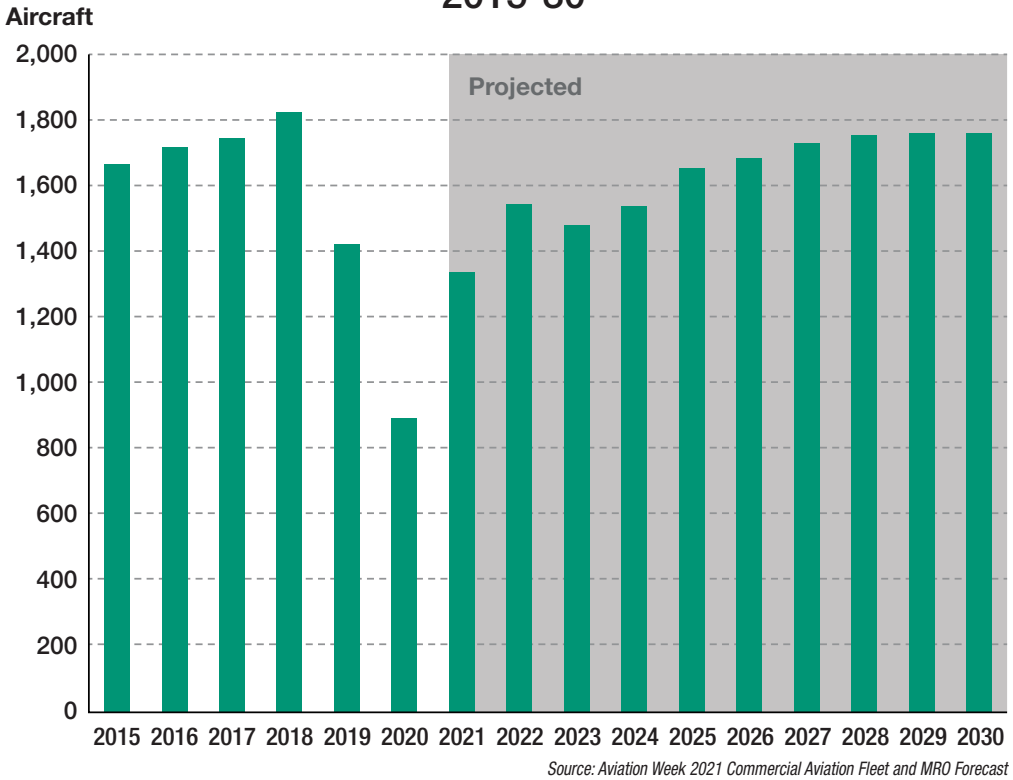
REALITY BITES

> MORE AIRCRAFT PRODUCTION CUTS LOOM, ANALYSTS SAY

> AVIATION WEEK DATA SUGGESTS 16,000 DELIVERIES IN 10 YEARS

> MARKET CONTRACTS BY 30% COMPARED TO PREVIOUS FORECASTS

Annual Commercial Aircraft Deliveries
2015-30



Source: Aviation Week 2021 Commercial Aviation Fleet and MRO Forecast

Jens Flottau Frankfurt and **Sean Broderick** and **Michael Bruno** Washington

Six months after commercial aerospace entered its worst-ever crisis, more data on traffic trends is becoming available, and analysts are beginning to better understand what the near- and long-term outlooks are for commercial aircraft production. New Aviation Week Intelligence Network data suggests demand will be down around 30% over the next 10 years compared to previous assumptions. The more worrying near-term threat is that OEMs have not yet cut production enough and will have to decide on more reductions quickly.

Some big-picture perspective is needed to recap where the industry is. Twenty-nineteen was the last year in what was called a super-cycle. Airlines in the U.S. in particular finally found ways to generate good profit margins—so good that American Airlines CEO Doug Parker predicted they would never suffer a loss again. Traffic growth flattened and overall airline profits declined toward the end of the last decade, but times were still really good.

Aircraft manufacturers believed in a never-ending growth cycle, too. Airbus at one point talked about monthly single-aisle production in excess of 70 aircraft. Boeing was chasing its rival, only to be held back by the grounding of the 737 MAX, angering customers that complained the OEM was destroying network expansion and profits at a time when more capacity was needed.

There is an argument that pre-COVID-19 production planning was too optimistic, even if the good times had persisted.

In its 2019 global market forecast (GMF), Airbus projected a demand for 39,000 new aircraft over the next 20 years, while Boeing saw a market for 44,000 units. If Airbus' projection had been accurate, the industry as a whole could have produced an average of 1,970 aircraft with more than 100 seats annually until 2038. But in 2019, Airbus and Boeing alone would have already ended up close to 1,900 aircraft had MAX deliveries continued as planned. Taking the GMF into account, there was already no more room for any growth beyond last year's rates. And there was hardly any room left for existing or emerging competitors such as Embraer, Comac or United Aircraft Corp. (UAC) that would surely take a share of the large regional/small narrowbody demand—or more painful for Boeing and Airbus, the domestic China and Russia markets.

Going into the COVID-19 outbreak, the thinking was still that there would be a relatively short-term dip through which narrowbody deliveries could be sustained at a relatively high rate. That rate would have even allowed Boeing to resume some level of MAX deliveries from the end of this year or when regulators unground the aircraft. The target OEMs had in mind was to reach the level of production they were used to as quickly as possible. Only a few weeks ago, Airbus CEO Guillaume Faury was still dreaming of a steep rise in narrowbody deliveries from 2022, which admittedly could still happen if things go exceptionally well. But the sentiment from most analysts has now changed. The summer, as illustrated by the July traffic figures released by the International Air Transport Association (IATA), continues to be disappointing. Global air travel is still down 80% from last year, and long-haul international travel is hardly existent as most countries keep some form of travel restrictions in place.

The outlook for the fall and winter, low seasons even in economic booms, is so frightening that IATA Director General and CEO Alexandre de Juniac is now calling for a second round of government bailouts: "The initial round of measures will need to be topped up, and the debt burden cannot be increased," he said. According to IATA, governments have pumped around $120 billion into the airline sector globally to avoid financial collapse.

"If airline passenger volumes don't start to improve meaningfully in 2021, we are likely to see further aircraft production rate cuts," writes Jonathan Root, senior vice president at Moody's Investors Service. Large commercial aircraft production will be around 30-40% lower than 2019 levels in 2021. New-aircraft build rates will partially depend on resumption of Boeing 737 MAX production, with manufacturing volumes for other aircraft remaining flat or even declining, Root wrote in an Aug. 27 report.

The outlook from credit analyst Root matches what a growing list of sell-side stock analysts are expecting. A trio of AllianceBernstein analysts told their investor clients on Aug. 24 that they are not seeing substantial improvement in prospects since a June industry report. Doug Harned, George Zhao and Caius Slater said they expect Airbus and Boeing to eventually deliver most airplanes currently in production, as airlines have already paid in cash and the aircraft have been built for specific carriers. But they see risk rising later this year and into 2021, with airlines reluctant to put more cash into progress payments.

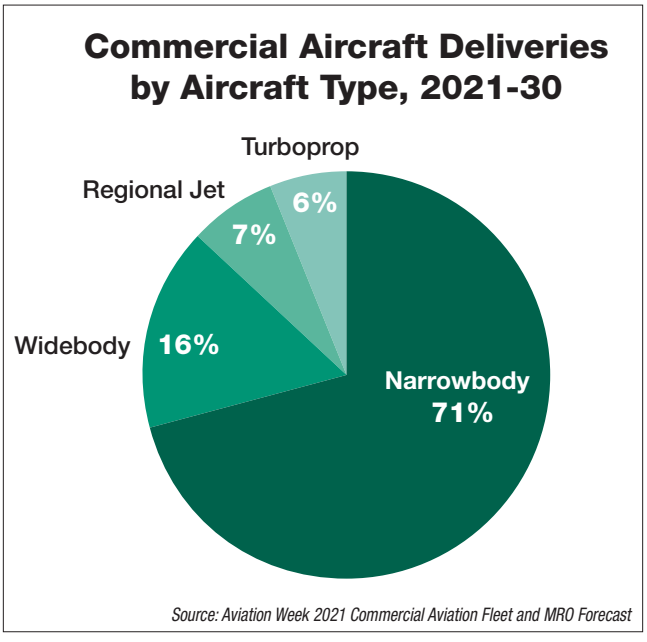
"Even with high replacement demand, which we expect, production rate plans at Airbus and Boeing through 2023 are too high relative to deliveries," they said. "This is particularly an issue for Airbus, which intends to produce 40 A320neos per month through 2021. Airbus was able to deliver those in July, but we do not believe that rate can be sustained. It is an issue for Boeing and Airbus on widebodies, [as both] are already delivering far fewer airplanes than they are producing. If one expects a global resolution of COVID issues in 2021 that could change the outlook. But we see the odds as against that."

Agency Partners analyst Sash Tusa wrote to clients: "We remain very surprised that, given an arguably weakening COVID-19 backdrop, and impending oversupply as Boeing restarts 737 MAX deliveries, Airbus should even be talking about raising production rates, let alone from as early as the second half of 2021. We suspect that Airbus and Boeing are now playing a potentially damaging game of chicken: Neither will cut rates until airlines agree to pay the costs of the deferrals, especially since premature cuts might cede deliveries share to the competitor."

Airbus so far cut rates for the A320neo family from 60 to 40 aircraft per month, for the A350 from 10 to five, and for the A330neo from five to around two. But Tusa argues more painful reductions have to be made. He predicts that A320neo rates will shrink to 24 aircraft per month in 2021, while A220 output will go from four per month in 2019 to two, new-build A350 aircraft will be down to three, and A330neo production will drop to two.

In 2025, Tusa expects Airbus to produce no more than 46 A320neo family aircraft monthly, as well as six A350s, six A220s and three A330neos.

However, Charles Armitage, European Aerospace and Defence analyst at Citi Research, has a different view. "What [Airbus] is doing is not stupid," he says. "If you believe that 2,400 aircraft is the demand over the next four years, then it is a sensible thing to do." He argues that it is not very painful to build up inventory in a low-interest-rate environment because it saves Airbus the difficulty of cutting back and then rebuilding in a few years and does not disrupt production unduly. The question is whether the market will recover to the expected level and when it will do so. "There are huge uncertainties," Armitage says.



JENS FLOTTAU/AW&ST

This factory-new Finnair Airbus A350 is one of thousands of aircraft currently stored.

Another twist comes from the opportunities for order cancellation and deferral stemming from the MAX debacle. "Earlier this year, we thought having 737 MAX exposure was a liability for U.S. airlines, and in January we downgraded Southwest Airlines on this," Vertical Research Partners wrote Aug. 19. "Now we view a MAX orderbook purely as a source of fleet optionality, a valuable asset when the demand outlook is less certain than ever."

What Vertical's Rob Stallard, Karl Oehlschlaeger and Darryl Genovesi mean is: Because Boeing has failed to meet its contractual commitments, firm MAX orders have become options for airlines to take MAX deliveries "if and when they see fit." Vertical's forecast is that Boeing will deliver only 45 MAXs this year and just 192 in 2021. That would equate to 53% of the currently parked MAX inventory, with the rest being delivered in 2022.

"While this means that our 737 production forecast is more elongated than Boeing's plan of getting to 31 [aircraft per] month in early 2022, we still think there is downward risk to our estimates," they add. "For airlines to be taking these 237 new MAX aircraft in 2020-21 is dependent on [re-certification] timing, demand recovering, no further coronavirus waves, and no additional trade war flare-ups."

According to the Aviation Week Intelligence Network forecast, the active global air transport fleet will be 10% smaller at the end of 2020, compared to a year earlier, thanks to a blend of retirements, temporary storage and a precipitous drop in deliveries. Looking further ahead, lower demand coming out of the novel coronavirus pandemic will reduce new-aircraft deliveries 30% in the decade ahead compared to pre-downturn projections.

Global passenger and cargo carriers will have 27,300 aircraft in service on Dec. 31, down from 30,500 at the start of the year, the revised figures show. The net decline of 3,200 aircraft includes a projected 720 retirements, or 2.4% of the active fleet.

Deliveries this year are projected to total just 895 aircraft. The timing of the Boeing 737 MAX return-to-service approvals could affect this number, as the manufacturer has more than 450 built MAXs sitting in storage that it would very much like to hand over to customers. Assuming regulators do not start granting MAX approvals much before late in the year, however, an aggregate delivery total of fewer than 1,000 new aircraft is a strong possibility.

If so, it would mark only the 10th time in the last three decades that air transport manufacturers jointly handed over fewer than 1,000 aircraft in a calendar year—and the first time since 2006. Last year's total, held down by the MAX delivery halt that kept some 400 aircraft from entering service, was 1,425.

The drop in deliveries and jump in both retirements and temporary removals will leave the year-end 2020 global fleet of aircraft certified for 19 or more seats on par with 2015's fleet size, underscoring the pandemic's ramifications on global air traffic demand.

While retirements are on the rise, many stored aircraft are expected to rejoin operators' fleets to support demand recovery. Aviation Week projects 2,100 aircraft returning from long-term storage by 2023.

The global fleet is projected to grow at a compound annual growth rate of 2.4% in 2021-30, resulting in a fleet of 38,300 aircraft, the forecast says. New deliveries will total 16,200 during the decade—about 30% lower than prepandemic estimates.

Widebody deliveries likely will total about 2,500 during the 10-year stretch, which is 42% below the prepandemic forecast, reflecting the slower expected return of long-haul demand. Narrowbody deliveries will top 11,500—a 28% decline compared to prepandemic calculations. Regional jets, already on the decline, thanks largely to upgauging trends, are projected to account for 1,150 deliveries, or 38% less than before the COVID-19 outbreak.

In other words, there is room for an annual average of 1,150 narrowbody deliveries for the entire industry, 250 widebodies and 115 large regional jets. In 2018, Airbus and Boeing combined delivered 1,225 narrowbodies (and only 816 in 2019 because of the MAX grounding). The two OEMs handed over 380 widebodies in 2018 and 426 last year, showing the degree of contraction that is needed to adjust to the new demand level.

Airlines will permanently retire nearly 9,200 aircraft during the decade, the Aviation Week forecast shows. Calendar-year peaks are projected to come in 2028 and 2029, with each year expected to see more than 1,000 retirements.

The average of 920 retirements per year during the coming decade is a notable jump over recent figures. Aviation Week data shows that annual retirements in 2015-19 averaged 657 before climbing to a projected 720 in 2020, in part due to the pandemic's fallout.

Check 6 *Aviation Week editors discuss why Airbus and Boeing will need to further trim output to ride out the COVID-19 crisis:* **AviationWeek.com/podcast**

Without answers, we're stuck on Earth.

To solve problems, do business, and work together to answer important questions like these, join the smartest and most ambitious leaders from around the world 16-18 November 2020 at ASCEND, online.

This international event is designed to deliver technical and non-technical content in a highly interactive format. Join representatives from 550 leading organizations in the space ecosystem for 90 technical sessions, 30 workshops, 4 keynotes and networking. Don't miss out.

ASCEND

16–18 November 2020 | Online

Save 25% Now

ascend.events

Powered by AIAA

INAUGURAL CORNERSTONE FOUNDING SPONSOR

LOCKHEED MARTIN

Two issues affecting Boeing 787 rear fuselage sections were introduced during production in Boeing's Charleston, South Carolina, facility.

SEAN BRODERICK/AW&ST

New 787 Problems Spotlight Boeing's Quality Issues

> AIRCRAFT-MAKER CONFIRMS THREE NEW 787 PRODUCTION ISSUES

> HUNDREDS OF AIRCRAFT COULD BE AFFECTED

Sean Broderick Washington and **Guy Norris** Los Angeles

Production mistakes on scores of Boeing 787s will intensify scrutiny of the manufacturer's quality-control capability and could place it in violation of a 2015 agreement with the FAA triggered by other manufacturing problems, including some on the 787 program.

Boeing has discovered two seemingly unrelated defects introduced in composite fuselage sections during 787 production and a third in the aircraft's horizontal stabilizers. One fuselage issue involves shims, or material added during assembly to fill gaps between structures or adjust how pieces fit together to ensure tolerances are met.

The composite material that makes up the 787 fuselage is extremely stiff when cured. Achieving the correct corner angle between the cured part and final shape is hard to control, so shimming is used to make parts of the 787 fuselage sections mate together. In some 787s, Boeing found the shims are not the correct size.

The second defect is an out-of-tolerance problem with the fuselage's inner mold line. The defect areas exceed Boeing's 0.005-in. tolerance limit for flatness, the source says.

Boeing determined eight 787s have both defects, which together make those aircraft susceptible to structural failure at loads they are designed and certified to withstand. This prompted Boeing to tell affected operators to ground the aircraft for immediate inspection and likely repairs that will take at least two weeks per airframe. The fuselage production issues were first reported by *The Air Current*.

The third issue came from stabilizer parts that were not assembled per Boeing's design specifications. While there is no immediate risk, premature aging of affected parts could require in-service repairs.

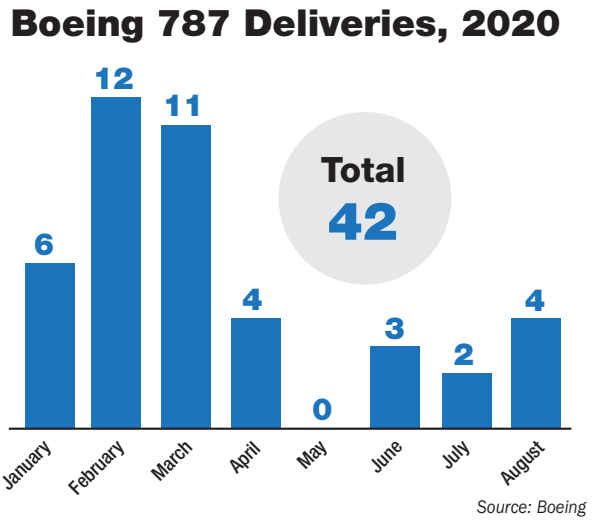
The manufacturer declines to say how many of the 980 787s built so far have one of the defects. A source with knowledge of the issue confirms that "many" airframes are affected, while a second industry source says the figure is "several hundred." Boeing acknowledges there are three issues but declines to discuss their scope.

"Boeing has identified two distinct manufacturing issues in the join of certain 787 aft body fuselage sections, which, in combination, result in a condition that does not meet our design standards," the company says. The issues were discovered during a "regular" production-system audit "as part of our quality management system," Boeing says.

The FAA confirmed it is "investigating manufacturing flaws affecting certain Boeing 787 jetliners," adding that it is "too early to speculate about the nature or extent of any proposed airworthiness directives that might arise from the agency's investigation."

The stabilizer issue, uncovered in an internal audit this year, affects subassemblies produced at a Boeing facility in Salt Lake City.

Certain parts were assembled with greater force than specified in Boeing's build documents, resulting in larger-than-specified gaps between certain pieces, the company



says. The target maximum gap tolerance is 0.005 in., and shims are used to fill in any extra space. Improper gap verification can lead to shims that are the wrong size.

While there is no immediate safety threat, Boeing says one ramification could be more rapid aging of the affected parts. Boeing and the FAA are analyzing the in-service fleet for potential action. The manufacturer said it has addressed the issue in its production process.

One near-term ramification has been a slowdown in deliveries. Boeing is producing 10 787s per month, but after handing over 29 in the first three months of 2020, it delivered only 13 in the five months ended Aug. 31, company figures show.

Part of the discrepancy is rework being done on the widebodies that is delaying handovers to customers, the company says.

The two fuselage issues are more urgent. Neither problem on its own creates an immediate safety-of-flight issue, Boeing says.

"Individually, these issues, while not up to specifications, still meet limit load conditions," or the maximum aerodynamic load the design is expected to experience in service, Boeing says.

"No immediate action is required for the rest of the fleet," the manufacturer adds. "We are analyzing data on the in-service fleet to determine if action is required, potentially including more frequent inspection or rework. It could also be determined that no further action is required if the condition is found to not impact the longevity of the structure."

Half the 787's airframe by weight consists of carbon-fiber-reinforced plastic and other composites, which was groundbreaking at the time it entered production. Known issues in a few hundred 787 fuselages in service could provide some of the most comprehensive information to date on how defects progress in pressurized composite airframe structures.

"Aluminum has been around [in airplane design] for 100 years," one veteran materials engineer and nondestructive testing expert says. "We have a lot of experience with it. Composite structures—we don't have that history. There's a big learning curve . . . on these airframes. We can speculate, but we don't know for sure."

The new fuselage defects affect the join between the 787's two composite aft fuselage sections, known as Section 47, which is pressurized, and Section 48, which is unpressurized and supports the empennage, or tail, section. Both sections are made in Boeing's Charleston, South Carolina, manufacturing facility, which it purchased from Vought Aircraft in 2009. The sections are then joined and moved to one of the two 787 final assembly lines—either in Charleston, which assembles all 787 variants, or in Everett, Washington, which assembles 787-8s and 787-9s.

Boeing has dealt with 787 fuselage-shimming problems in the past. A 2014 FAA review of 787 design, certification and manufacturing states that Boeing "identified a significantly higher number of nonconformances related to shimming as compared to other fuselage sections" with similar design features. "Aft fuselage shimming issues were identified in production and in the full-scale fatigue test," explains the report, prompted by overheating incidents of in-service lithium-ion batteries that led to the fleet's 123-day grounding in 2014.

Although most of the shim problems were found and corrected before delivery, five aircraft entered service with "potentially discrepant shims," leading Boeing to issue an alert service bulletin to ensure they were fixed.

Word of new, extensive production issues expands on a long-running series of quality-control deficiencies that have affected several Boeing aircraft programs. In December 2015, Boeing and the FAA agreed to a settlement after the agency dug into two main issues—using noncompliant fasteners and missing deadlines for providing instructions on the installation of fuel tank inerting systems. During the FAA's probe of those issues, 11 others came to light, including some "production quality-control problems," the agency said in its 2015 announcement of the settlement.

Boeing is evaluating the in-service 787 fleet for possible repairs.

JOEPRIESAVIATION.NET

One issue involved incorrectly installed 787 engine fuel feed manifold couplings. Boeing found three problems with coupling assemblies—incorrectly installed or missing O-rings, lock wires and fastener retaining rings. In November 2012, Boeing revealed that 38 of the first 787s built had at least one of the flaws, and 31 had all three. Fuel leaks on at least two in-service aircraft were traced to the problem, prompting the FAA to issue an immediately effective air-

worthiness directive in December 2012. The 2014 report cited "a lack of clarity and verification for certain fuel coupling installation requirements" for the problems, adding that they did not comply with Boeing's quality management system.

Under the settlement agreement, Boeing agreed to pay $12 million—half of what the FAA proposed—and commit to a series of process improvements. Among them was using a safety management system to "proactively seek continual process improvements and correct undesired conditions," the agreement says. It also requires Boeing Commercial Airplanes (BCA) to "implement improvements to processes to ensure that assembly installations that have been affected by process or design changes continue to conform to type design."

The agreement's "performance period" lasts through January 2021. "In the event that BCA does not meet its commitments under this agreement, BCA and the FAA agree that BCA shall be subject to additional civil penalties up to $24 million," states the agreement, made public following a 2017 Freedom of Information Act request by *The Seattle Times*.

Boeing's latest 787 problems come as it grapples with ongoing quality control issues on its KC-46 tanker and 737 MAX programs. In both cases, numerous instances of tools and other foreign object debris (FOD) left inside completed aircraft have drawn scrutiny and concern.

Border Openings and Uniformity Crucial to Airline Recovery, CEOs Say

> SOME NATIONS ARE WORKING TO RESUME TRAVEL, BUT OTHERS ARE RELUCTANT

> AIRLINES WANT STANDARD APPROACH TO COVID-19 RESTRICTIONS

Adrian Schofield

Reopening borders is one of the most urgent concerns for airlines as they grapple with the COVID-19 crisis—not just to ensure immediate survival but also as an essential ingredient for long-term recovery.

The importance of this issue made it a hot topic for airline leaders at the CAPA – Centre for Aviation Australia Pacific Aviation Summit, held as a virtual event on Sept. 2. Industry CEOs and senior executives stressed the need for more action and uniformity on relaxing border restrictions, both for international travel and between states in the same country.

Scoot CEO Campbell Wilson notes that Singapore has been one of the most proactive in terms of easing entry and quarantine requirements for certain countries identified as low risk. There is no quarantine needed for inbound travelers from New Zealand or Brunei, and it has been halved for those from six other countries. COVID-19 tests are still required, however.

Singapore has also negotiated travel corridors with at least four countries, but these are for essential travel only. Unlike the quarantine reductions, the travel corridors are bilateral rather than unilateral moves.

The Singapore government "clearly gets the necessity" to open borders, says Wilson. This aligns with the country's strategy to be a regional hub for shipping, aviation and finance.

However, there is a "reluctance" from other Asia-Pacific countries to follow suit, except for the essential travel corridors, Wilson says. So Singapore does not have reciprocal agreements for its unilateral initiatives to reduce quarantines.

There have also been no multilateral travel arrangements involving more than two countries formed in the Asia-Pacific region. Progress in this regard is "frustratingly slow," Wilson says. "The ingredients are there, [but] we just don't see a shared appetite yet."

Whether or not countries take a more progressive approach is "very much driven by domestic politics," he says. Factors include how much political capital a government has, the country's economic dependence on trade and tourism, and the degree of isolationist sentiment. The countries that open first will be those "where there is an understanding that interconnectedness is a necessity for economic success."

Proximity, familiarity and economic ties will determine which countries open their borders to each other first, Wilson says. This means "neighbors will open to neighbors" before looking further afield. But they will still need to develop trust in each other's COVID-19 testing and reporting.

Development of a vaccine will help, but "will not be a silver bullet," says Wilson. "Rapid, cheap and effective testing is what we're all waiting for."

Japan is another country where the government is taking steps to reopen international travel, says Tadashi Fujita, vice chairman and director for Japan Airlines. The government is opening travel corridors—described as business or residence tracks—with multiple Asian countries. It is also considering relaxing entry restrictions more broadly for travelers from Australia, New Zealand, Thailand and Vietnam.

Fujita says the expansion of COVID-19 testing capacity "is one of the essential factors" in the government's plans to resume international travel. In July, 2,000 tests per day could be carried out on inbound passengers. But this rate is expected to increase to 10,000 tests per day, thanks to new testing centers at Haneda Airport and Narita Airport in Tokyo, and at Osaka's Kansai Airport.

Qatar Airways CEO Akbar Al Baker says the wide variety of national standards for closing borders or restricting flights due to COVID-19 is one of the airline's main challenges in operating internationally.

There needs to be more uniformity regarding when and how airports are opened or closed to international traffic, Al Baker said during the CAPA summit. He urged international organizations to become more involved in establishing global standards on this issue.

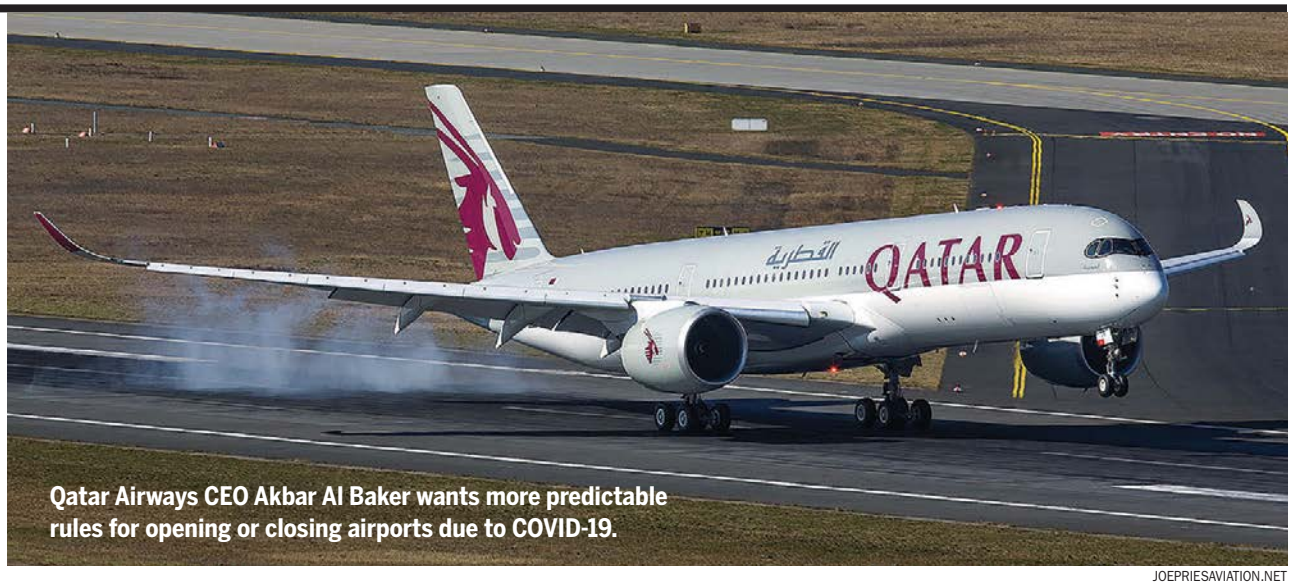
Standardized requirements would allow airports to open safely and efficiently, Al Baker says. He notes that differing quarantine standards are also confusing passengers and airlines. When COVID-19 vaccines

The U.S. Air Force has halted deliveries of the 767-derivative KC-46 multiple times due to FOD discovered during both routine production and nonroutine rework. The FOD issue is one of several that has hampered the program.

Boeing in recent months made changes to its 737 production line to combat rampant FOD issues discovered in 737 MAX fuel tanks. The model has been grounded since March 2019 to correct design- and training-related shortcomings linked to two fatal accidents in five months, and production was briefly paused earlier this year.

The fallout from the MAX accidents and prolonged grounding have prompted Boeing to make a series of organizational changes aimed at elevating safety concerns to the top of the company and ensuring aircraft are built as designed. One emphasis is granting—many would say returning—more influence to engineers, in part by reorganizing them out of business units and under one line of leadership.

"I believe that the alignment of our company—the centerpiece being the [single] engineering function with its eye on safety—will have the authority and the charter" to drive across-the-board improvements, CEO David Calhoun told Aviation Week in July. The Boeing boss is confident the revamped approach gives the right internal stakeholders "the ownership and the visibility to get ahead of issues, as opposed to catching up to them."



Qatar Airways CEO Akbar Al Baker wants more predictable rules for opening or closing airports due to COVID-19.

JOEPRIESAVIATION.NET

become available, internationally recognized health certificates should be issued, he says.

Al Baker says some airports have extended international traffic closures with just one or two days' notice, forcing last-minute cancelations. He says national authorities should provide notice at least 15 days in advance if they are going to extend closures. The carrier has cut back plans to add more destinations next month because of the uncertainty regarding border closures, says Al Baker.

Australia remains closed to most international travelers. Qantas does not expect to see meaningful levels of international traffic return until the middle of 2021, although individual travel bubbles with countries such as New Zealand could come earlier than that.

The immediate concern for Australian airline CEOs is reopening domestic borders between states. A resurgence in coronavirus cases has caused most Australian states to restrict or block domestic travel from certain other states.

Qantas, Virgin Australia and Regional Express Holdings (Rex) have all reported strong demand for routes within individual states, but interstate flights have been reduced to a trickle. Getting state borders open "will make a huge difference" to domestic demand, said John Sharp, deputy chairman of Rex.

Qantas CEO Alan Joyce contends that state border closures are currently not based on scientific or fact-based criteria. He is urging the development of nationally agreed upon standards to determine when COVID-19 restrictions should be removed from travel between states or applied in more specific localities. "Business doesn't like uncertainty," he says.

While Qantas has enough liquidity to survive the state closures for some time if necessary, the same is not true for smaller tourist operators, says Joyce. He notes that it will be a big blow for the economy and leisure travel if the tourist ecosystem disappears.

Australian Prime Minister Scott Morrison has been pushing for states to reopen their borders and instead focus on isolating smaller "hot spots." He wants Australian state border restrictions to be removed by Dec. 25.

Taking a more localized approach to domestic travel restrictions would be better than the "blunt instrument" of shutting down an entire state, says John Hart, executive chair for tourism of the Australian Chamber of Commerce and Industry.

Virgin Australia CEO Paul Scurrah says he agrees with Joyce's calls for "medical [and] fact-based decision-making" regarding state borders. It "doesn't make sense" when cities with low COVID-19 rates cannot be connected, he says. There should be more of a "market-by-market decision process."

Scurrah says Virgin Australia would also welcome the chance to resume flights to New Zealand. "If that opens up soon, we'd jump at it. We've got aircraft we want to deploy there and New Zealand is part of our future plans. . . . The sooner we can be back there the better," he says.

European Airlines Warn of Barriers to Recovery

- NORWEGIAN CAUTIONS IT MAY NOT SURVIVE WITHOUT MORE CASH
- RYANAIR CUT ITS SEPTEMBER AND OCTOBER CAPACITY

Helen Massy-Beresford Paris and **Jens Flottau** Frankfurt

Summer 2020 was far from a bumper season for Europe's COVID-19-hit airlines, but by offering cheap deals and flexible tickets to lockdown-weary travelers in need of a change of scene, they managed to make the best of it. Now, in September, with infection rates on the rise and travel restrictions tightening, airlines face a brutal reality check.

According to the latest figures from Eurocontrol, the recovery in air traffic has stalled at just under half the levels seen in 2019. Airlines and airports blame the inconsistent travel regulations put in place by individual governments, which they say are harming traveler confidence.

The International Air Transport Association (IATA) called for governments to implement International Civil Aviation Organization guidelines globally, reopen borders and create an effective system of COVID-19 testing, as it reported on a "disappointing" July, in which traffic levels were below what it had forecast.

According to IATA, July traffic came in at 79.8% below last year's level, whereas airlines offered 70.1% less capacity. The combination of low traffic and excess capacity led to an all-time low load factor of 57.9% for the industry. The Asia-Pacific region had recovered the most after a decline of 72.2%, whereas demand in North America was still down 80.6%, and traffic in Europe dropped 81.3%.

The trade association also said further government financial assistance would be needed for the industry and called for the European Union to suspend the 80-20 slot rule for the upcoming winter season. That slot waiver is seen as so important that IATA and other airline and industry associations have put forward a set of conditions that they hope will allow the Commission to swiftly approve it.

Since a COVID-19 vaccine—the key development needed for a return to more normal levels of air traffic and long-haul activity—is still months away even under the most optimistic forecasts, airlines must adjust to the new reality.

"We were all looking forward to a good summer," says Thomas Reynaert, managing director of European airline industry body Airlines for Europe. "Even in difficult times, there was some optimism because the general economy was picking up just before the summer. But unfortunately, the airline business hasn't followed the economic trend as it usually does."

The gloom is not limited to Europe. Airports Council International expects passenger volumes to be down 59.6% in 2020 compared with its precoronavirus forecast, and it believes that passenger volumes will not recover to 2019 levels before 2023. Markets that rely on significant international traffic are not expected to rebound until 2024.

In the near term, statistics released by Eurocontrol on Sept. 7 show that traffic for the week of Aug. 31-Sept. 6 reached 47.9% of 2019, or 16,769 flights a day on average; that represents a drop of 511 flights per day compared with the previous week. Eurocontrol Director General Eamonn Brennan previously warned that the recovery has reached a "plateau," partly because of state restrictions.

Reynaert also points out that while Eurocontrol numbers show evolving patterns in traffic, they do not take into account load factor and booking trends. "This summer, we [did not see] the amount of passenger traffic and the revenue that we hoped for," he says.

"We have also seen many late bookings, which are a challenge for airline planning. In terms of load factors, we've seen a very diverse picture, with some of the LCCs doing relatively well. But overall load factors have been well below 70%."

Eurocontrol says it expects very limited growth in September, as airlines adjust their schedules to reflect the evolution of COVID-19 travel restrictions in the region.

Ryanair, by far Europe's busiest carrier—with 1,400 daily flights on average during that week compared with its closest competitor EasyJet's 781—said on Aug. 17 it would cut capacity in September and October by almost 20% because of weak forward bookings due to the uncertainties about COVID-19 case rates and travel restrictions.

Wizz Air says capacity may recover more slowly than forecast because of travel restrictions.

JOHN MACDOUGALL/AFP/GETTY IMAGES

British Airways is still operating less than 20% of its schedule.

JOEPRIESAVIATION.NET

Among the recent changes, the UK has removed Spain, France and the Netherlands from its safe list of "travel corridors"; arrivals from those countries must self-isolate for 14 days or face a fine. In response, Willie Walsh—CEO of International Airlines Group, the parent company of British Airways, which is still operating less than 20% of its normal schedule—wrote in *The Times* on Sept. 1: "The UK has officially hung up the 'Closed' sign. . . . Safeguarding people's health is obviously the top priority. But enforced quarantine from an ever-shifting list of countries is not effective."

Budapest-based Wizz Air warned on Sept. 1 that it would restore less capacity than previously expected in the coming months if COVID-19 travel restrictions persist across Europe. Wizz Air's announcement came after Hungary abruptly closed its borders to all nonresidents, with a few exceptions.

Wizz Air said it expected capacity for the three months ending in September to reach roughly 60%, but for the third quarter it would probably remain at that level rather than rise to 80% as previously anticipated, if travel restrictions across its network remain in place. It also warned that further capacity reductions remained a possibility and that it could park part of its fleet throughout the winter season to protect its cash balance.

Air France has already seen the effects of rapidly changing travel rules such as the UK quarantine but is still ramping up its capacity; the airline plans to operate at about 50% of 2019 levels in September and 60% in October, up from 35% in July and 40% in August. Over the summer, Air France served 150 destinations, about 80% of its normal network. In September, it plans to fly to 170 destinations using 163 aircraft—up from 106 in July and August—from its total fleet of 224.

Germany intends to enact a mandatory quarantine for arrivals from high-risk zones beginning in October. The travel industry has criticized this rule change, warning it may soon halt forward bookings to many destinations. In August, the federal government had introduced a control regime that replaced mandatory quarantines with broad testing for passengers arriving from what were considered high-infection-risk countries or regions. Every traveler, regardless of point of origin, could be tested at the arrival airport on a voluntary basis, free of charge; arrivals from one of the high-risk locations had to take a COVID-19 test prior to onward travel.

Only three weeks later, however, the German government changed course again, arguing that the system was unsustainable because of insufficient testing capacity. Instead, every passenger arriving from a high-risk point will again be required to self-quarantine for 14 days, a period that can be shortened if a COVID-19 test taken after five days is negative. The new rules are to be made effective in October, though the exact timing has not been confirmed.

Lufthansa and industry lobby group BDL criticized Germany's decision, saying it would lead to a second lockdown: 80% of the world would no longer be reachable without quarantine upon return, and demand would collapse.

The country's largest airline, having received a €9 billion ($11 billion) government bailout in June, has already told its employees in internal briefings that Lufthansa is falling behind the worst-case scenario laid out in the recovery business plan because people are returning to air travel more slowly than anticipated. Lufthansa plans more draconian measures, including asset disposals and layoffs, uncommon even in times of crisis.

On the fleet side, the airline will soon decide whether it will permanently phase out the Airbus A380s and A340s and Boeing 747-400s, measures that would reduce the widebody fleet by 70 aircraft. The group operated 181 passenger widebodies at the end of June.

With the bailout assumptions looking increasingly unrealistic, industry insiders believe the airline may ask for a second round of government financing in early 2021. The first package, however, came with tight conditions and a commitment on interest rates that spiral up to about 9% after three years. Lufthansa sources say it is unimaginable that it would be in a position to repay a second bailout that has the same or similar conditions, particularly if revenues and cash flow become even more depressed than foreseen.

But without further assistance and no quick recovery, Lufthansa could soon run out of options. Before the first bailout, the airline had considered filing for voluntary restructuring as part of the protective shield process, roughly equivalent to the U.S. Chapter 11 process. At the time, that idea was rejected as too disruptive to employees, customers and investors; however, it could be back on the agenda if traffic does not rebound.

If the future looks bleak even for one of the region's stalwarts, the fate of less financially stable airlines is even more uncertain. And the COVID-19 crisis may well lead to additional casualties in the coming months and years.

Long-haul low-cost carrier (LCC) Norwegian Air Shuttle has said a government loan guarantee may not be enough to get it through the prolonged crisis; on Aug. 28, the LCC warned of a significant risk of insolvency after it reported a net loss of 5.3 billion Norwegian krone ($605 million) for the first half of 2020 and a 71% decline in passenger numbers.

After initially saying it would keep its fleet largely in hibernation mode until next year, Norwegian relaunched some short-haul services during the summer: It operated 20 aircraft in July, and planned to have 25 in service in September.

The airline also plans to restart some transatlantic services in December. Travel restrictions between the U.S. and Europe, however, are still in place—an obstacle not only for Norwegian but also for Europe's legacy carriers, as they contemplate a challenging winter season in which they are still largely locked out of lucrative transatlantic activities.

UK Plans Bespoke AESA for Typhoon Retrofit

> FIRST UK TYPHOONS TO BE FITTED WITH AESA IN 2022

> RADAR WILL USE BOTH GALLIUM ARSENIDE AND GALLIUM NITRIDE SEMICONDUCTORS

Tony Osborne London

The UK has made a long-awaited commitment to the development of an active, electronically scanned array radar for the Eurofighter Typhoon.

The British government is plowing £317 million ($414 million) into the development of the European Common Radar System (ECRS) Mark 2 version of the Euroradar Captor-E—also known as Radar 2—a multifunction array that British officials say will be among the most advanced active, electronically scanned array (AESA) radars yet installed on a Western combat aircraft.

Insertion of the Mk. 2 radar into the Typhoon would make the platform an "ideal partner for the fifth-generation and unmanned-force mix" and would give the fourth-generation Typhoon a "second lease of life," defense officials close to the program told Aviation Week.

In addition to broadening the capability of the aircraft to use existing weapons such as the MBDA Meteor beyond-visual-range air-to-air missile, Radar 2 will provide the UK's Typhoon fleet with electronic attack and electronic warfare (EW) capabilities. Furthermore, its open architecture could enable an evolved version of the sensor to be featured on the UK-led Future Combat Air System, the Tempest, which is due to enter service in the mid-2030s and to which the radar program has "strong ties."

But Radar 2 also arguably adds another complication to the convoluted web of development for the four-nation fighter, which now has three largely different AESA radars in its development road map.

Kuwait this year will take delivery of its first AESA-equipped Typhoon, fitted with the Radar 0 derivative of Captor-E; Qatar expects to receive this version of the radar as well.

In June, Germany and Spain made commitments for the development of Radar 1, a version of Radar 0 equipped with a new multichannel receiver and new modes that will be produced by Germany's Hensoldt and Spain's Indra.

Radar 2, on the other hand, will be almost entirely bespoke; the commonality will be limited to power generation, cooling systems and the existing interface to the Eurofighter's attack computer.

"From there forward, you are talking about a completely different set of hardware," program officials confirmed.

The Mk. 2 sensor will feature a new processor; a new receiver, along with a dedicated EW receiver and techniques generator; and a new system for rotating the swashplate that gives the radar its increased field of view over fixed-position AESAs. A new radome will also be developed to support the bandwidths required for the radar while maintaining the existing form factor of the current Eurofighter nose. The Radar 2's array will feature a larger number of transmit and receive modules over the other ECRS variants, allowing the delivery of narrower, focused beams to support the electronic attack capability as well as boosting the sensitivity to detect lower radar cross-section targets. According to Leonardo, the array will use a combination of both gallium arsenide and gallium nitride semiconductors.

By using the two materials, Leonardo says it will "blend the strengths of the different technologies." Both Radar 0 and Radar 1 versions use gallium arsenide.

Development of the Mk. 2 radar builds on a number of UK sovereign radar research programs, notably the Advanced Radar Targeting System (ARTS) technology demonstration program, which saw the installation of an experimental AESA in a Panavia Tornado and in a BAC 1-11 testbed during the 2000s. The ARTS demonstrator was then adapted for fitment into the Typhoon's nose through a program called Bright Adder. Radar 2 has yet to fly, but a prototype is undergoing extensive testing in a rig at Leonardo's facilities in Edinburgh, England.

The contract, announced on Sept. 3, provides funding to BAE Systems and Leonardo for the development and integration of the sensor. Although BAE is the prime contractor, the lion's share of the contract will flow to Leonardo.

The contract funds the production of sets for test and evaluation. The first examples of Radar 2 will be installed on UK Typhoons as early as 2022. Also funded are the first three production radar sets.

An initial operating capability (IOC) of Typhoons with the radar is expected "soon after 2025," officials say. Contracts for full-scale production will follow later.

Currently, the Royal Air Force is planning to retrofit Radar 2 in its 40-strong Tranche 3 fleet but is mulling whether the sensor should also feature in the 65-strong Tranche 2 fleet. Such a decision could form part of the planning currently underway for the UK's Integrated Review of defense and foreign policy. The review is due to be published this November. The radar installation program is separate from the UK's Project Janus, the follow-on to Centurion that enabled the Typhoon to take on the missions and weaponry of the Tornado GR4 in early 2019.

Radar 2 is also under consideration for Germany's Tranche 4 fleet, which will partly replace the Panavia Tornado. In addition, Radar 2 forms part of the UK's offer to Finland for its HX Fighter requirement and for Saudi Arabia's 48-strong Batch 2 order, for which Riyadh signed a memorandum of intent in 2018. Most likely, as with Germany's Tranche 4, these Typhoons will go on to replace the kingdom's own fleet of Tornados. Remaining Eurofighter partner Italy has yet to make a decision on an AESA retrofit.

SAAB

Sweden's Gripen proposals for Finland include jammer pods, the LADM and Saab's GlobalEye airborne early-warning platform.

Finnish Needs Prompt Saab Air-Launched Decoy Development

> LADM IS PART OF FINNISH GRIPEN CAMPAIGN

> SAAB IS ALSO INVOLVED IN EUROPEAN AEA ACTIVITIES

Tony Osborne London

Saab has revealed air-launched decoy development efforts as regional concerns grow about the proliferation of anti-access/area-denial (A2/AD) air defense systems.

The company's planned Lightweight Air-Launched Decoy Missile (LADM) forms a component of Sweden's proposal for the Gripen E in Finland's HX Fighter requirement, but it also reflects Europe's growing interest in airborne electronic warfare (EW) capabilities. Having relied heavily for decades on U.S. capabilities, European air forces both NATO-aligned and neutral are looking to develop more extensive sovereign EW capacity. Plans call for escort and standoff jamming provided through pods or dedicated platforms, as well as making use of electronic attack capabilities inherent within the latest generation of active, electronically scanned array radars (AESA).

The LADM would become Europe's second air-launched decoy development, following in the footsteps of MBDA's Spear EW, a derivative of the network-enabled standoff missile also being developed. In addition, Raytheon has offered its Miniature Air-Launched Decoy (MALD) for export to European air arms.

Saab is remaining tight-lipped about the development—revealed at Finland's Kauhava Air Show in August—because it does not want to give away too much about its proposal to Finland. Yet work on the LADM is quite advanced, explains Petter Bedoire, Saab's chief technology officer and previously the deputy head of the company's EW business.

"The A2/AD threat has become a huge challenge," Bedoire says. "Sweden and Finland are among several countries who are in the vicinity of an adversary with A2/AD capabilities, and [they] really need something to be able to tackle them."

While the future Gripen will be kitted out with an organic EW system, Saab's analysis of the A2/AD threat concluded that the company also needed to develop active jamming capabilities to increase the aircraft's offensive capabilities. The additional jamming capacity would be provided through Saab's development of its Electronic Attack Jammer Pod.

Once launched, the aerial decoy can be used to screen larger formations and create protective corridors for aircraft and standoff weapons to fly through.

Bedoire says the decoy, like the jammer pod, would essentially become an extension of the Gripen's own EW system. "It will use the same kind of interfaces and interpretation of threats using the same kind of technique and threat libraries on Gripen," he says.

The company does not discount being able to use the LADM from different platforms, although at the moment

the capability is being devised with the Finnish campaign in mind.

Bedoire would not say how many of the decoys a single Gripen would be able to carry, but the idea is to create a swarm.

The LADM likely would be powered by a small turbojet engine as on other air-launched decoys, but no details have been given on range or endurance.

Saab's EW business is working with the company's Dynamics unit on adapting previous designs of weapons to fulfill the role, although it is unclear whether this design would be of a weapon previously integrated onto the Gripen.

"We currently have that [missile] platform at [technology readiness level] of 6-7, so it is quite mature," Bedoire says, noting that development is aligned with the timelines of Finland's proposed procurement plans. The LADM will use off-the-shelf commercially available components for the active systems to be installed inside the decoy, with the work leaning heavily on Saab's technology center in Tampere, Finland—where the company was able to draw in engineering experience from the telecommunications industry, from such companies as Nokia and Microsoft, to work on radio-frequency antennas and sensors. Work is also being supported by academia, Bedoire says, including students from Finland's

Russia Reveals Loyal Wingman Concept

> RUSSIA'S FIRST LARGE UAS HAS ENTERED SERVICE

> ALTIUS-RU AND OKHOTNIK UAS TRIALS CONTINUE

Piotr Butowski Gdansk, Poland

The Kronstadt Co. is building on the success of Russia's first modern large unmanned aircraft system Inokhodets-BLA (Orion), revealing a full-scale mockup of its loyal wingman concept aircraft as well as its ambitions to expand in the large UAV market.

Russia's foray into modern UAV development began long after that of the U.S. and other countries—and after the war with Georgia in 2008 revealed Russia's military weaknesses. Moscow has since developed and started production of the Orion, the Russian equivalent of the General Atomics Aeronautical Systems MQ-1 Predator. Behind it, multiple projects are in the pipeline that could be exported to nations that do not want to buy aircraft from Europe, Israel or the U.S.

Kronstadt's Grom UAS mockup is a concept for a loyal wingman that would target an enemy's air defense systems ahead of Russian manned fighters.

Kronstadt began with that Predator-replica Orion, mastering design and production of thin-walled ultralight structures made of carbon composites using a vacuum infusion method. Orion is also the first fully electric aircraft of this size in Russia. The company aims to use that experience to stay ahead of other Russian manufacturers and the needs of the nation's defense ministry and to gain ground in the export market.

At the Army 2020 exhibition in Kubinka near Moscow in August, Kronstadt's stand was dominated by a full-size mockup of the Grom strike aircraft. The Grom is intended as an unmanned "loyal wingman" that will fly in front of a group of manned aircraft to pave the way through an enemy's air defense system using anti-radiation missiles.

According to the company, the manned fighter can guide three or four Grom unmanned aircraft systems (UAS). The Grom also can destroy surface targets and conduct reconnaissance and electronic jamming. It can carry weapons weighing up to 500 kg (1,100 lb.): two inside the fuselage and two suspended from underwing pylons, up to a total of 2 tons. The Grom is to be powered by two 2,500-kg-thrust (5,500-lb.) AI-222-25 turbofans, also used by the Yak-130 jet combat trainer.

For now, the Grom is being developed using internal funding, with the expectation of a Russian defense ministry contract. "Today, the [defense ministry] has an understanding that a UAV of this class should en masse come into service with the Aerospace Forces," says Nikolai Dolzhenkov, designer general of Kronstadt.

The Orion is currently Kronstadt's main product, developed under the defense ministry's Inokhodets-BLA program. It is the first large UAS in Russia to enter production.

Kronstadt CEO Sergey Bogatikov said during Army 2020 that the first Inokhodets-BLA system had been delivered to the Russian Armed Forces and the company had been awarded a contract for further deliveries. The military also requested additional requirements, and a modernized version with weapons that were not included in the original requirements will be produced. "We are showing a modernized version with greater takeoff weight and weapons," Bogatikov said.

Aalto University, which has done extensive research into AESA technology.

The LADMs could be preprogrammed prior to takeoff, but the close integration with the Gripen means that an EW operator in the backseat of a Gripen could also task the decoys while in flight. This would allow for "increasing flexibility to react to adversary actions," Bedoire suggests.

Sweden is proposing a mix of single-seat and twin-seat Gripens for Finland: Some two-seat aircraft could be used as dedicated EW aircraft or suppression-of-enemy air-defense platforms.

Saab would not comment if the LADM is desired by Sweden, but the company is paying close attention to Germany's luWES requirement, which calls for the creation of a fleet of standoff and escort jamming platforms. Saab is also involved in the European Commission-funded Preparatory Action on Defense Research program as well as in the Responsive Electronic Attack for Cooperative Task program, which forms part of a tri-national European PESCO program to look at the creation of a European podded airborne electronic attack (AEA) capability.

The Gripen is one of five Western fighters being proposed for Finland's €9.4 billion ($11.1 billion) HX requirement. A selection decision is expected in 2021.

Kronstadt is counting on traditional importers of Russian military equipment to buy the Orion, but the company faces stiff competition from China. The Chinese Casc CH-4 and Chengdu Wing Loong have been bought by Algeria, Egypt and Iraq as well as former Soviet Union states Kazakhstan and Uzbekistan. In civilian tasks, the Orion is being proposed to monitor large areas, such as for early detection of forest fires in Siberia or patrolling the Northern Sea route in the Russian Arctic. Russia's legislature is developing a legal framework for the use of UAS in civilian airspace.

Kronstadt Grom UAV Specifications

Dimensions [m (ft.)]

Length	13.8 (45.3)
Wingspan	10 (33)
Height	3.8 (12.5)

Weights [kg (lb.)]

Max. takeoff	7,000 (15,400)
Max. payload	2,000 (4,400)

Performance

Max. speed	1,000 kph (620 mph)
Cruising speed	800 kph (500 mph)
Ceiling	12,000 m (40,000 ft.)
Operational radius	700 km (380 nm)

Source: Piotr Butowski

In addition to the Orion, Army 2020 featured a full-size mockup of the twin-engine Inokhodets-RU aircraft (Sirius), which is twice as heavy as the Orion. The name "Sirius" might cause a bit of confusion because at the MAKS 2019 exhibition that name appeared on a different aircraft, which is now being called the Helios. The new Sirius is important because the company received an order for it this year, said Bogatikov.

The aircraft has a takeoff weight of 2.5 tons, including 450 kg of weapons and stores, and can stay in the air 20 hr. at an altitude of 7,000 m (23,000 ft.). Bogatikov pointed out that Inokhodets-RU has a built-in satellite communication terminal, in contrast to the current Orion, whose radius is limited to the range of direct communication. "The system also includes a communication suite for cooperation with piloted aviation, which allows the use of our [UAS] in mixed formations," he said.

The Russian Sirius UAV includes a built-in satellite terminal to enable longer-range communications.

A mockup of the aforementioned Helios UAS, also made by Kronstadt, was presented in the early-warning Helios-RLD radar picket variant with a large surveillance radar under the fuselage. The aircraft weighs 4,000 kg and can fly 30 hr. at 11,000 m altitude.

The Army 2020 exhibition also included displays closed to the public; footage of them was released by the defense ministry. That imagery showed two exhibits in a hangar at Kubinka Air Base on display for the defense minister and his entourage. Those included the new-generation Sukhoi Su-57 fighter and a large Sukhoi S-70 Okhotnik (Hunter) unmanned combat aircraft. The Okhotnik copy displayed in Kubinka carried the number "070;" it was probably a full-size mockup. The S-70B demonstrator, which has been undergoing flight tests since Aug. 3, 2019, bears the number "071."

The S-70 Okhotnik is a flying-wing aircraft that weighs about 20 tons and is powered by a single 117BD turbojet engine, which is a nonafterburner version of the AL-41F1 (117) engine of the Su-57. It carries weapons in two internal bays, similar to the Su-57. The armament itself is common to both the Su-57 and S-70 as well.

The 7-ton Altius-RU high-altitude long-endurance UAS also was in the closed section of the exhibition. Two likely small air-launched UAVs, the Molniya (Lightning) and Pirania (Piranha), were among the closed exhibits, too.

Vega, Electron Return to Service With New Offerings

Arianespace's Vega launcher delivered 53 satellites into orbit during its Sept. 2 return-to-flight mission, demonstrating a new ride-share service.

EUROPEAN SPACE AGENCY

> 53 SMALLSATS REACH ORBIT ABOARD VEGA

> ELECTRON KICK STAGE CONVERTS TO SATELLITE

Thierry Dubois Lyon and **Irene Klotz** Cape Canaveral

Sidelined by launch accidents, Arianespace's Vega and Rocket Lab's Electron have returned to flight, with both companies unveiling new services in an increasingly competitive market for small satellite launch services.

Operated by Arianespace from Kourou, French Guiana, Vega flew its first ride-share mission, with 53 satellites onboard owned by 21 customers. Meanwhile, Long Beach, California-based Rocket Lab launched its 14th Electron mission from New Zealand's Mahia Peninsula, placing a 220-lb. synthetic aperture radar Earth-observation spacecraft into orbit for startup Capella Space. Rocket Lab later revealed the rocket's kick stage transformed to become the company's first operational Photon satellite.

Electron, a much smaller-class vehicle than Vega, offers dedicated rides for small satellites. With Vega's 16th flight, Arianespace debuted a ride-share service similar to one offered by SpaceX and the Indian Space Research Organization to haul dozens of satellites into orbit on a single mission.

Vega's ride-share is like a bus, whereas Electron—like Virgin Orbit's LauncherOne and other dedicated smallsat boosters—resembles a taxi. Arianespace also plans to offer ride-shares on its upcoming heavy-lift Ariane 6.

The 98-ft.-tall Vega lifted off at 9:51 p.m. EDT on Sept. 2 (10:51 p.m. local time) from French Guiana on the Small Spacecraft Mission Service (SSMS) demonstration, with 53 spacecraft mounted on a new European Space Agency (ESA)-financed payload dispenser.

The satellites, with a combined weight of 1,667 lb., were released in two tranches into sun-synchronous orbits 320- and 329-mi. above Earth. The launch was shared by 21 customers, addressing a range of applications including Earth observation, telecommunications, science, technology and education.

Seven microsatellites, weighing 55-320 lb., were attached to the upper portion of the carbon-fiber payload dispenser, while 46 nanosatellites, weighing 0.6-15 lb. rode beneath, along with several deployers. One of the cubesats, PhiSat-1, will experiment with artificial intelligence to improve the efficiency of sending vast quantities of data to Earth. It will acquire numerous images and allow scientists to monitor changes in vegetation and water quality, detect urban heat islands and carry out experiments on the role of evapotranspiration in climate change.

The SSMS project was proposed by Arianespace. An ESA product, it was developed by Vega prime contractor Avio and built by Czech Republic-based SAB Aerospace. Satellite integration was performed in the Czech Republic. The European Union funded the proof-of-concept flight.

The successful 16th flight of Vega on the SSMS mission followed a series of delays due to the July 2019 launch failure of Vega's 15th mission, the coronavirus pandemic and a spate of poor weather. Investigators found that the most likely cause of the accident was thermo-structural failure in the forward dome area of the Zefiro 23 motor, which powers Vega's second stage. The event led to a breakup of the launcher in two main parts: the Zefiro 23; and the assembly composed of the fairing, satellite, flight adapter, AVUM (Attitude and Vernier Upper Module) fourth stage and the Zefiro 9 third stage.

The inquiry commission recommended an unspecified set of "corrective actions on all subsystems, processes and equipment concerned."

Rocket Lab had a much speedier return to flight, launching its 14th Electron rocket at 11:05 p.m. EDT on Aug. 30 (3:05 p.m. Aug. 31 local time), following a July 4 accident.

The booster carried a synthetic aperture radar (SAR) satellite into orbit for Capella Space, a San Francisco-based information services company.

Engineers traced the July 4 failure to a faulty electrical connection that triggered a premature shutdown of the rocket's second stage. The failed flight claimed seven satellites owned by Canon, Planet and In-Space Missions.

Capella's first commercial satellite, named Sequoia, fared better, arriving in its intended orbit 500 km (310 mi.) above Earth and inclined 45 deg. relative to the equator. The location will maximize coverage over the Middle East, Korea, Japan, Europe, Southeast Asia, Africa and the U.S.

Capella's SAR technology is designed to capture images at 0.5 m (1.6 ft.), revealing changes on the planet's surface useful for security, agriculture, infrastructure monitoring, and disaster response and recovery, among other applications. The company plans to operate an initial constellation of seven satellites following successful trials with a demonstration satellite, named Denali, that launched in December 2018.

On Sept. 3, Rocket Lab revealed that the kick stage motor used to circularize Sequoia was repurposed to become the company's first operational Photon satellite, named First Light. "For the first time, we are a complete end-to-end service," CEO Peter Beck told reporters.

The satellite, which is expected to remain operational for 5-6 years, is intended as a technology demonstration, testing systems—such as power management, thermal control and attitude control—that do not have flight heritage.

"The whole point of this is to be able to provide full mission end-to-end service," Beck says. "I've just seen so many companies and governments struggle and take such a long time—there's always lots of compromises and dances you have to do between the launch vehicle and the satellite and then the ground piece as well—to be able to really provide something useful and [do so] quickly. This is an effort to really smash all that down."

DefenseChain Conference

Business Strategy ∞ Supplier Opportunities ∞ Program Excellence

OCTOBER 20-21, 2020

The Ritz-Carlton Tysons Corner
McLean, VA

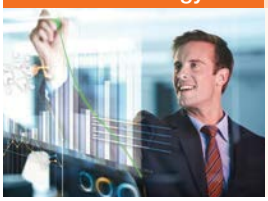
The DefenseChain Conference is designed for leaders and decision-makers from primes to suppliers, including strategic planning and business development leaders, program and project managers, supply chain executives, market analysts, investment bankers and financial institutions.

DefenseChain Conference incorporates the unique **Aviation Week Program Excellence** initiative, an industry-led process that reveals best practices and honors leaders who are setting the standard for performance excellence. Day two of the Conference culminates with the **Program Excellence Awards Banquet** where industry highlights the best.

The THREE MAIN PILLARS of the DefenseChain Conference are:

Business Strategy, **Supplier Opportunities** and **Program Excellence**. Knowledge gained from each pillar is actionable—enabling delegates to effectively secure significant and sustainable growth opportunities.

Business Strategy



Supercharge Your Business Strategy

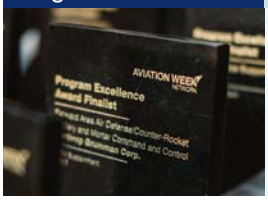
Delegates at DefenseChain engage with top industry analysts who offer their views of the industry, provide forecasts for business planning, present DoD priorities, long-term strategies around defense operations, consolidation and restructuring, and OEM and prime initiatives.

Supplier Opportunities

Grow Your Business or Organization

DefenseChain shows suppliers how to make their mark with top Defense programs and clear the fiscal realities and the deal-making models that prime contractors are utilizing today. Delegates discover how the Defense supply chain is reshaping itself to create winning positions on major programs.

Program Excellence



Stay Informed on Breakthroughs to Program Performance

Discover program breakthroughs and technological innovations as speed and disruption become increasingly important factors. Gain visibility into the processes and systems that enable program and project leaders to reach the highest levels of program execution as we honor the 2020 Program Excellence finalists and winners.

Register and learn more at:
conf.events/DCPE

Topics focus on key components driving the industry:

- Defense industry and Pentagon budget outlooks
- Shaping acquisitions of the future
- Supply chain opportunities
- The technology innovation capacity of the industry
- The program leadership response to 2020s

Who benefits from attending?

- Strategic planning, business development, engineering and technology leaders
- Supply chain executives and senior decision makers
- Program and project leaders
- Analysts, investment and financial community members

Sponsorships

Sponsorships enable you to promote your brand, products and/or services on the expansive Aviation Week Network, and on-site throughout the Conference. Customized sponsorships are also available. The earlier you begin your Sponsorship – the more valuable it is! The Aviation Week Network averages more than two million page views per month – that's millions of potential views of your logo if you start today!
To become a Sponsor contact Joanna Speed, Managing Director, A&D Conferences at +1-310-857-7691.

AVIATION WEEK NETWORK

Reliable Robotics Reveals Autonomous Caravan for Unmanned Cargo

> RELIABLE ROBOTICS HAS FLOWN A CESSNA 172 SKYHAWK FULLY UNMANNED IN U.S. AIRSPACE

> CARAVAN IS TO BE CERTIFIED FOR AUTONOMOUS OPERATION

Graham Warwick Washington

In cargo feeder service with package carriers such as FedEx Express, Cessna Caravans and their pilots fly only a couple of hours a day. Startups seeking to disrupt the aviation market see an opportunity in converting the aircraft to supervised autonomy and moving the pilot to a ground station to increase utilization and improve economics.

Reliable Robotics, founded by former SpaceX and Tesla engineers, is developing an autonomy platform to convert the Cessna 208 Caravan for unmanned cargo operations. The company performed its first automated landing with a Caravan on June 30, having already flown a Cessna 172 Skyhawk fully unmanned in national airspace. Another U.S. startup, Xwing, is also flight-testing a Caravan modified to autonomous operation (*AW&ST* Aug. 31-Sept. 13, p. 34).

Reliable Robotics has a "singular focus" on certification, says co-founder and CEO Robert Rose, who led flight software development on the Falcon 9 rocket and Dragon capsule at SpaceX and the Autopilot diver-assistance program at Tesla. Juerg Frefel, co-founder and vice president of engineering, led development of the computing platform for the Falcon 9 and Dragon.

The San Francisco-based startup's autonomy platform is divided into layers that can be certified incrementally with the FAA. "Others talk about developing the minimum viable product, we joke internally about minimum viable autonomy. And that means breaking the problem down into bite-size chunks that you can push through the certification process," Rose says.

The layers divide up the overall system into pieces that different parts of the FAA can handle, he says, from aircraft certification to flight standards.

"Certification of these systems is about more than just the equipment that goes on the aircraft. You also need the communications system, ground network and control center—for the foreseeable future, you are going to have pilots operating these systems remotely. And then you have maintenance and the Part 135 and Part 121 [operating requirements] aspects," he notes.

"What makes us different from others out there is we are looking at solving this problem holistically and how you vertically integrate all this together to create a complete operation," Rose says. "For the first approval to do this, you are going to have to answer questions about the onboard system, control center, maintenance plan and training for the pilots."

The core layer of the autonomy platform is a fly-by-wire control system "that's responsible for keeping the aircraft flying and following trajectories," Rose says. On top of this is an outer-loop layer that performs trajectory definition and manages other aircraft systems. A layer on top of that deals with issues extrinsic to the aircraft, while a further layer enables remote operation of the entire system.

After unmanned flights with a Cessna 172, Reliable Robotics conducted an autonomous landing with a Caravan.

RELIABLE ROBOTICS

SEPTEMBER 2020

InsideMRO™

Gaining Visibility Across the Aftermarket

How Japan Airlines Is Coping With COVID-19

Turbocharging Innovation

AVIATION WEEK NETWORK

BAE Systems' LinkEdge™ solution is a retrofit technology that brings the benefits of force feedback and tactile cueing to non-fly-by-wire aircraft. Our system provides warfighters the improved control and situational awareness benefits of active stick technology today.

Tomorrow's technology today

baesystems-ps.com

BAE SYSTEMS

BACKGROUND: BAGOTAJ/GETTY IMAGES. HAND: PAVEL ZHURAVLEV/GETTY IMAGES. LINE ART: RATTIKANKEAWPUN/SHUTTERSTOCK INC.

MAINTENANCE CHECK

Engine Evolution or Disruption?

If you're not following the development of new engine technologies, you should if your business includes propulsion maintenance because big changes could be coming.

First, consider that engine MRO accounts for about 40% of total aftermarket expenditures and that many engines are covered by flight-hour agreements that (not surprisingly) charge on a flight-hour basis whether the aircraft flies with a 30% or 90% load factor. "Airlines are very, very good at working out the cost and value that they have in every engine," says Sash Tusa, an Agency Partners aerospace analyst, so he expects a disruption in engine scheduling within the next 18 months. Did OEMs' lucrative flight-hour service agreements reach their peak before the pandemic without them knowing it?

Meanwhile, the push for more sustainable operations and lower carbon emissions is accelerating the development of alternative propulsion technologies based on all-electric, hybrid-electric and hydrogen power. While an all-electric 100-plus-seat aircraft is unlikely in the near future, "different flavors of electric" will start to emerge over the next few years, on everything from commuter and regional aircraft to single and twin-aisle transports, says my colleague Guy Norris, a propulsion specialist and author of this issue's Viewpoint (page MRO31).

Ranging from higher-energy-density batteries and embedded motor/generators to distributed propulsion systems driven by hybrid-electric engines or hydrogen fuel cells, these technologies could also lead to significantly more efficient future airliner designs. There will be innovations as well over "the next few decades that will creep in in ways we didn't expect," he predicts.

Did flight-hour service agreements reach their peak before the pandemic?

Since the 1960s and '70s, when engines such as the Pratt & Whitney JT8D and General Electric CF6 enjoyed 50 years of service, each subsequent decade has shaved off several years of engine life, Tusa pointed out during a recent Aviation Week webinar. The 1980s-era engines' lifespan maxes out at about 40 years, while the 1990s engines' expected duration decreases by about another 10.

What does that mean for today's newest engines such as the Pratt & Whitney geared turbofan, the CFM International Leap and General Electric GE9X? Tusa predicts their lifespans will shorten to two decades, "given the immense pressure on the industry to move to more-electric or alternative fuel" versions to decrease emissions. OEMs have done a good job producing incremental improvements, but the industry needs a bigger leap.

So how will this affect the aftermarket?

Sustainable fuels work with existing engines and hydrogen needs a "high-temperature gas generator," so the aftermarket is less affected by those two alternatives, says Tusa. Hybrid-electric still requires a gas turbine core, but due to the lower power output, aftermarket demand as we know it could be reduced, he believes. However, the all-electric engine will require a different aftermarket model.

Tomorrow's engines could dictate some significant changes for MRO. So keep an eye on this space.

—Lee Ann Shay

Highlights

MROs, eVTOL Manufacturers Begin Collaboration

Urban air mobility (UAM) vehicle manufacturers and MROs are beginning to lay the groundwork for the maintenance ecosystem the industry will need to service electric-vertical-takeoff-and-landing (eVTOL) vehicles.

At Aviation Week's UAM Virtual event in August, German startup Lilium—which is developing its Lilium Jet eVTOL for operations starting in 2025—noted that it is beginning to create maintenance manuals for the aircraft and collaborate with MRO providers to identify how the maintenance process will work.

A number of MROs are already working to build up expertise in maintenance and repair services for unmanned aircraft systems (UAS). In August, AFI KLM E&M subsidiary Barfield joined the Robotic Skies network to provide maintenance and repair services for UAS in its Louisville, Kentucky, facility. According to Barfield, it is equipped with the appropriate test benches and expertise to support UAS and is well-positioned to adjust technician knowledge to meet the emerging market.

Meanwhile, Lufthansa Technik (LHT) is offering a SafeDrone Health service for UAVs. LHT says the cloud-based service helps drone manufacturers and operators monitor the technical condition of their drones by providing data on failures and maintenance recommendations so repairs can be "carried out at the optimal time rather than too early or in reaction to a critical situation." It says the service can reduce maintenance costs by 50% or more.

UIA's MRO Subsidiary Approved by EASA

A subsidiary of Ukraine International Airlines (UIA) has become the first MRO provider in the country to receive European Union Aviation Safety Agency (EASA) Part 145 certification for base maintenance services.

MAU Technik, launched by the carrier in 2017, will now be able to maintain commercial aircraft registered in the European Union. Since its inception, the company has carried out a mix of UIA fleet work and third-party line and base maintenance services for local operators based in Ukraine from its base at Kiev's Boryspil Airport. With the new approval, MAU Technik will be able to undertake base maintenance on Boeing 737-700, -800 and -900 aircraft along with Embraer 190 aircraft in accordance with EASA requirements.

Algirds Mikelsons, CEO of MAU Technik, says that despite difficulties related to COVID-19 that have affected the entire industry, the company has further plans to bolster its offerings. "Next, we shall improve marketing and sales so that more companies may use our capabilities to receive quality service and advantages in a lower cost base," he says.

Azul Opens New MRO Center in Sao Paulo

Brazilian airline Azul has opened a new MRO center at Viracopos International Airport in Sao Paulo, which it says is the largest MRO complex constructed in Brazil in the last 40 years. The $35 million investment is aimed at improving maintenance efficiencies and better supporting Azul's fleet.

Construction on the 377,000-ft.^{2} MRO center, designed by Ghafari Associates, began in 2018 and was completed this year despite some delays related to COVID-19. In addition to a hangar that can accommodate one widebody the size of an Airbus A350 alongside two or three narrowbodies or three or four ATRs or Embraer E-Jets, the complex features support spaces for technical shops, logistics management, administrative areas, a technical training center and management and engineering offices.

Azul says the hangar has been certified for Airbus A320neo checks and is expected to be certified for the A330neo by year-end. It intends to have 75 technicians for each line in the hangar, along with 20-25 support staff.

Contracts

Aeronautical Engineers was selected by **Aero Capital Solutions** to convert three Boeing 737-800s to freighters. Mod touch work will be performed by **Staeco** in China. It also won a contract with **KF Aerospace** to convert a fourth 737-400 to a freighter. Mod touch labor will be performed at KF Aerospace's facility in Canada.

Airinmar was selected by **Frontier Airlines** to provide warranty management and value engineering services.

FLYdocs was selected by **Argo MRT** to be its records platform of choice for end-of-lease return services and maintenance records review.

HAECO Xiamen was named by **Aeronautical Engineers** as an authorized conversion center and will be operating two lines starting in April 2021, increasing Aeronautical Engineers' capacity to 14 simultaneous lines at five facilities.

Joramco was selected by the **Ryanair Group** to perform heavy checks on five Boeing 737NGs and seven Airbus A320s through March 2021.

Lufthansa Technik extended its 737NG Total Base Maintenance Support contract with **Norwegian.**

Magnetic MRO was selected by **BOC Aviation** to provide continuing airworthiness management organization services. The first 737NG has been sent to Tallinn.

Piedmont Propulsion Systems and **Malaysia Airlines** signed a joint venture memorandum of understanding to provide ATR/Dash 8 propeller maintenance for **Firefly/MASwings** and third parties. The airline will manage the supply chain of OEM replacement parts.

Contract Source: SpeedNews

MAX Mods

JOEPRIESAVIATION.NET

Modifying wiring bundles will take most of the time needed to implement mandatory changes to Boeing 737 MAXs as part of return-to-service preparation, instructions provided to operators by Boeing and used by the FAA to develop the requirements show.

The FAA on Aug. 6 released its notice of proposed rulemaking (NPRM), detailing most of the work MAXs must undergo before being cleared to return to service. The draft rule references three already-issued service bulletins (SB) that will be mandated, each requiring different modifications and, in one case, a comprehensive "readiness flight" to verify the aircraft are airworthy after months of inactivity. Other requirements, including modified flight-control computer (FCC) software and new pilot training, are still being finalized and will be included in new Boeing operator bulletins. The mandates exclude maintenance-related work that operators must conduct to ready stored aircraft for line flying.

Most of the required work has no direct link to the two fatal accidents, Lion Air Flight 610 in October 2018 and Ethiopian Airlines Flight 302 in March 2019, that led regulators to ground the fleet and Boeing to halt deliveries 18 months ago. Operators will spend up to 200 work hours per aircraft modifying wire bundles that do not meet electrical wiring interconnection system (EWIS) separation standards put in place in 2007 and applicable to the MAXs, the Boeing document shows.

"A simultaneous short circuit between the [horizontal stabilizer arm], one of the [stabilizer control] signal lines, and a 28-volt direct current source, will cause uncommanded stabilizer movement, and potentially result in a stabilizer trim runaway," Boeing explains in the SB detailing the changes. "Physical separation of the horizontal stabilizer arm and control wiring implemented by these changes will ensure that uncommanded stabilizer motion and a stabilizer runaway cannot result from a single EWIS failure."

Instructions differ slightly between the 737-8 and 737-9, but the general fix is the same. On the 737-8, it involves changing the routing of two existing bundles and installing five new ones so that separation standards are met in 12 different places. The work requires accessing the nose wheel well, forward cargo compartment, electrical and electronics compartment and the rear fuselage area, or section 48. The new bundles add 2.6 lb. to the 737-8's gross weight and 3.2 lb. to the 737-9's.

Boeing's estimated work hours for the wiring changes vary based on the aircraft model and configuration but range 160-200 hr. per aircraft—more than twice the FAA's draft-rule estimate of 79 hr. per aircraft. The Boeing bulletin assumes most of the work will be done by four-person teams, suggesting each aircraft will require 4-5 days of work.

Another SB explains a MAX flight-deck display system (MDS) software update that changes how the MAX's angle-of-attack (AOA) disagree alert functions. The update requires less than 1 hr. per aircraft.

A third SB covers an AOA sensor system test and an operational readiness flight. The AOA test should follow a MAX aircraft maintenance manual procedure added in July, the SB said. Estimated time for the test is 40 hr., which Boeing breaks down as one five-person team working eight hours.

The operational readiness flight, to be conducted after all other work is accomplished, includes "flaps retracted flight at or above 20,000 ft. Mean Sea Level," the SB explains. System tests should begin during pre-flight, including brakes and steering, extend through the flight itself and continue following arrival. The flight should use "normal procedures and appropriate supplementary procedures as needed," Boeing says.

The bulletin does not specify flight conditions that would test the modified Maneuvering Characteristics Augmentation System (MCAS) flight control law implicated in both MAX accidents. Boeing estimates that the readiness-test process will take 50 combined work hours, with a five-person crew working a 10-hr. stint.

Boeing released the wiring and MDS update instructions in June and the AOA/readiness flight bulletin in July, following consultations with the FAA. Operators and Boeing have begun doing some of the required work in anticipation of the agency approving the MAX changes and clearing the model to return to revenue service sometime in the next few months. The global grounding forced airlines to park 385 in-service MAXs, and Boeing has more than 450 undelivered aircraft in storage awaiting delivery to customers.

The FAA's draft directive's public comment period runs until Sept. 21. The agency, which is not operating on a specific timeline, will then make necessary changes and issue a final version of the rule, incorporating the FCC software and training requirements.

Efforts to have the MAX approved by regulators are slated to check off a major milestone in mid-September. The Joint Operations Evaluation Board, including pilots from Brazilian, Canadian, European, and U.S. regulators, will evaluate proposed new training during 10 days of simulator trials outside of London, England. Feedback from the trials, which will follow flight tests by Canadian and European regulatory representatives, will be used by the FAA to help finalize initial and recurrent training requirements for all MAX pilots.

—Sean Broderick

ARSA UPDATE

Create the Best

QUICKLY FOLLOWING ARSA'S 2020 Annual Conference in March, with its usual focus on the aviation maintenance workforce crisis, things changed dramatically. Much of the industry went from urgently seeking new hires to desperately looking for ways to pay current employees. In the first half of this year, staffing cuts may have put some 50,000 maintenance technicians out of work just in the U.S.

Despite this seminal shift in the short-term employment outlook, the original crisis isn't over—in fact, it has been amplified. Market recovery and sustainability depend on developing robust talent pipelines. Many experienced technicians have accepted early retirement options or transitioned out of full-time employment and will never return. The remaining workforce may not come back to aviation, following a long-troublesome trend for workers whose skills transfer easily to other technically advanced and more stable employment options. The additional loss of experience only makes recruitment and development problems more serious.

As work comes back, who will be around to do it?

To answer that question, we need to use the current crisis to avert the future one. We need to worry less about whether workers stay within the walls of aviation or take their skills to another industry needing talented technicians. It means getting back to the skills-based education that has proven sustainable—including investing in apprenticeship programs; job shadowing; local, national and international partnerships; and constant internal and external education.

To do that, we need to support long-term workforce training efforts now. These are the next steps we need to take.

Engage government for industry relief. In the U.S., ARSA advocates for the future of aviation even as businesses struggle to survive the present. ARSA's survey assessing the impact of the current crisis described the ways the CARES Act has benefited much of the industry. You can add pressure on both the Congress and the Executive Branch to address these problems by sharing the information from arsa.org/covid-relief with your elected officials. (Find congressional contact information at govtrack.us/congress/members/map)

Update technician school curriculum. ARSA is working to require an update to 14 CFR Part 147, the regulation that establishes maintenance technician school requirements. The rule and its curriculum haven't been updated in 50 years; overhauling it will ensure technicians of the future are better prepared for careers in the 21st century aerospace industry. You can support those efforts, too, by following the steps outlined by the Aviation Technician Education Council at atec-amt.org/news/reform147

Use workforce programs for change. As mandated by the 2018 FAA Reauthorization Act, the Transportation Department created and appointed representatives to the Women in Aviation Advisory Board and the Youth Access to American Jobs in Aviation Task Force. Those bodies will be vehicles to advance improvements in government and industry policies for technical career development. ARSA is represented on the "youth" panel and has colleagues supporting the women's effort. All will push for aviation engagement programs that start young and never stop. As these workforce bodies develop recommendations, ARSA will seek input. Once the recommendations are made, you can help make them a reality. Stay tuned.

Follow through with existing efforts. The FAA reauthorization process established a grant program to invest in aviation technician career development. With the program authorized and funds appropriated, ARSA and its allies are pushing the FAA to implement the program—$5 million is available this year for distribution—and ensure its long-term future through continued funding. A letter to your congressional representative asking where the agency is in its process wouldn't hurt.

Embrace new technology. Use the industry's two-year-old effort to obtain FAA acknowledgment that remote-connectivity tools are acceptable for use under the current rules. Once U.S. regulators recognize this reality, the industry must implement technologies that support business operations respecting the "new normal" of social distancing.

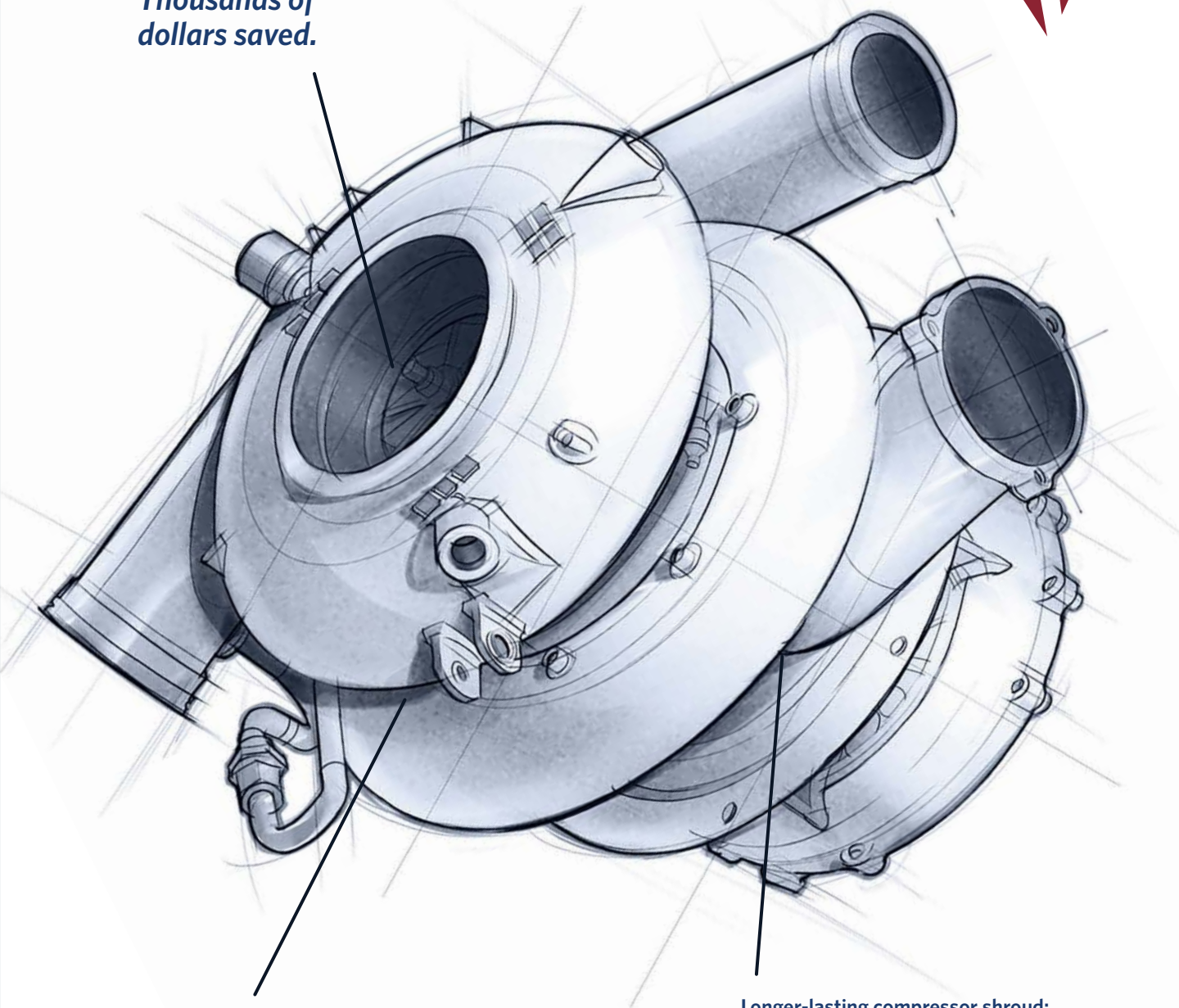
A strong workforce will power recovery and sustainability for the maintenance community. Building a baseline of technical knowledge and awareness of skills-based value will give the industry its needed talent pool. We can have the best once we create the best.

To learn more about these efforts or share the work you are doing on behalf of the industry, reach out to me directly at brett.levanto@arsa.org.

Brett Levanto is vice president of operations at Obadal, Filler, MacLeod & Klein, managing communications for regulatory and legislative policy initiatives. He provides strategic support for the Aeronautical Repair Station Association.

Custom-repaired flange:

Thousands of dollars saved.



Corrosion-free bearing plate:

Hundreds of cool, comfortable passengers.

Longer-lasting compressor shroud:

More uptime for your fleet.

DELTA TechOps

A small component repair that translates into big savings.

We know a lot about your air cycle machine. Like that when one isn't working, passengers will get heated. Or that our DER repair costs 50 percent less than the standard OEM replacement — and lasts longer. So, if you want an MRO that will give your bottom line a lift, visit **DeltaTechOps.com** and learn how our Oper-chanics mindset can work for you.

JAL Engineering

As with most carriers, Japan Airlines (JAL) has had to make major fleet adjustments in response to a sharp traffic decline. Schedules have changed, flying hours have been reduced, and many widebodies are parked. JAL Engineering executives outline the carrier's MRO operation and how it has been affected by the COVID-19 crisis.

Does JAL do all of its airframe heavy maintenance or are some heavy checks contracted out?

Currently, heavy maintenance is performed in Japan. Prior to the global pandemic, JAL did the majority of heavy airframe maintenance in Japan but also contracted some work overseas on an overflow basis. Because of the strict quarantine and border control measures in place, JAL has been handling all heavy maintenance duties in Japan since March.

Where did the contracted work go?

To China (TAECO) and Singapore (SASCO).

What about engine heavy maintenance—does JAL typically handle this itself?

As with the answer above, heavy maintenance can be handled in Japan, as well as overseas.

Does JAL do any third-party heavy maintenance work, and does it plan to add more?

JAL has contracts with over 50 domestic and/or international airlines to conduct maintenance work in Japan. The level of maintenance work depends on each agreement, but includes general repairs as well as engine maintenance agreements. This is mostly for general [or line] maintenance for aircraft flying to Japan. In addition to these customers, JAL Engineering will oversee maintenance duties for its new [long-haul low-cost carrier] subsidiary, Zipair Tokyo.

How many hangars does JAL have at its main MRO facilities?

There are two hangars each at Tokyo Narita and Tokyo Haneda airports, and there is one hangar at Osaka Itami Airport.

Do you plan any expansion at these locations?

We have no immediate plans to expand the facilities.

Does JAL handle heavy maintenance on Boeing 787s, and does it plan to do its own heavy checks on Airbus A350s?

Yes, JAL can handle [this] heavy maintenance in Japan.

Are there any new MRO capabilities or technology that you have introduced recently?

Last year, JAL conducted a virtual reality (VR) maintenance training program. VR technology was used to train engineers on the Embraer 170 and 190 aircraft. JAL and Toshiba System Technologies Corp. developed a VR simulation of an engine run-up scenario. Through the trial, the carrier aimed to improve mechanics' skills by providing an immersive learning environment even when these aircraft are not available in the hangar. Increasing reliability means there are fewer opportunities now for engineers to work on actual aircraft.

Are you seeking any new certifications to work on additional airframe types?

Currently, we have the certifications we need. We will train and receive additional certifications as needed based on the company's decisions on future aircraft purchases.

Approximately how many aircraft has JAL parked due to the pandemic?

Japan Airlines has increased its domestic flights since June, but the recovery has slowed due to a second wave of coronavirus cases.

There are no set numbers of parked aircraft, as JAL has been operating approximately 70% of its domestic network on a daily basis and has been operating around 800 cargo-only flights per month, including international services. However, as JAL is operating only 10% of its international [passenger] network at this time, many widebodies in international configuration are either parked in Japan or used only for cargo flights.

Are some of the 787s and Boeing 777s being used operationally?

JAL is operating 787s on domestic and international flights, and 777s on international routes. Revised operating schedules mean an aircraft may spend a night at an overseas airport and return the next day, versus operating return flights to Japan two hours after landing at the overseas destination.

How has your engineering workload changed with so many aircraft parked?

In general, regular aircraft maintenance is performed based on the number of flights or hours operated. However, there are many duties we perform regardless of the number of flights, and for parked/stored aircraft. These include electrical system maintenance; engine maintenance and regular checks; lubricant maintenance

CHARLY TRIBALLEAU/AFP/GETTY IMAGES

Japan Airlines Fact File

HEADQUARTERS: Shinagawa, Tokyo
PRESIDENT: Yuji Akasaka
ALLIANCE: Oneworld
FISCAL YEAR GROUP PROFIT (2019): ¥53.4 billion ($503.2 million)
FLEET, IN SERVICE AND STORED:
Airbus A350-900: six (12 on order)
Airbus A350-1000: (13 on order)
Boeing 737-800: 48
Boeing 767-300: four
Boeing 767-300ER: 29
Boeing 777-200: 10
Boeing 777-200ER: 11
Boeing 777-300: four
Boeing 777-300ER: 13
Boeing 787-8: 27 (two on order)
Boeing 787-9: 20 (three on order)

Note: Fleet total is JAL only, not group total.

Source: Aviation Week Fleet database and Japan Airlines

on parts; maintenance of parts including tires; removal of any mold that may build up on parked aircraft, and interior cleaning.

Have social distancing, travel restrictions or other new workplace requirements affected how your engineering staff work?

The company has proactively implemented social-distancing measures in the workplace and given staff the ability to telecommute. While telecommuting, staff are encouraged to conduct online training and use educational training materials (not focused on maintenance matters only) provided by the company. [Regarding travel], there are difficulties in sending staff overseas to support maintenance duties, but these needs are limited at the moment due to the pandemic.

Have your engineering logistics or parts supply chains been affected during the COVID-19 crisis?

We have had no major issues with supply.

Has the COVID-19 crisis led to any long-term changes in your MRO practices, or approach to outsourcing?

Yes; we have decreased outsourcing for the time being. When travel demand returns, the company may need to review outsourcing contracts again.

A New Digital Dawn

The quest for better visibility across the aftermarket is leading to expanded digital options and tools

James Pozzi London

Managing an MRO supply chain made up of multiple players spanning a global network of facilities and line stations can be a complex and challenging enterprise.

For instance, a common problem for an MRO provider is ensuring the availability and delivery of necessary replacement parts and maintenance materials on time and at the location where they are needed.

Should a disruption occur, keeping the part from reaching its destination on time, the customer will be affected by the delay, and the provider of the part in turn will incur additional expedited shipping costs to ensure the component reaches its destination as soon as possible. This scenario is also particularly bad news for the MRO, which typically wants the part immediately because it often does not hold much inventory in order to minimize costs.

Underpinning these situations is a cost-conscious environment, given the relatively small margins associated with the commercial aftermarket. "Customers are looking to reduce their cost by all means," says Didier Granger, CEO of OEMServices, which provides MRO services encompassing aircraft components and logistics covering the supply chain between the OEMs and the airlines. "But they [airlines] also want to upgrade the quality of their purchases at the same time, because they know that the quality of their aircraft and the value of their inventory will be linked to these choices."

THE IMPACT OF COVID-19

The partial shutdown of commercial air transport due to the COVID-19 crisis, which resulted in nearly 80% of the global passenger fleet being grounded in May, not only battered airline revenues but inevitably disrupted the global supply chain. "Manufacturers' lead times have started to increase, and the OEMs are also finding it hard to achieve their normal five-day turnaround, all of which affects MROs," says Lee Kelsey, director at UK-based Farsound Aviation, which specializes in component supply and supply chain consulting and includes Iberia and HAESL as customers. "Total acquisition costs [of components] are also becoming more important as both airline maintenance divisions and non-airline-affiliated MROs have cut overhead due to COVID-19." Another consequence is payment deferrals on MRO services and parts from airlines looking to preserve liquidity.

Naturally, shifting demand brought about by COVID-19 is leading to different supply chain approaches, particularly from MROs seeking better cross-border and time-zone connectivity. By embracing digital innovation, MROs hope to gain greater visibility into their operations—a process that could accelerate further due to the changes brought about by the pandemic. This trend is already being seen by Eric-Jan Schmidt of ILS, which has provided an inventory locator service for more than 35 years. He says demand for certain services has increased since the outbreak of the novel coronavirus. Specifically, he is seeing greater interest in ILS' IPC Analyzer, which helps both buyers and sellers gauge their respective opportunity windows for selling, dismantling costs and resale values. "A direct result of the large number of aircraft parked is the likely increase of frame and engine retirements and the demand and supply impact this will have for specific products in specific geographic regions or segments," he says. In addition, Schmidt has seen growing requests for inventory-stocking support, mainly from parts-stocking companies. "Particularly those with large inventories increasingly need real-time fair market value data to support their credit facilities," he says.

Most MRO operations use enterprise resource planning (ERP) systems for functions such as sales quoting and accounting, along with more specialized MRO management software developed to track maintenance orders and organize inventory. Farsound's Kelsey says that having an ERP system tailored to fit an organization is extremely important, given all the changing data companies are continuously receiving. He says Farsound invested heavily in a Microsoft Dynamics Nav package a few years ago. "We have tailored our business around this, and as we expand, we can grow within Microsoft Dynamics," he explains. As is becoming increasingly common, the company has since moved this ERP system up to the cloud, enabling remote usage anywhere across the world and around the clock.

Citing the primary challenges of running an MRO supply chain as obtaining parts just in time, managing lead times for parts availability and general overspending, Vincenzo Quaranta, head of maintenance and engineering at Alitalia, runs its operation using two main tools that specifically target greater visibility into its aftermarket business. The airline uses SAP software to manage and monitor its orders and inventory, along with other functions such as finance and human resources.

Alitalia's MRO activities are tied together by AMOS MRO management software, developed by Swiss Aviation

New tools for supply chain and parts management will make the process more transparent and efficient.

LINE ART: RATTIKANKEAWPUN/SHUTTERSTOCK INC. PHOTO: VIEW STOCK/GETTY IMAGES

Software, which the carrier rolled out in 2011. Operating within a broad framework, the package covers both long- and short-term planning and minimum equipment list management, up to the creation and management of work packages, orders and task-card issuance both for aircraft and components. "It's also helping us in managing stock levels and [issuing] relevant repair orders for removed components, both for internal repair departments and for external repair stations," Quaranta says.

Since rolling out the AMOS product some nine years ago, Alitalia says the consolidated MRO software has brought about markedly improved visibility. "Previously, we were using around 27 different types of software to manage maintenance activities not linked to each other and therefore completely ineffective in gaining visibility on maintenance operations. Also, [it helps] in areas such as rebuilding the maintenance history of a certain component, in case of need such as back-to-birth traceability," he adds.

Quaranta believes systems like these give its maintenance division, which has a roughly 60/40% third-party/in-house Alitalia fleet MRO split, enough visibility across its operation but says other initiatives are underway to drive this objective further. "We use our enormous amount of maintenance data and correlate between them to create predictive algorithms that allow us to build preventive and predictive maintenance tools," Quaranta says.

For airlines operating on a smaller scale without the in-house maintenance setup of their larger contemporaries, juggling the right software with tailored maintenance contracts serves an especially critical function. Guy Borowski, head of engineering and maintenance at Canada-based Flair Airlines, says that being a small carrier with a fleet of just six aircraft means it seeks to take advantage of economies of scale when acquiring parts from its vendors. Much of its parts supply emanates from German MRO Lufthansa Technik, with an agreement covering pool access, home-base kit and repair and overhaul services, while its management software is supplied by RAAS from AIS. "Our rotable contract takes much of the complexity out of our parts supply management and allows us to benefit from scale that we would otherwise not enjoy," Borowski says.

Even so, he says Flair Airlines is reviewing ways to manage its maintenance more effectively as its fleet grows and may look to some of the broader ecosystem packages in the future. He identifies several areas ripe for greater visibility across the Edmonton-headquartered carrier's supply chain, including: "Visibility and availability of used parts, availability of low-use, high-dollar items without having to purchase them, and the ability to identify pending failures and improved troubleshooting."

EXPANDED OFFERINGS

Naturally, demand for greater visibility is leading to expanded options from specialist software vendors but also from well-resourced MROs looking to bolster their digital service offerings. These maintenance providers include Lufthansa Technik, which, as part of its ongoing digital efforts, brought its open-source data-sharing platform Aviatar to market in 2017 in partnership with Palantir. The platform offers a suite of products for airlines, MRO providers, OEMs and lessors ranging from predictive maintenance to fulfillment and automated solutions to improve customer access to pool stock, material planning solutions and dedicated home-base stocks.

"We run a big database that includes operational, material-related and supply-chain-related information for components from more than 5,000 aircraft on a regular basis," says Frank Martens, head of customer development for digital products at Lufthansa Technik. "Every change of pattern, whether it is flight schedules of airlines, new component modifications or changes in our supply chain, is fed into our self-learning algorithm and is utilized to optimize our material stock."

The predictive maintenance part of the offering is widely seen as a boon for forecasting failures, thus giving inventory managers better foresight about where to stock parts by region. However, industry adoption of predictive maintenance platforms remains sluggish. "The number of airlines using predictive solutions is limited but growing fast," Martens says. "Many visionary airlines are looking at such solutions right now, but the offerings of real predictive maintenance are limited. Many are just offering digital results without a direct connection to maintenance actions."

Given the abundance of data generated by their new-generation aircraft types, along with the high volumes of parts stocks being moved around to different locations, airframe OEMs are also developing a series of digital offerings. To much fanfare, Airbus launched its Skywise open-source data platform in 2017 aimed at connecting inflight, engineering, and operations data in a single ecosystem. Three years after its launch, its user base has grown to more than 100 airlines.

In the same year, Boeing rolled out its AnalytX solution, which, unlike Skywise, was less of a data platform and more a collection of digital solutions and services including more than 130 related applications. One of these is its maintenance-focused application Airplane Health Management, which identifies maintenance needs in advance using predictive algorithms before delivering the needed components.

Duane Wehking, vice president of digital solutions and information technology and data analytics business partnerships for Boeing Global Services, believes that in the commercial aviation segment, collecting, analyzing and leveraging data produced by aircraft will be paramount in increasing efficiency for maintenance work, improving safety and reliability, managing MRO records and lowering overall operating costs. "Commercial airlines spend 2-4% of their revenues upgrading information services and analytics solutions, and we see this continuing to grow," he says.

BLOCKCHAIN

If predictive maintenance can provide ways to better forecast component failures, then blockchain is seen by some as the answer to improving supply chain transparency and traceability across a part's life cycle. Characterized as a shared ledger offering users a complete, time-stamped record of transactions and processes within it, the technology is only just beginning to be adopted across aviation.

Nevertheless, interest in the concept is evident, with AFI KLM E&M, Honeywell and GE Aviation just some of the aftermarket players developing blockchain-related platforms in the past few years with specialist partners. The technology took another step forward in the aftermarket this year through the formation of the SITA-led MRO Blockchain Alliance, comprising more than a half-dozen aviation entities including an MRO (HAECO Group), airline (Cathay Pacific) and software vendor (Ramco Systems).

While acknowledging that blockchain is in its infancy, Borowski of Flair Airlines nevertheless believes these types of developing technologies, along with other platforms, will be positive for the MRO supply chain. "Technology will allow collaboration among multiple entities to improve efficiencies and lower costs," he says. "Safety stock at individual entities will continue to decrease, and data will drive operational decisions that could improve an airline's reliability."

CONSOLIDATED SERVICES?

Many in the commercial aftermarket, including Alitalia's Quaranta, expect the COVID-19 crisis will inevitably lead to the acceleration of digitalization of many MRO processes. "This includes the supply chain, through the utilization of new technologies and digital applications, such as big data and predictive maintenance," he says.

This view is shared by OEMServices' Granger, who foresees more functionality being added across digital supply chain tools as the segment seeks to become better connected across multiple entities. "The need is to create links that connect the diversity of the systems and the various entities that operate these systems, including airline engineering departments, MRO providers and vendors," he says.

What is certain is that supply chain management product suppliers will continue to grow their offerings. From the perspective of an OEM, Boeing's Wehking believes the development of integrated products that support airline operators is on the horizon. "Currently, airline engineers or crew members use multiple applications to complete their daily tasks. Integrating these various products into a single interface will be more efficient," he says. "It can also become a learning product that features embedded machine learning to analyze local data and derive insights in real time. Prediction models can move beyond day of operations to weeks or months in advance."

ILS, meanwhile, will look to further expand its product line. Having developed four new platforms this year alone, Schmidt says more products are likely, with recent customer demand centering on applications of its intelligence and data solutions to navigate liquidity-related business needs. Among these, he anticipates more applications for part-pedigree tracing and autonomous procurement, further developing personalized predictive algorithms and building its supply chain hub with integrated workflows designed to optimize processes and user experiences.

Appetite for Acceleration

Despite pandemic-related uncertainty, aviation industry tech accelerators press on with innovation efforts

Lindsay Bjerregaard Chicago

Over the past five years, the aviation industry landscape has followed in the footsteps of Silicon Valley, with dozens of specialized startup accelerators and in-house innovation labs popping up across OEMs, airline groups and MROs. Some companies have opted to stick with in-house technology development efforts while others are replicating the Silicon Valley model of investing capital and resources into outside startups, but the focus ultimately remains the same: to nurture emerging technologies in an effort to address aviation industry challenges.

Prior to 2020, the industry had plenty of money to burn. However, the International Air Transport Association projects airlines will lose $84.3 billion this year, while aftermarket providers are reporting a 40-50% decline in second-quarter revenues, and orders for new aircraft and engines have nearly ground to a halt due to unprecedented numbers of parked aircraft. With so many companies needing to tighten their belts to survive, will the technology investments in these innovation accelerators be neglected in favor of core business areas, or will the downturn be an opportunity to adopt new technologies even more quickly to gain a competitive advantage?

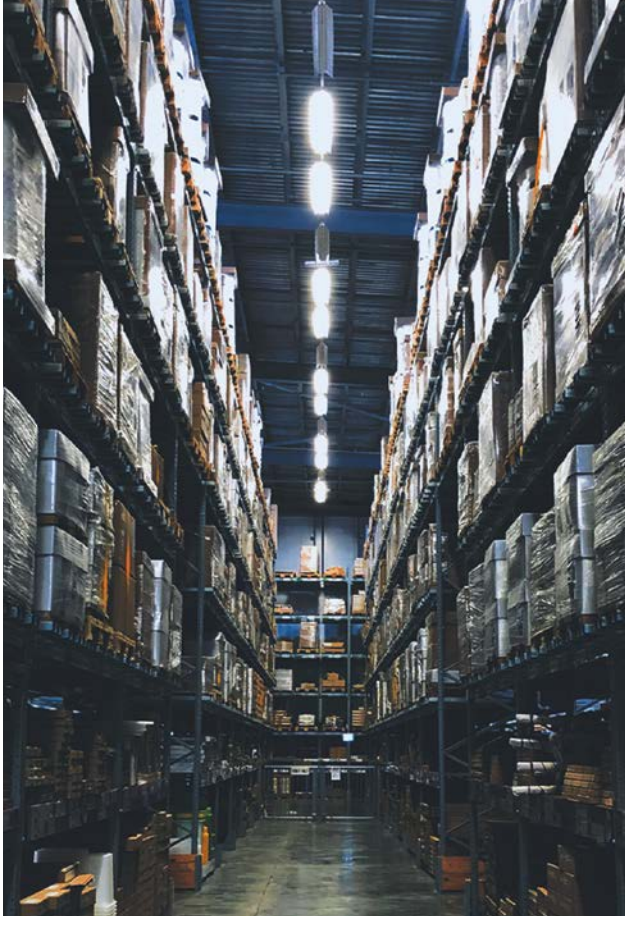
"From an innovator's perspective, change is the only constant in life," says Dupsy Abiola, head of global innovation at International Airlines Group (IAG), which established the Hangar 51 accelerator program in 2016. "COVID-19 has presented wide-ranging uncertainty in nearly every industry, but the world and technical possibilities are changing all the time. Innovation is one of the ways that we can embrace and harness change."

Abiola notes that Hangar 51's fifth program, launching this year, will be a virtual accelerator in light of the pandemic. The program, which enables startups and innovators to work with IAG's operating companies to solve real-world business challenges, has now incubated 35 companies—more than 60% of which have gone on to further trials, commercial contracts or investment from IAG. Hangar 51 has increased its number of finalists and categories each year, and Abiola notes that contactless travel and connected operations are of particular interest this year.

Both SIA Engineering Company (SIAEC) and AFI KLM E&M, which operate in-house innovation labs, note that this year there is increased focus on technological developments for immediate needs such aircraft disinfection and remote-collaboration solutions. A representative for SIAEC says the pandemic's impact on the industry has presented innovation opportunities despite reduced demand. "We need to invest in the right areas, such as digital transformation and automation, to improve our competitiveness," says the

Since March, startups in the ATI Boeing Accelerator have raised more than £6 million ($8 million) in post-program investment and created over 30 new jobs.

SIAEC's RepairJet tool automates the removal of composite layers for composite repairs.

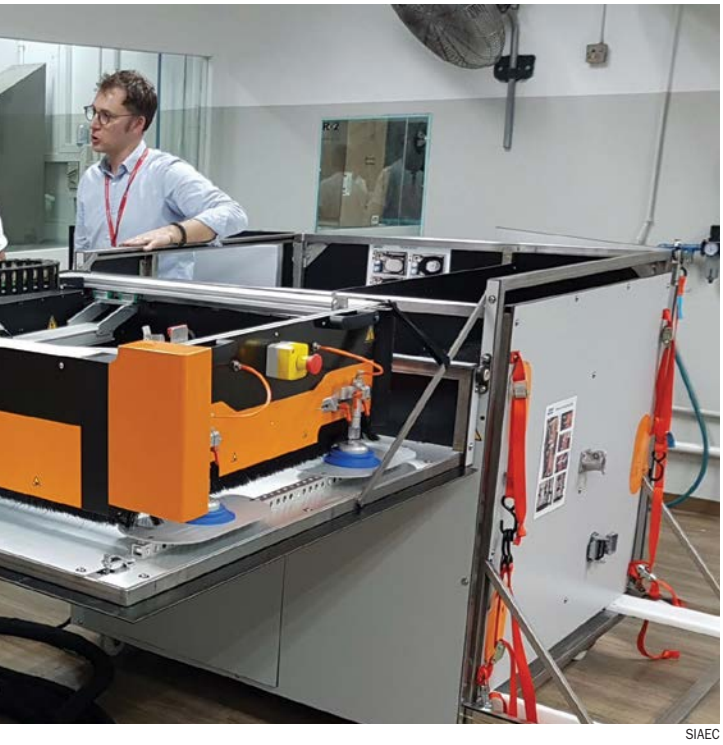


ATI BOEING ACCELERATOR PHOTOS

representative. "It is also an opportune time to reimagine, redesign and lean out our processes, leveraging digitalization and data analytics."

James Kornberg, director of innovation at AFI KLM E&M, says the company's in-house innovation arm—called The MRO Lab—was already careful about only pushing development on technologies that solved real pain points, and the pandemic has amplified the need to approach innovation strategically. "For sure we will have to do more with less investment available. One large part of our activity is to test new solutions without any cash-out or also better use all the data available," says Kornberg. "At the end, to implement the solutions, the return on investment will have to be very good or the investment to keep what we have tested and developed very low. Nevertheless, we continue to identify and test solutions that can help our operations."

Some of the startups in the ATI Boeing Accelerator program are investigating blockchain technologies for sustainability and traceability of the aviation supply chain.



SIAEC

MIXED REALITY AND AUTOMATION

Two areas on which both innovation labs are heavily focused right now are robotic process automation and augmented/virtual reality (AR/VR). The MRO Lab has implemented AR/VR training and has been in the process of testing mobile climbing robots from startup Invert Robotics for aircraft inspections. Both The MRO Lab and SIAEC are testing drones for automated visual inspections. According to SIAEC, the drone trial it conducted in December 2019 at SIA Engineering Philippines reduced inspection time by 80% on average.

SIAEC recently developed a tool called RepairJet to automate the removal of composite layers for repairs, and it also implemented a pneumatic tube system to automate delivery of small spares between its warehouse, hangars and workshops, which it says has reduced average delivery time to 5 min. from 90 min. In late 2019, it deployed VR headsets to train operational staff on tasks such as opening/closing engine fan cowls, replacing slide rafts and calculating aircraft fuel amounts.

AR specialist Atheer was a part of Hangar 51's most recent accelerator round, which ran for 10 weeks in late 2019. During the accelerator, Atheer worked with Iberia's MRO team in Madrid to explore the use of AR to digitalize two complex processes: engine incoming inspection—which can take up to 16 hr.—and making structural damage assessments of aircraft. According to Atheer, its projects with Iberia helped reduce engine incoming inspection time by 30% and saved 30 min. of time per aircraft-on-ground event during structural damage assessments.

STREAMLINING TURNAROUNDS

Two startups devoted to streamlining airline processes and improving communication went through Hangar 51's accelerator last year. Assaia, which uses cameras installed at airports paired with an artificial intelligence (AI) system to analyze turnaround operations and offer predictive analysis to airlines, was paired with British Airways. It provided the airline with a video stream and live dashboard to detect turnaround events such as line maintenance arriving at the stand.

AFI KLM E&M

"Before our technology was available, each and every turnaround had to be actively managed and controlled to ensure that no delay occurred during the turnaround process," says Max Diez, founder and CEO of Assaia. "Now, British Airways is able to monitor several turnarounds at the same time remotely and only act if our system detects an actual problem." Diez adds that the "management by exception" approach enables more effective use of staff time, faster corrective action and reduced number and magnitude of delays.

SynapseMX, which uses a cloud-based AI platform to address unscheduled maintenance challenges, worked directly with two organizations under the IAG umbrella. SynapseMX CEO Shane Ballman says the nature of the projects entailed working with both companies at five work groups spanning multiple physical locations across an airport, which caused "natural bottlenecks in information availability."

"Since our focus is on improving maintenance velocity during unscheduled maintenance (i.e., gate calls), our goal was to increase team coordination across work groups, improve visibility of work status and reduce the work steps required from the existing manual processes," says Ballman. "We were able to streamline how their teams stayed in sync while reducing the number of work steps—even removing the 'productivity quicksand' of trips back into the office to deliver that dual-entry paperwork."

Ballman notes that the COVID-19 pandemic has proven even more interesting for the aviation industry's usage of and investment in technology, since companies are both pausing or embracing new technology depending on their business needs. "One of the fascinating and challenging things about the industry restarting is the nature of how it's happening. Commercial aviation typically doesn't do things like large increases in operational capacity month-over-month, for instance," he says. "How do you enable network planning to add capacity to the schedule in a way that engineering and crew scheduling can support? How do we collectively identify and share storage-related failure modes that haven't even been seen before?"

Ballman suggests that a key component in solving current and future challenges will be industry collaboration through innovation accelerators, including via collaboration platforms such as Rolls-Royce's Yocova, launched by its acceleration hub R2 Data Labs earlier this year.

AFI KLM E&M says its use of remote-collaboration technologies has allowed it to continue operations during the pandemic.

SynapseMX is a launch partner in the platform, and Ballman says Rolls-Royce has "been putting quite a bit of effort into helping the industry form working groups to solve these and other challenges so that we can collectively pull each other back up."

SUPPLY CHAIN TRACEABILITY

One of the aviation industry's newest incubators, the ATI Boeing Accelerator Program, launched last year, right before the pandemic broke out. The accelerator is a joint effort between Boeing, GKN Aerospace and the Aerospace Technology Institute to support innovation and growth of startups in the UK's aerospace ecosystem. The pandemic delayed the launch of its second cohort of startups, so the program made the most of the situation by extending its support for the nine companies from its first cohort as they "settled into this new 'normal,'" the consortium says. Its second cohort, which will launch in January 2021, will have both physical and virtual elements.

Since the accelerator's first cohort of startups was chosen from both inside the aerospace ecosystem and adjacent industries such as automotive or oil and gas, one of the emerging areas of interest for Boeing and GKN was using blockchain technologies to provide better traceability within the supply chain. Startup Circulor, which cut its teeth in tracking and tracing the origin of raw materials used in automotive supply chains to help companies improve sustainability, turned its eye toward solving a number of supply chain challenges for the OEMs.

SES
Fly Certain

We're the people to keep you flying

Shannon Engine Support has the world's largest leasing portfolio of CFM56 and LEAP engines strategically located across the globe. Short or long-term leases, our tailored solutions are created by people with unrivalled knowledge and expertise, who understand your business and the strength of partnership. In challenging times, that's good to know.

SES. A CFM International company.

www.ses.ie

Julie Dickerson

Julie Dickerson
Chief Executive Officer

SES Fly Certain

According to Circulor, its efforts during the accelerator included working with GKN on tracking the carbon footprint within its supply chain, such as emissions related to production of aircraft parts and traceability of powder used for 3D printing of parts. It also worked with both GKN and Boeing on the authenticity and traceability of aircraft parts. Circulor notes that Boeing in particular was interested in maintenance use cases, such as keeping a better record of the location of aircraft parts so they can be procured more efficiently as maintenance occurs.

Also new to the aerospace industry is Kraken IM, which has addressed supply chain traceability issues for industries such as energy and oil and gas. According to its director, Ian Cornwell, Kraken IM's software platform creates a set of transparent digital requirements for a supply chain, making it easier for customers to see whether the materials they receive are what they requested—all while creating a "digital birth certificate" for all parts that come from the supply chain.

"It's the first stitches in a digital thread that can give you data for the whole life of the aircraft, from requirement through into use. We're really just getting started, but where we'd like to get to is the ability to create a digital twin for all the parts and components that get updated as the aircraft is maintained, serviced and inspected and move away from the idea of a 'system of record' to [a] distributed 'ledger of record' that may involve multiple systems," says Cornwell. "If we can get there, then it will increase transparency, resulting in reduced losses from downtime and unplanned maintenance, [an] enhanced secondary market and improved productivity."

He notes that an additional use case Kraken IM has found through the pandemic is tying remote visual inspections to smart legal contracts, which automatically enforce conditions specified in code. These contracts include digital components that enable them to communicate with software systems and respond to events that occur physically. For instance, says Cornwell, if a company wants to ask for new information from suppliers such as precise 3D metrology data, it could be called out in a smart contract clause. Cornwell says this means "you can drive behaviors commercially, not just as an aspiration" by rewarding suppliers for doing things they have never done before.

"COVID-19 has caused a huge supply chain shock from top to bottom. This has been a double-edged sword," says Cornwell. "As one of our clients described, it's been 'digitization by force.' Tools and processes that might have taken months or years to adopt in normal times have been rolled out in days." While Cornwell says tech spending was initially confined to immediate business-continuity use cases such as video-conferencing tools, conversations have begun to change now that things are starting to normalize.

"There's a big emphasis on coming out of the other side of COVID with improved sustainability (economically and en-

vironmentally), resilience and efficiency. It's still a bit early to say for certain, but the discussions we're having are that technologies that can support these things are going to be in demand with the added bonus that people have realized that they can move fast," says Cornwell. "The stresses that supply chains have had if anything have started to drive new behaviors now that the shock is over."

Wil Benton, venture and ecosystem director of the ATI Boeing Accelerator, is seeing similar trends among aerospace companies cautiously returning to service. "Investment has started to pick up, proofs of concept are slowly coming back online, and revenues are starting to reappear. We've also seen some of the more established businesses in the industry focus on investing into 'operations resilience,' where collaboration with startups (and startup-driven innovation) is being used to lessen the impact from COVID-19," he says.

HANGAR 51

The MRO Lab is testing Donecle's drones for aircraft inspections. Donecle also was selected for the Hangar 51 accelerator.

Although the innovation sector within aerospace is remaining optimistic, Benton notes that change will not happen overnight. "We aren't out of the woods. The impact of the pandemic, or its long-term effects, are yet to be seen and are likely to be severe—unlike anything we've seen before," he says. "Innovation will be the key to surviving this, so hopefully we [will] see more industry and startup collaboration moving forward."

China Airlines: Not Taking Chances

The Taiwanese carrier prepares its aircraft for lease returns, more cargo demand and typhoons

Chen Chuanren Singapore

Eight months into the outbreak of the COVID-19 pandemic, Taiwan continues to be the only country that has the virus under control and has not seen a second-wave outbreak. However, the wings of its flag carrier China Airlines (CAL) remain clipped, and its 2,500-strong Engineering and Maintenance Organization (EMO) is not taking any risks that might hinder its ability to provide MRO capabilities for the airline.

Paul Shiao, CAL's assistant vice president for the maintenance division prior to the pandemic, says the EMO's plans to renovate its facilities, including the hangar offices and material storage building, have been put on hold. It also planned to implement innovative projects such as ground support equipment management systems, an aircraft exterior inspection system and a "smart" workshop, all of which have been paused due to the pandemic.

He says the group is tackling a "cost-down scheme" in five areas, consisting of contract reviews, streamlining maintenance schedules, adjusting maintenance capacity, reviewing time and material management, and managing equipment and material by setting up project plans and savings targets. The results are reviewed on a monthly basis.

The EMO has implemented physical-distancing measures such as working in separate buildings, a "masks-on" policy and recording body temperature twice daily. To prevent a long line in the canteen, the company caters lunch boxes, and each table can only accommodate one person. Shop floors, stores and elevators are marked with distance markers to enforce physical distancing between employees.

China Airlines created a designated team to manage and optimize the demand for aircraft parking.

CHINA AIRLINES

To prevent cross-infection, the workforce is separated into two teams, and each works every other day and on different aircraft, meaning there is no chance that two teams will meet each other at the same time and space.

"To further reduce the possibility of cross-infection in between, we require each party to implement disinfection measures every day at the public area, office area and especially the changing area. We didn't see our productivity going down," Shiao says.

AIRCRAFT PREPAREDNESS

Aviation Week Fleet Data Services estimates CAL now has around 20 aircraft parked or on reserve, mostly the Boeing 737 series. The airline set up a designated team to manage and optimize the demand for aircraft parking based on the trend of flight cancellations, aircraft maintenance requirements and relevant regulations. The airline used 30-day active storage guidelines derived from the manufacturers' aircraft maintenance manuals and engineering orders to keep the aircraft in a high state of readiness.

In the event of an impending typhoon, the EMO will participate in an "anti-typhoon committee meeting" held at the CAL control center to decide which aircraft will be tied down at Taipei Taoyuan Airport and which will be flown elsewhere to avoid the strong winds.

"To protect aircraft from a typhoon, we are not only tying down the aircraft at the airport, but we also are assigning an engineer to stay in each aircraft cockpit while the typhoon arrives to pressurize flight control surfaces to keep it steady on the ground," Shiao adds.

Air cargo continues to be a lifeline for CAL's revenue and has contributed NT$41 billion ($1.4 billion) to the carrier's coffers. Until the arrival of the new Boeing 777F due this year, the freighter fleet is still anchored by 17 Boeing 747-400Fs, all of which are 13-20 years old. Shiao says manufacturers are committing fewer resources to enhance the 747-400F's reliability, as the type is gradually being phased out.

"However, due to CAL EMO's long experience on the type, our 747F's reliability has been kept satisfactory by adding more maintenance tasks and shortening the intervals of the mandatory work. In addition, a special task force has been formed to closely monitor the key components of our freighters for smooth operation," he says.

Spares have taken a longer time to arrive during the pandemic, especially larger parts that have longer lead times due to high demand for cargo space, with the average lead time ap-

China Airlines overhauls CFM56-7B, CFM56-5C, GE CF6-80C2 and CF6-80E1 engines.

CHINA AIRLINES

proximately two weeks longer than before. Shiao stresses that the airline does not cannibalize parts.

The task force's sole purpose is to maximize the freighter dispatch rate, focusing on maintenance defects tracking and corrective measures to make sure the freighters are always dispatched on time.

The EMO also carried out cabin modifications on Boeing 737-800 and 777-300ER and Airbus A350-900 models based on Taiwan Civil Aeronautics Administration and manufacturer's guidelines, enabling the aircraft to conduct mixed passenger-cargo flights to supplement the carrier's revenue.

While domestic flights continue, most of these are operated by the group's Mandarin Airlines, which flies the ATR 72 and Embraer 190, hence there is no transfer of engineers and technicians due to the different type ratings.

THE ROAD AHEAD

Shiao has identified two fronts the EMO will focus on as it adjusts its strategies for the future. In the area of human resources, the organization is planning to fine-tune employee roles to better cope with future demand, and it has been conducting both on-the-job and recurrent training over the last few months.

It is also adjusting its maintenance capabilities to meet the airline's needs while the 30-day active storage plan continues. To do that, it readies spares and reviews individual technicians' qualifications to prepare for future lease returns. CAL currently has 10 A330-300s, six 777-300ERs and 15 737-800s on lease.

The lease returns of the 737-800 are also in line with the introduction of the Airbus A321neo, with 11 under a memorandum of agreement with Airbus and another 14 placed on lease. Shiaosays CAL is now preparing maintenance capabilities for the A321neo as well as the 777F to guarantee a smooth entry into service.

CFM56 Repairs Outlook

CFM fleet MRO is on the upswing

Lee Ann Shay

It will likely take at least a couple of years for airlines to recover from the devastating impact that COVID-19 has wrought, so expect operators to scrutinize how best to balance operating efficiency and cost containment even more than before.

Repairing parts instead of replacing them is often one way to do this, and given that engine MRO typically accounts for about 40% of total civil aviation aftermarket costs, the engine repair market could receive extra attention. For the CFM56 fleet, which is one of the largest active engine types, there are already many repair options from both the OEM and independent shops.

CFM partners GE and Safran Aircraft Engines typically develop about 150 repairs annually. (The company does not disclose the cost of those.) Because CFM has an open aftermarket, airline and independent MROs also develop repairs, and CFM cannot ascertain the number of repairs, says Maureen Normoyle, CFM's life-cycle engineering leader. "Suppliers own the design content and provide the aftermarket support" for those, she says.

To put the scope of today's fleet in perspective, CFM International says more than 16,000 CFM56-7B and –5B engines are in service, which represents about 75% of the fleet.

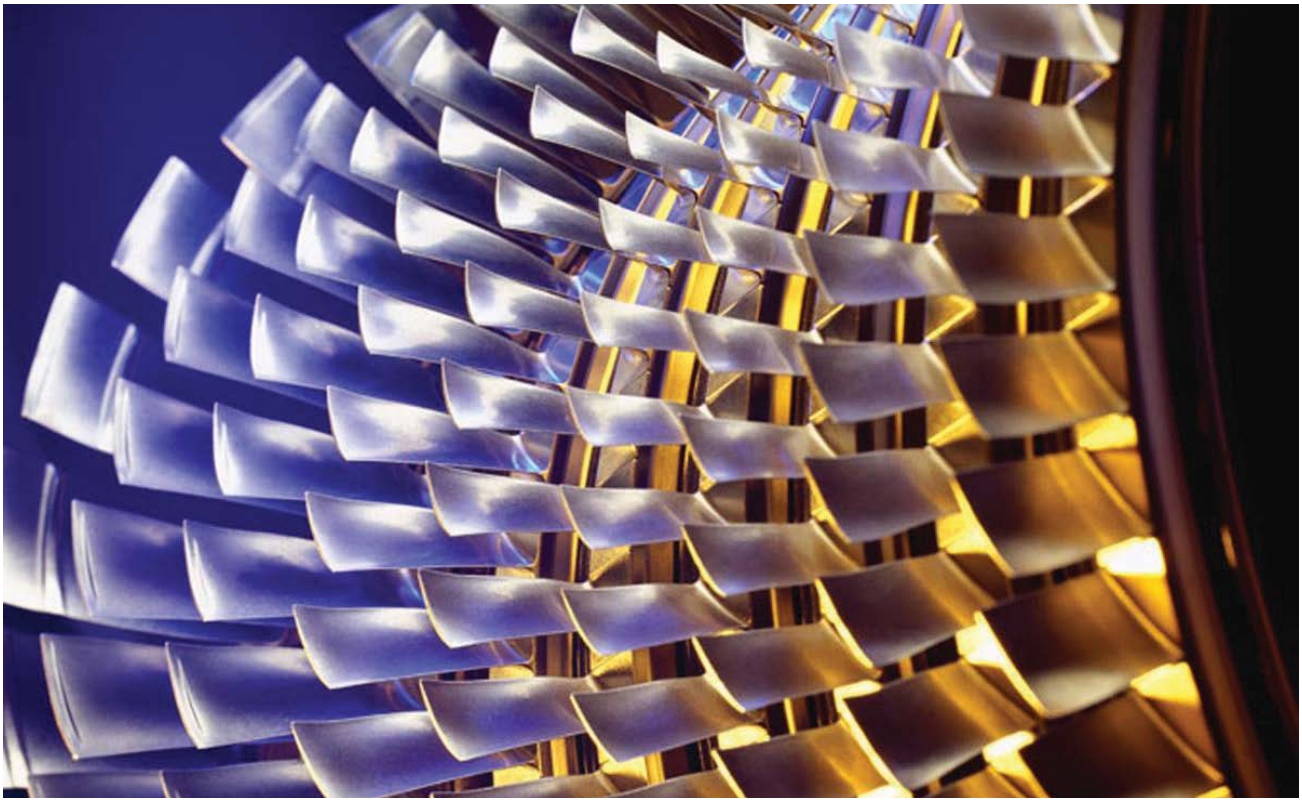
The -7B, which powers the Boeing 737NG, is the most active of the type. Over the next three years, the -7B is forecast to generate $106.5 million in MRO revenue, and the -5B, which powers the Airbus A320, will generate $57.6 million, according to Aviation Week's 2021 Fleet & MRO Forecast.

"Even though new-build production of the CFM56 is winding down [with 84 engines delivered by CFM International during the first six months of 2020, compared to 258 engines during the first half of 2019], the engine still has a long service life ahead of it, with over 50% of CFM56-5B/-7B engines yet to undergo their first shop visit," says Alex Youngs, StandardAero vice president of strategy and analysis.

Next year should see the highest number of CFM56s in service, at more than 21,000, according to Aviation Week forecast data. That number will gradually decline over the decade, until about 16,000 engines are in services—which is about the number of engines flying now because of decreased airline traffic caused by the pandemic. Peak utilization will occur near 2023.

To identify repair priorities, CFM looks at part scrap rates and other things driving engine shop costs, as well as at "repair-limit extensions based on updated engineering analyses," says Normoyle.

CFM INTERNATIONAL



CFM develops about 150 repairs annually for its engines, including the very active CFM56-7 (pictured).

INTEGRATED GLOBAL SOLUTIONS

WWW.SIAEC.COM.SG

At SIAEC, we invest in our people, capabilities and technology to constantly deliver best-in-class aircraft maintenance solutions, across our MRO network. From base maintenance in Singapore or Clark, Philippines, to cabin hygiene solutions, we deliver a suite of integrated MRO services, for you and those you serve. A trusted partner and MRO of choice, speak with us to discover more on our services.

22 - 24 September 2020

MRO Asia Pacific Virtual Event
Come visit our virtual booth

SIA Engineering Company Ltd
31 Airline Road, 06-M Hangar 2, Singapore 819831
Email: siaec_commercial@singaporeair.com.sg
Company Registration No. 198201025C

SIA ENGINEERING COMPANY

StandardAero, which is part of GE's engine shop network but also an independent MRO so it can perform customized workscopes, focuses repair priorities on "cost-saving opportunities, supply chain and turn-time operational improvement opportunities, as well as improved durability and quality assurance," says Youngs.

StandardAero bolstered its CFM56 repair capabilities when it acquired Jet Aviation Specialists and PAS Technologies in 2017.

Normoyle says the pandemic hasn't changed the process of how it develops repairs. "We are staying closely coordinated with customers, as well as the CFM MRO network for industrialization (shop implementation) and repair development prioritization."

Interestingly, Safran CEO Philippe Petitcolin recently said that while the company's shop visit volume has decreased this year, it has not seen a significant dip in per-shop-visit workscope.

The CFM56-7B has logged more than 430 million hr. and about 222 million cycles, while the -5B has logged 238 million hr. and almost 136 million cycles.

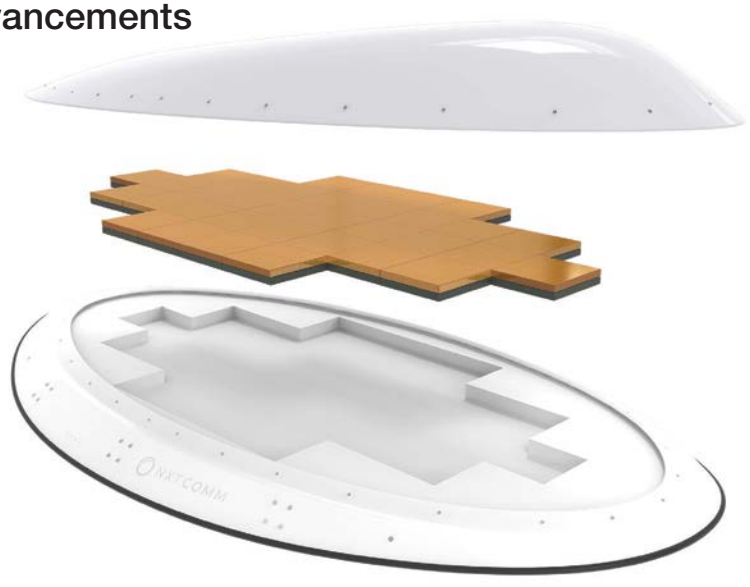
STANDARDAERO

StandardAero develops CFM56 repairs at its Winnipeg, Manitoba, facility and through its global StandardAero Component Services team.

Given these numbers, it is clear that the CFM56 aftermarket will be robust for years.

Constellation Compatibilities

New satellite systems speed up antenna advancements



NXT COMMUNICATIONS

A NXT Communications AeroMax flat-panel, electronically steered array antenna is pictured in an industry-standard radome.

Paul Seidenman and **David Spanovich** **San Francisco**

Inflight connectivity has revolutionized the passenger experience, but it continues to have issues with undependable internet connections and content delivery. As higher-capacity satellite networks come on-stream, however, that could change. In preparation, antenna OEMs are implementing innovative engineering concepts.

"Content providers are asking for antennas that are future-proof," stresses Jake Sauer, vice president and general manager at Ball Aerospace. "They want to put one antenna on a plane and be confident that it will support the satellites in space today and the new NGSO [non-geostationary-orbit] satellites planned for tomorrow."

Sauer reports that Ball Aerospace has focused on electronically steered phased-array (ESA) antennas to be satellite and constellation agnostic. He describes a novel approach to the design and production of flat-panel arrays that builds upon modular antenna building blocks called subarrays. These subarrays are combined like Lego pieces to form larger flat-panel arrays.

"This modular design enables scalability that cannot be achieved with traditional, mechanically steered antennas," Sauer explains. "These products are architected to be modular so the transmitting and receiving antennas can be independently sized to meet specific customer needs."

Ball Aerospace is also leveraging other innovations for its antennas, including advanced semiconductor processes such as radio frequency complementary metal-oxide semiconductors (RF CMOS), a low-cost, high-volume, digital-process technology. RF CMOS, Sauer says, provides excellent radio frequency performance and enables high levels of integration. This technology—used in the beam-forming chips and developed by Ball Aerospace partner Anokiwave—is what Ball's ESA employs to control phase, amplitude and polarization of every element, giving the product the ability to create and move beams almost instantaneously. This allows a single antenna to communicate with geostationary (GEO), medium-Earth-orbit (MEO), highly-elliptical-orbit (HEO) and low-Earth-orbit (LEO) satellites.

"Software individually controls the performance of thousands of antenna elements, allowing beam control and shaping not available before to the commercial satcom industry," Sauer says. "Along with that, the antenna's RF performance benefits from advanced printed-circuit-board materials, which support higher RF performance and lower costs."

He adds that the antenna can now meet the regulatory requirements of GEO satellites and the beam mobility requirements to communicate with a LEO satellite. "With a software upgrade, this same antenna can be configured to work with future satellite constellations and waveforms," Sauer points out.

PLAYING CATCH-UP

At this time, antenna technology is largely in catch-up mode, according to David Horton, co-founder and CEO of NXT Communications (Nxtcomm) in Atlanta. Horton, in fact, likens inflight connectivity (IFC) development to "a game of leapfrog."

"The satellite operators invested a lot of money in new high-throughput satellites," he says. "However, the ground segment—the teleport side of things—hadn't made the strides they needed to interface with them. By the time the satellite technology and the ground infrastructure caught up, the on-aircraft antenna hardware was not where it needed to be. Today, we have relatively poor-performing antennas on airplanes."

To address performance issues, Nxtcomm expects to roll out AeroMax, initially with a K_u-band antenna, by the fourth quarter of 2021, and a K_a-band version by the spring of 2022.

As Horton explains, AeroMax will be able to work with all satellite constellations, with the capability to transition seamlessly among them, and yet deliver consistent, uninterrupted connectivity in flight. To do that, AeroMax uses an ESA, incorporating a single flat panel. Less than 2 in. thick, the installed antenna re-

sides within a radome that sits below the boundary layer, reducing drag. According to Horton, it is the first true flat-panel ESA developed for the commercial aviation market.

"This innovation, embedded within our fragmented aperture technology, makes this possible," Horton notes. "Also our proprietary algorithm enhances beam forming and beam steering, especially important for LEO, MEO and HEO. All other antennas in the market—either the mechanically steered parabolic or the quasi ESAs—are dependent on multiple antennas for non-GEO operation."

BALL AEROSPACE

Ball Aerospace is focused on producing electronically steered, phased-array antennas, like the one pictured, that are satellite- and constellation-agnostic. The antenna is built on modules that are called subarrays, which click together like Lego pieces to form larger flat-panel arrays, enabling scalability.

Horton adds that the economics of maintaining mechanically steered antennas are challenging: "ESAs are more efficient and reliable than mechanical-array systems, with no moving parts or gears to fail."

Horton reports that Nxtcomm's fragmented aperture technology is core to its antenna's functionality. "AeroMax is fundamentally manufactured as a printed circuit board. "Our technology has a smaller LRU [line-replaceable unit] count and features consolidated electronics. We don't waste space under the radome, which is a huge benefit of our flat-panel design."

Asked if content providers will move away from legacy GEO satellites, Horton says he believes that they will use all available satellite architectures. "The difference will be in what percentage," he notes. "Right now, we are GEO dominant, but over the course of time, the mix of bits delivered from each of those architectures will change. That's why it's important to have an antenna that does it all."

MECHANICALLY STEERED VERSIONS

Although ESA technology has its advocates, at least one OEM differs. Gregg Otto, vice president at ThinKom Solutions, has manufactured mechanically steered, variable-inclination, continuous transverse stub (VICTS) phased-array antennas, which Otto says have proved to be extremely reliable and cost-effective.

To illustrate, Otto reports that before the COVID-19 pandemic, more than 1,500 aircraft were flying with ThinKom's Ku3030 VICTS antenna privately labeled by Gogo for its 2Ku IFC service. Before the pandemic, the antenna accumulated more than 16 million hr. of operation with a mean time between failures of approximately 100,000 hr. "The antenna has provided gap-free, pole-to-pole coverage on all aircraft types, at all altitudes and with a low-profile radome," he says.

According to Otto, electronically scanned array antennas, though in development for decades, have been unable to overcome numerous technological challenges that limit their efficiency, cost effectiveness, excessive power demands and poor low-elevation performance. "ESAs have been promised for many years, but no viable product has made it to market, and the schedules keep moving to the right," Otto remarks.

The VICTS antenna architecture can support either Ku- or Ka-band frequencies. To that end, Otto points out that ThinKom has entered commercial production of its Ka-band ThinAir Ka2517 IFC antenna subsystem, including the entire outside antenna equipment (antennas, adapter plate, radome and fairing) as well as the inside antenna equipment—specifically the Ka-band network data unit and the Ka-band radio frequency unit. The Ka2517 system has already been deployed on a fleet of U.S. military aircraft and is in production for several large IFC service providers.

Otto calls the VICTS antennas the most area-efficient phased-array antennas available in the market.

"They are low-profile [3-4 in. tall] and have extremely low front-end losses, as they are based on ThinKom's patented parallel-plate antenna design," Otto says. "Compared with electronically steered antennas, the VICTS antenna is 2-5 times more efficient, which translates into a footprint that is 50-80% smaller for a similarly performing ESA. Excluding the solid-state power block converters, the antenna and antenna controller dissipate less than 150-watt average power."

The VICTS antennas, he adds, are designed for accelerations of up to 1,000 deg./sec.^{2}, enabling them to switch from one satellite to another in less than 1 sec.

"That speed, which cannot be matched by parabolic dish or flat-panel gimbaled antennas, is what enables ThinKom's VICTS antennas to interoperate effectively between GEO and NGSO constellations," he says. "We have successfully conducted live on-air trials with our commercial, off-the-shelf Ku- and Ka-band VICTS antennas, proving that we can support seamless automatic roaming between GEO and NGSO networks."

Time and SpaceJet

Mitsubishi Aircraft's regional jet development has been slow, but competition has fallen off as well

Alex Derber London

When Mitsubishi launched its regional jet program in 2008 the business case was questionable. Incumbent manufacturers Embraer and Bombardier dominated the regional jet market with an installed base of thousands of airframes, flight tests were already underway for the rival Sukhoi Superjet, and closer to home China was pouring considerable resources into its ARJ21 program.

Fast-forward 12 years, and many of those challenges have evaporated. Embraer is reeling from an aborted takeover by Boeing, Bombardier no longer makes commercial aircraft and Mitsubishi has acquired its CRJ program, the Superjet has flopped outside—and increasingly inside—Russia, and the ARJ21 has garnered little interest other than from China's state-owned airlines.

But despite this implosion of the competition, the case for the Mitsubishi SpaceJet is as tenuous as ever. The havoc wrought on the airline industry by COVID-19 is one reason for this, but even before the pandemic the Japanese regional jet program was grappling with multiple delays and a limited orderbook.

In May 2019, seeking to draw a line under the program's internal troubles, Mitsubishi Aircraft rebranded it from the MRJ to the SpaceJet, focusing on the 90-seat M90 (then in flight tests) and also launching a new 76-seat variant, the M100, which would be scope-clause-compliant for the U.S. market.

Only a few months later, U.S. regional airline group Trans States canceled an order for 50 M90s due to scope-clause concerns. At the time, Mitsubishi said it was in talks to replace the order with the M100, but then COVID-19 struck, and by May of this year the company was forced to announce suspension of the M100 program and a halt to flight testing of the M90.

Mitsubishi Aircraft is now reporting 287 orders and options for the M90. Of those, 163 are firm orders, although these include 100 from SkyWest, a U.S. regional airline group that faces the same scope-clause obstacle as Trans States. That means a big question mark hangs over its order.

Flight testing of the M90 has been halted as Mitsubishi Aircraft reorganizes.

MITSUBISHI AIRCRAFT

Given this situation, many wonder why Mitsubishi has not scrapped the SpaceJet program altogether. And the finance department of Mitsubishi Aircraft's parent—Mitsubishi Heavy Industries (MHI)—may have agreed, after the SpaceJet program accounted for almost all its ¥71 billion ($670 million) loss in the three months ending on June 30, 2020.

MHI estimates that fiscal 2020 development costs for the SpaceJet could be ¥60 billion. And while this is less than half the previous budget, commercial considerations about the program appear to have become entangled with national strategic objectives—and pride.

"We are developing the first commercial jet for Japan," says a representative for Mitsubishi Aircraft. "This is significant, not only for our company but also for our country. Working closely with our business partners and the [Japan Civil Aviation Bureau], we are establishing the foundation for the commercial aviation industry in Japan."

PROGRAM STATUS

Although Mitsubishi Aircraft has halted flight testing of the M90 and closed its Moses Lake, Washington, testing site in the U.S., the company is continuing to work toward type certification for the regional jet.

In February, Mitsubishi Aircraft said that the SpaceJet would enter service in April 2021 "at the earliest." But now the company will not disclose a target date for type certification or for entry into service of the M90, stating that plans for the former will proceed once Mitsubishi Aircraft completes its reorganization and restructuring. Part of that process included the appointment of Yasuhiko Kawaguchi as executive chief engineer. Kawaguchi had a key role in the M90's flight-test program, which produced 3,900 hr. of data that now needs to be validated. Mitsubishi has said it will also focus on "improving the current design at the aircraft level."

"These are our priorities now," says Jeff Dronen, director of strategic communications for Mitsubishi Aircraft. "Once we achieve type certification, at that point we will reevaluate the market and the needs of our customers and determine entry into service in line with their schedules."

Regarding the effect of Mitsubishi Aircraft's restructuring on its relationship with key suppliers, Dronen says: "COVID-19 has obviously had an impact on us and our partners. We all are suffering now, and we must work together as we move forward."

He adds that organization of aftermarket support for the SpaceJet will be determined closer to the M90's type certification.

"Once we have a clear vision to achieving [type certification], then we will begin reevaluating the market and customer needs and determine the best approach for supporting our customers and our aircraft," Dronen says.

MITSUBISHI AIRCRAFT

The SpaceJet's first flight was performed with flight-test vehicle No. 10 on March 18, 2020.

Although as yet there are no details on how Mitsubishi Aircraft will support the SpaceJet, it may well gain some valuable insights from its parent company's acquisition of the CRJ program from Bombardier. MHI closed the deal in June, acquiring the maintenance, support, refurbishment, marketing and sales activities for the CRJ series, plus their type certificates. The sale included Bombardier's CRJ services and support network in Montreal and Toronto, as well as its service centers located in Bridgeport, Connecticut, and Tucson, Arizona.

Following the deal, an MHI representative says the company has become "the largest maintenance and support provider for the CRJ family of aircraft." The representative adds: "The SpaceJet program will be able to take full advantage of this unparalleled customer support workforce and be ready to jump back into the competition once it fully restarts the program."

THE LONG GAME

Despite Mitsubishi's tortuous development of its regional jet—the original iteration, the MRJ90, was supposed to have entered service in 2013, but the first flight-test vehicle rolled out in 2014—the company still has time on its side. The COVID-19 pandemic means there is scant demand for new aircraft at present and probably for the next year at least and thus little chance for competitors to steal a march on the SpaceJet.

Commenting on the state of the regional aircraft market, Dronen says that Mitsubishi Aircraft's "research is in line with recent industry analysis, and we expect that it will take several years to recover to the previously expected levels."

Another point in favor of a further extension to development is that Embraer is the only player of note left in the regional jet market. Yet there is a huge fleet of aging regional jets that will need to be replaced over the next decade, a process that airlines and lessors would prefer not to enter being on the wrong side of a monopoly.

Completed before the pandemic, Embraer's most recent market outlook projects demand for 10,500 aircraft of up to 150 seats in 2019-38, 45% of which will be replacements. Over the same period, Boeing forecasts deliveries of 2,240 regional jets, a category in which aircraft like the M90 and Embraer 175-E2 are at the top end of the size range.

Both the M90 and the Embraer E2 line use variants of Pratt & Whitney's PW1000 family of geared turbofan engines. The appeal of the efficiency gains these offer over current-generation powerplants is somewhat negated by scope-clause restrictions in the critical U.S. market, which accounts for almost half the global regional jet fleet. Both the M90 and E175-E2 are excluded from this market due to their maximum takeoff weights.

One result of this has been continued demand for the current-generation E175, which is scope-clause-compliant. Prior to the pandemic, most analysts expected 2023 to be the next date when renegotiation of scope clauses might be possible, although few predict success in such talks.

However, COVID-19 has upended the airline industry in ways that are only beginning to be felt. One unforeseen consequence may be a loosening of scope-clause restrictions by U.S. unions. And even if that does not happen, there remains a large market outside the U.S. into which both Embraer and Mitsubishi are hopeful of selling. Failing that, the Japanese company also has the option of restarting development of the M100.

Yet the long term brings its own challenges. The further Mitsubishi extends SpaceJet development, the closer it may find itself in conflict with new technologies such as ultra-high-speed rail and electric aircraft, not to mention changing societal attitudes toward the environmental impact of flying.

While electric aircraft are still an unproven concept, the 90-seat M90 lies at the upper end of what aerospace engineers think might be possible for commercial passenger airliners using electric powerplants.

Innovative Startups

Lindsay Bjerregaard Chicago

1

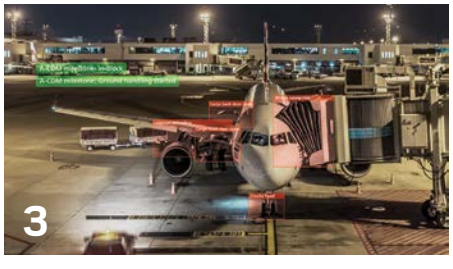
1. Automated Part Recognition

Company: Pzartech
Specifications: Israeli startup Pzartech provides digital tools for part recognition and tracking. The company's Snapr application uses shape and industrial optical character recognition to extract part and serial numbers, so technicians can capture a picture of a part, quickly confirm it is the correct one and take appropriate action. The tool also enables semi-automatic entry of the serial number to simplify the mechanical part identification process. Snapr was developed in partnership with Israel Aerospace Industries as part of its innovation lab efforts to support teams maintaining aircraft in performing incoming/outgoing engine inventory.
marketplace.aviationweek.com/company/pzartech-ltd

2. Sustainable Sourcing

Company: Circulor
Specifications: Originally getting its start by helping the automotive supply chain track cobalt used for batteries, Circulor is now working with Boeing and GKN Aerospace through the ATI Boeing Accelerator to track carbon emissions during the production of aircraft, as well as the authenticity and traceability of aircraft parts and powder used for 3D printing. Circulor tracks supply chain data along the journey from source to consumption, creating a digital footprint for raw materials that maintains the integrity of its credentials throughout its lifetime. Circulor says this helps OEMs manage their supply chains more effectively while enabling them to make informed choices about sustainability and ethical sourcing.
marketplace.aviationweek.com/company/circulor


2


3


4

3. Monitoring Aircraft Turnarounds via AI

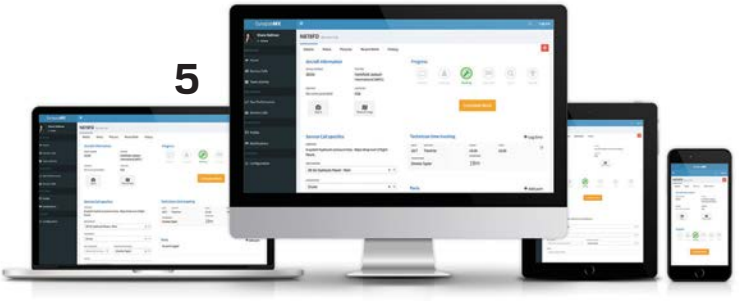
Company: Assaia
Specifications: Assaia's Apron AI system uses cameras installed at airports paired with an artificial intelligence system to analyze turnaround operations and offer predictive analysis to airlines. Through the Hangar 51 accelerator, Assaia worked with British Airways to monitor and detect multiple aircraft turnaround events simultaneously through a video stream and live dashboard, which it says enabled more effective use of staff time and faster action and reduced the number and magnitude of delays. The company has been working with several other airlines to explore other safety use cases for Apron AI, including detecting speed during aircraft pushback operations and understeering while entering an aircraft stand.
marketplace.aviationweek.com/company/assaia

4. Continuous Asset Tracking

Company: Uwinloc
Specifications: French startup Uwinloc provides an indoor Internet of Things location monitoring system that enables continuous tracking of goods. The system combines beacons, a server, visualization software and battery-less tags that collect energy from the surrounding radio field to track assets on a 2D or 3D map. Uwinloc says the system can increase productivity and improve stock management. It is now working to develop tags that can adapt to products in various shapes and sizes, as well as tags integrating sensor characteristics such as temperature and speed measurements.
marketplace.aviationweek.com/company/uwinloc-0

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

5. Real-Time Maintenance Management



Company: SynapseMX
Specifications: SynapseMX's cloud-based maintenance management and execution platform uses real-time data tools and machine learning to help deal with maintenance challenges as they occur. The platform enables monitoring and management of operations such as coordinating teams, assigning jobs, performing and signing off on work and notifying downline stations when issues are headed their way. SynapseMX says the platform improves team efficiency and helps operators keep track of trends during "the crisis of the day." It recently won a contract with the U.S. Air Force to explore how the platform can improve visibility of unscheduled maintenance activities and streamline team workflows.
marketplace.aviationweek.com/company/synapsemx

6. Robotic Mapping of MRO Operations

Company: Reckon Point
Specifications: Based at the Port San Antonio innovation center, Reckon Point uses 360-deg. imaging technology mounted to robots to develop GPS for indoor spaces. The technology can be used to map maintenance operations and track materials through the line, or even track assets and staff when paired with sensors, wearables or mobile devices. Reckon Point says this could enable tracking of technicians' exposure to dangerous elements such as toxic materials, vibration or fumes. It is now working to develop robots that can climb stairs or drive off-road to scan building exteriors and terrain.
marketplace.aviationweek.com/company/reckon-point

7. Transparent Supply Chains

Company: Kraken IM
Specifications: UK startup Kraken IM provides software to help customers procure what they need from their supply chain by ensuring materials have conformity, traceability and meet all requirements. The company creates transparent digital requirements and captures information deliverables, quality requirements and paper documents, then uses blockchain to create a "digital birth certificate" for all parts coming from the supply chain. Kraken IM is working toward the ability to create a digital twin for all parts and components that can be updated as aircraft are maintained, serviced and inspected, which it says will provide greater transparency and reduce losses from downtime and unplanned maintenance.
marketplace.aviationweek.com/company/kraken-im

8. Augmented Part Inspections

Company: Anomalous
Specifications: Scottish startup Anomalous provides AI-based software to improve the speed and accuracy of aircraft part inspections. The company says humans performing visual inspections miss 20-30% of visible defects on average, but its software can improve the process. Inspectors can capture data about a part via mobile devices, and the software uses AI models to look for defects and produce a digital report, which helps inspectors determine whether the part has passed or failed inspection. In addition to improving inspection consistency, Anomalous says the software can be used to identify used serviceable material or parts that may have been taken out of service too soon.
marketplace.aviationweek.com/company/anomalous

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

By GUY NORRIS

Guy Norris is Aviation Week's Senior Propulsion Editor

Power Disruption

Engine MRO change is coming, but don't panic!

Engine-makers are laying out tentative development strategies for a new generation of advanced lower-emissions powerplants that embrace everything from more-electric and hybrid-electric technology to distributed propulsion architectures, hydrogen fuel cells and carbon neutral-fuels.

But what does this mean to the established multibillion-dollar engine aftermarket industry that has flourished for so long on maintaining, repairing and overhauling the conventional gas turbine? Is the game about to change, and will the traditional service providers be increasingly left out in the cold as the industry moves toward a brave new, sustainable world?

While the shift to new technologies will inevitably be more radical than anything the aftermarket has seen since the start of the jet age, there are currently more questions than answers when it comes to what directions the engine OEMs will take and when. The only certainty is that changes are on the way as airframe and engine-makers work toward reducing CO_2 emissions to 50% of 2005 levels by 2050.

A short-term change with almost no known implications for engine MRO will be the broader adoption of sustainable aviation fuels. But beyond this, the picture is murkier. Although development of all-electric propulsion systems is underway, the limited energy density of batteries means the concept will necessarily be limited to applications such as unmanned cargo drones, urban air mobility and other electric vertical-takeoff-and-landing vehicles.

However, this doesn't mean engine MROs can ignore the electric revolution. Engine-makers are already planning to make turbofans more electric—both to feed future airliner power needs as well as to potentially gain fuel savings by using electric power to optimize engine operation.

MRO providers should think about not only how to adapt but also how to take advantage of potential market opportunities.

Pratt & Whitney is studying a next-generation PW1100G geared turbofan that could be a parallel turboelectric hybrid engine, which could be up to 5% more efficient than current engines and be available for the next generation of single-aisle airliners.

Rolls-Royce, which is building the first demonstrator of its new UltraFan geared turbofan for tests starting in 2021, is already pondering "micro-hybrid" electric versions with embedded starter-generators.

Paving the way for a more electric future, in August the U.S. Energy Department awarded $33 million in contracts to develop all-electric powertrain and fuel-to-electric power-conversion technologies to reduce emissions of future single-aisle airliners.

Covering everything from high-performance energy storage and power generation subsystems for electric aircraft—including fuel-to-electric power conversion—to developing ultra-efficient all-electric powertrains with advanced thermal management systems, the programs make a statement that the U.S. does not intend to fall behind in the more-electric race.

The clear message is that electric power, in various forms and levels of hybridization, is coming, and MRO providers should think about how not only to adapt but also to take advantage of the potential market opportunities. As well as more electric features on future single-aisles, a new generation of all-electric small commuter and hybrid-electric regional aircraft is on the horizon and, because of their promised low operating costs, they could be in service in far greater numbers than today's generation.

Beyond electric power lies a growing interest in hydrogen. Although discounted as a viable option for aircraft until very recently, hydrogen is now viewed as a way to deeply decarbonize aviation—particularly in Europe. Airbus sees the fuel as one way to meet its stated commitment to bring an aircraft with net-zero carbon emissions to market by 2035.

While earlier efforts to bring hydrogen to aviation have failed because of the high cost of the infrastructure required for production and distribution, the climate-change imperative and the "flight-shaming" movement in Europe have forced a reconsideration.

So what could the adoption of a hydrogen ecosystem mean for the MRO industry? Almost certainly it would present significant new support opportunities, as hydrogen can be used in fuel cells powering electrified propulsion systems or directly combusted in gas turbine engines. Hydrogen, renewable electricity and captured CO_2 can also be used to produce carbon-neutral synthetic fuels.

Against this backdrop of dramatic change, there is one great certainty to warm the heart of all engine MRO operators: The gas turbine is not going away—at least not for the next few decades. Alan Newby, director of aerospace technology and future programs at Rolls-Royce, echoes his competitors when he says gas turbines have plenty of runway left ahead. "From our point of view, whether or not it is fueled by sustainable aviation fuel or even ultimately hydrogen in the long-term future, you're still going to need a highly efficient gas turbine," he says.

Aviation Week Marketplace is an online service that connects **buyers and sellers** in the MRO industry. *Become a power user by registering at marketplace.aviationweek.com/register. Registration is FREE, enabling you to find hundreds of products like the ones featured below and to connect with more than 8000 companies. You can create a personalized save list, learn about companies' specialties, get contact details and request information at marketplace.aviationweek.com.*

To advertise in the Marketplace, contact **Elizabeth Zlitni at 913-967-1348 or elizabeth.zlitni@aviationweek.com.**

AVIATION WEEK MRO ASIA-PACIFIC

AVIATION WEEK AeroEngines ASIA-PACIFIC

MRO Asia-Pacific Virtual, September 22-24, 2020: Overcoming Unprecedented Change and the Challenge of What Lies Ahead! While live events are on hold, virtual events will provide digital content, networking, and a marketplace where the airline, OEM and MRO supplier communities can discover and showcase new products and innovations, connect with and source new and existing business partners, and share knowledge and best practices. Our virtual platform breaks down physical barriers and builds virtual communities and ensures that **MRO Asia-Pacific and AeroEngines Asia-Pacific** continue to deliver the same high-quality content that our audience has come to expect and will deliver information on the region in terms of industry recovery from COVID-19 crisis, workforce furloughs, layoffs, shop closings, and survival strategies for smaller MRO's and third-party MRO services. **To learn more about the virtual events and register to attend, please visit: mroasia.aviationweek.com.**

Visit **aviationweek.com/events** for more information, including complete exhibitor listings!

AEROWELD INC

Aeroweld Inc. Providing Quality Helicopter Repairs at most competitive cost. Helping Reduce Operator DOC's TIG Welding - All Exotic Materials and Aluminum Resistance Spot Welding - All Materials Torch and Furnace Brazing Metal Forming and Fabrication Plasma and Laser Cutting Machine and Dimensional Restoration Non-Destructive Testing Liquid Penetrant Inspection

www.Aeroweldinc.com

Airframes ▪ Engines ▪ Parts Distributors

https://marketplace.aviationweek.com/company/aeroweld-inc

AMSAFE BRIDPORT

Leading Net & Evac Slide MRO in North America!

AmSafe Bridport's Part 145 repair centers in Bridport, UK and Anaheim, CA provide aftermarket repair services covering Safety Restraints, Cargo Liners, Main Deck Nets & Smoke Curtains. The Anaheim facility specializes in Emergency Evacuation Systems and carries a full line of Slide and O2 Cylinders.

www.amsafebridportmro.com

Services

https://marketplace.aviationweek.com/product/leading-net-evac-slide-mro-north-america

BOMBARDIER MRO

Brand new Hydraulic Repair Service

Specialising in meeting the hydraulic component maintenance requirements of airlines, repair stations and parts distributors worldwide, we now offer full inspection, testing, repair and overhaul of individual hydraulic components and hydraulic assemblies for Bombardier, Airbus and Boeing aircraft.

www.mro.aero.bombardier.com

MRO

https://marketplace.aviationweek.com/product/brand-new-hydraulic-repair-service

JEWERS DOORS LIMITED

Doors for the largest hangars in the world

The flagship of our Esavian range, the TYPE 126 straight sliding door has been installed on the largest hangars in the world. With an unlimited span and heights from 6m to 40m, it is also the most popular and cost-effective form of hangar door available.

www.jewersdoors.co.uk

Consulting Services ▪ Engineering and Design ▪ Hangars & Equipment

https://marketplace.aviationweek.com/product/doors-largest-hangars-world

Go to marketplace.aviationweek.com for more information.

K&H INDUSTRIES, INC.

For over 55 years, KH Industries has been a U.S. manufacturer of portable lighting and temporary power solutions for a wide variety of industries. We have a dedicated group of skilled professionals that take pride in manufacturing quality, durable products locally, and helping our customers design and build customized solutions. Our website showcases our most popular lighting and power products, including explosion proof lights, retractable power cord reels, and LED work lights. We offer thousands of products to meet our customers' unique needs, including custom configuration. Let us know how we can provide a solution for you.

KH INDUSTRIES
The Permanent Name in Temporary Lighting & Power

khindustries.com

Original Equipment ▪ Consumables/Supplies

https://marketplace.aviationweek.com/company/kh-industries-inc

ORAPI

NOVIRUCLEAN - 3471 - Concentrated Disinfectant Cleaner and Deodorant

NOVIRUCLEAN is a broad spectrum, bactericidal, yeasticidal and viricidal disinfectant cleaner, designed to control the hazardous cross-contamination on all internal surfaces of aircrafts, trains, metros, buses, etc. It cleans, deodorizes, and disinfects all inanimate hard and non-porous surfaces such as holding bars, seats, armrests, tray tables, seatback pockets, overhead compartments, crew rest area, galleys, lavatory, walls, doors, panels, etc.

orapiasia.com

Cabin Interiors/ InFlight Entertainment ▪ Consumables/Supplies ▪ Chemicals

https://marketplace.aviationweek.com/product/noviruclean-3471-concentrated-disinfectant-cleaner-and-deodorant

PROMRO CLOUD ERP

ProMRO Cloud ERP

ProMRO software is designed for the MRO (maintenance, repair and overhaul) industry with a focus on the aviation industry. ProMRO is embedded within Acumatica Cloud ERP and provides fast quoting, costing of labor and materials, tracking of customer equipment, serial and N numbers, invoicing, payables, financial reporting, and dashboards/KPI for every role in your business — in one easy-to-use system.

www.promrosoftware.com

Technology ▪ Software

https://marketplace.aviationweek.com/product/promro-cloud-erp

TITAN ROBOTICS INC.

Non-Destructive Inspection

Titan's robotic systems can deliver the latest sensor technologies to complex surfaces for data collection. Applications include 3D scanning, non-contact thickness measurement, and other challenging inspection tasks.

www.titanrobots.com

Original Equipment ▪ Components ▪ Hangars & Equipment ▪ Aircraft on the Ground ▪ Painting/Coatings

https://marketplace.aviationweek.com/product/non-destructive-inspection

TITAN TOOL SUPPLY, INC.

Modular Videoscope for Aviation Inspection and Maintenance

Titan Tool Supply's TVG-PRO Videoscope features a single video unit with five different combinations of insertion tube lengths and diameters. Available in lengths of 1, 2 and 3 m; diameters of 2.8, 4.0 and 6.0 mm. All feature 180° or full 360° articulation. A 5" LCD monitor includes five levels of brightness via high intensity LED illumination with 100,000 hours of life.

www.titantoolsupply.com

Tools & Equipment ▪ Hangars & Equipment ▪ Ground Support Equipment

https://marketplace.aviationweek.com/product/modular-videoscope-aviation-inspection-and-maintenance

UNITED INDUSTRIAL TEXTILE PRODUCTS, INC.

Long-Term Storage Covers

Our covers are designed to create the stable, controlled environment required for long-term storage of advanced equipment at a fraction of the cost of other methods. Made from a vapor moisture impermeable vinyl, the covers feature a unique vapor lock closure and humidity indicator technology.

www.uitprod.com

Tools & Equipment ▪ Ground Support Equipment ▪ Safety/ Emergency Equipment

https://marketplace.aviationweek.com/company/united-industrial-textile-products-inc

Go to marketplace.aviationweek.com for more information.

AVIATION WEEK
Fleet&MRO
FORECASTS

DISCOVER
ANALYZE
PLAN
FORECAST

2021 Commercial Fleet & MRO Forecast – **Just Released!**

Predictive Intelligence to Drive Results

With Aviation Week Network's **Fleet & MRO Forecast**, gain a 10-year outlook to **minimize risk** and **maximize revenue**.

- Fleets, trends, and projections
- Predictive view of market share
- MRO future demand

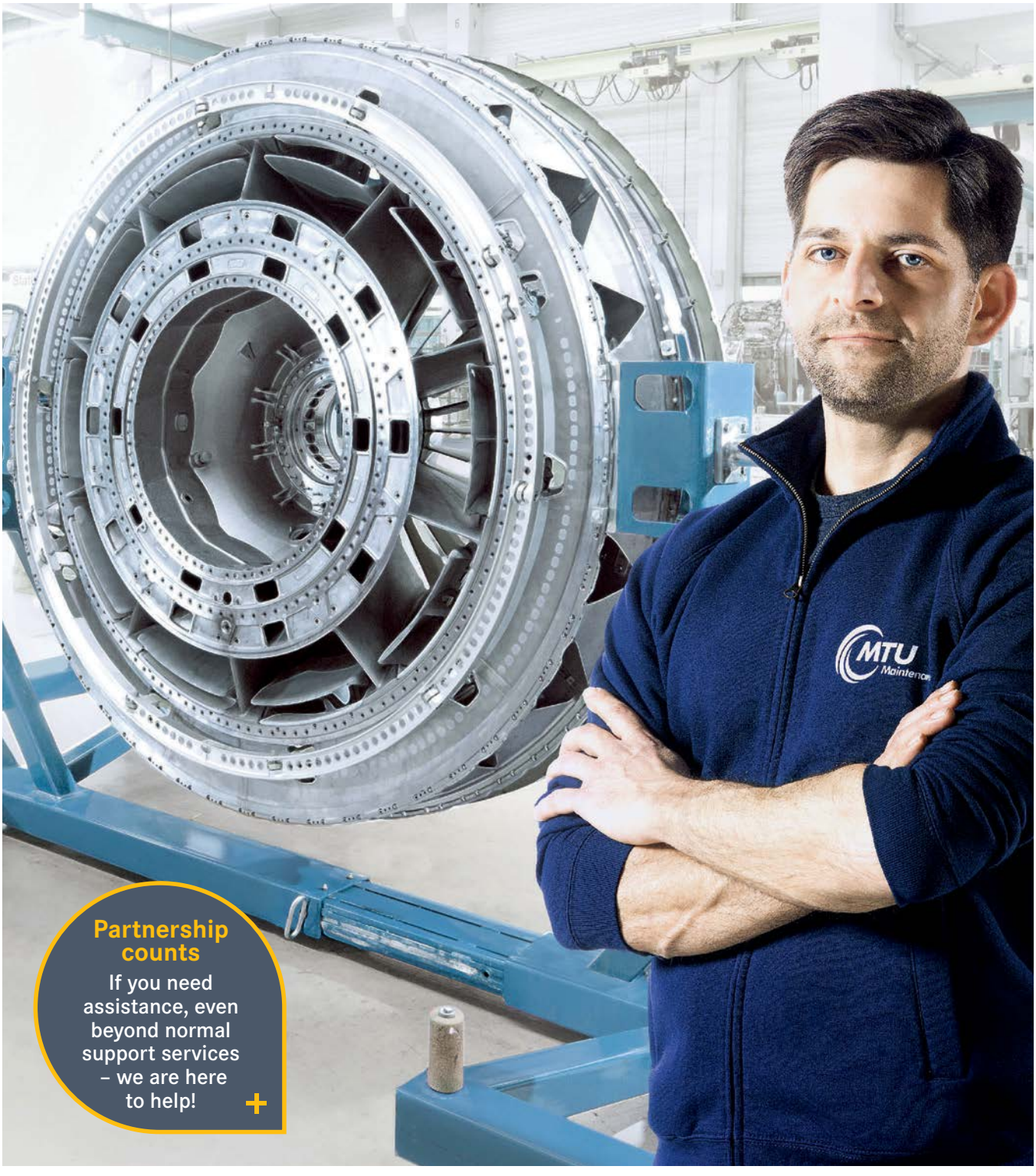
Take your business to the next level.

For more information, visit
aviationweek.com/forecasts

or call Anne McMahon at +1 646 291 6353
or Thom Clayton +44 (0) 20 7017 6106

Available for:
COMMERCIAL
MILITARY
BUSINESS
HELICOPTER

AVIATION WEEK
NETWORK



We are your engine experts

Our people make the difference. We are passionate. We are dedicated. We marry engineering with intelligent creativity. And we never give up unless an optimal solution has been found. As the global market leader in customized solutions for aero engines, MTU Maintenance supports you with the right product across the lifecycle of your engine. From innovative maintenance, repair and overhaul (MRO) services, to integrated leasing and asset management.

Contact us and find your solution today.

www.mtu.de/en

Supervised autonomy makes best use of the pilot in the control center, Rose says, with the onboard system detecting problems and presenting a menu of options. "What the remote pilot sees is a very high-level control interface to all of this, where the person is going to be engaged in high-level decision-making such as to how to modify the trajectory if another aircraft becomes a factor," he explains.

The complete platform is a single, vertically integrated stack developed in-house by Reliable Robotics that can fly the aircraft autonomously from gate to gate—from starting up, taxiing out and taking off to landing, taxiing in and shutting down. The system will be installed in parallel with conventional controls and instruments so that the aircraft can still be flown piloted.

When it started in 2017, the company thought it would be able to integrate systems from other vendors, but it could not find suitable components off the shelf. "We thought we could buy certified avionics computers, but there was nothing with the computer, memory and input/output required to automate an entire aircraft," Rose says. The company developed its own electric actuators. "You can't buy actuators off the shelf for these types of aircraft to automate the vehicle through all phases of flight" with the required performance, integrity and reliability, he notes.

Reliable Robotics has developed its own navigation solution to provide the high-precision positioning required to enable a fully automated landing, even if GPS is unavailable. The company is not providing details, but "we've applied techniques that have been commonplace in the space industry," Rose says, referencing the fusing of information from different navigation sources. The detect-and-avoid system "will pull together as much off-the-shelf as possible," he says, and use both onboard and offboard sources.

Reliable Robotics began flying the Cessna 172 with automation equipment installed in February 2018, and the aircraft made its first automated landing in October that year. In December 2018, the 172 made its first fully automated, remotely operated gate-to-gate flight. After a detailed safety analysis, the 172 made its first FAA-approved unmanned flight in September 2019, according to Rose.

The startup completed its Series B funding round in March 2019 and has so far raised $33.5 million. The company has developed an extensive simulation capability to model the 172 and 208, and the modified Caravan accomplished all its test objectives on its first flight in June this year, Rose says, adding that the first automated landing followed on the third day of flight testing.

Reliable Robotics is aiming for FAA supplemental type certification for the modified Caravan, and its goal is to begin commercial cargo operations with the aircraft within two years. "By necessity we will have to be the operator, because certification is about more than what goes on the aircraft," Rose says. "This first approval will be a holistic approval. We also have to certify how to train remote pilots, etc."

U.S. Air Force Contract Launches New Supersonic Jet Startup

> EXOSONIC HAS RAISED MORE THAN $1.5 MILLION SINCE 2019

> SUBSCALE UAS PROTOTYPE SET FOR ROLLOUT AROUND 2025

Steve Trimble Washington

Raising money for a supersonic passenger jet is not an easy sell. Most investors want to make a profit within 3-5 years, not wait a decade or more merely for the product to become available to sell. And that is before the fundraiser mentions the product is likely to cost $500 million dollars or more and, if successful, needs a 50-year-old law to change before it can enter commercial service.

But as the saying goes, "Where there's a will, there's a way," and Los Angeles-based startup Exosonic thinks they have found the right formula to develop a low-boom supersonic airliner: Start with the U.S. military.

EXOSONIC

The U.S. military is considering a supersonic passenger jet for executive airlift and special operations missions, while a subscale prototype could become a candidate for a supersonic unmanned aircraft system.

The U.S. Air Force awarded Exosonic a $1 million, two-year contract on Aug. 12 to deliver a virtual reality model of a supersonic jet that could one day serve as a presidential or executive transport. The deal added to $325,000 previously awarded by the Air Force to Exosonic and nearly $150,000 chipped in by Silicon Valley seed-funding investor Y Combinator.

Exosonic founder Norris Tie, a Lockheed Martin Skunk Works alumnus, says he wants to produce a 50-70-seat airliner with 5,000-nm range. By shaping the fuselage to soften the irksome sonic boom created by a supersonic shockwave, Tie is seeking to capitalize on legal changes that may come within a decade.

The NASA/Lockheed X-59 QueSST low-boom flight demonstrator program is about to start an acoustic survey to quantify the audible footprint of an aircraft specially designed to produce a shockwave signature of 75-80 PLdB. The results of flights over U.S. communities to measure the public acceptability of a reduced sonic boom will inform a review of international regulations that effectively prohibit civil, overland supersonic flight.

Even if the noise created by X-59 flights over U.S. cities meets NASA's and Lockheed's expectations, it is unclear how regulators will respond. A group of 62 environmental organizations is already organizing to block any changes. In July, the group called on the FAA to drop a proposal to amend noise standards during takeoff and landing that would permit louder supersonic aircraft to operate from U.S. airports.

Existing players in the supersonic renaissance say they are not counting on changes to the overland supersonic flight ban. Boom Supersonic, for example, has raised over $100 million by promising to deliver a Mach 2.2, 55-seat airliner to serve only overwater routes. Boeing-backed Aerion, meanwhile, is developing a Mach 1.4, 12-seat business jet, with a promised capability to cruise at Mach 1.2 over land without its supersonic boom reaching the ground.

The Exosonic concept, however, relies on overland routes at supersonic speed to justify a business case for producing hundreds of aircraft, Tie says. The 5,000-nm range gives Exosonic the ability to fly from San Francisco to Tokyo over the Pacific but also from Los Angeles to London by crossing over much of North America. The twin-jet design is limited to Mach 1.8 to avoid a need for variable-geometry inlets, Tie says.

A "realistic" schedule, which Tie acknowledges is still ambitious, sets a marker for delivering the first certified Exosonic aircraft in the mid-2030s. The schedule includes a demonstration of a subscale design to validate Exosonic's low-boom prediction tools, followed first by a piloted demonstrator and then by the airliner prototype. If most private investors lack the patience for commercial aircraft development, the Air Force could offer a near-term financial bridge.

Not only does the Air Force have a long-term interest in a supersonic jet for executive or special operations transport, the service may also have a near-term interest in the subscale, low-boom demonstrator. Exosonic plans to develop a 30-ft.-long unmanned supersonic jet within five years for $40 million, Tie says. The GE Aviation J85-powered aircraft could help verify Exosonic's boom prediction tools and possibly offer the Air Force an option for a supersonic, attritable drone design, he adds.

The Air Force expects a rollout of the subscale prototype around 2025, according to the presidential and executive aircraft program office at Wright-Patterson AFB, Ohio.

Aerion has recently unveiled a military derivative of the AS2 concept, but Exosonic is the first of the supersonic jet startups to target the Air Force as a seed investor.

"That differentiates us," Tie says. "We have a military-first approach."

Discover more
www.engineleasingandfinance-europe.com
#ELTF |

AVIATION WEEK NETWORK

AVIATION WEEK

ENGINE LEASING TRADING & FINANCE EUROPE

10-11 NOVEMBER 2020
LONDON, UK

THE PREMIER CONFERENCE SOLELY FOCUSED ON ENGINE LEASING MANAGEMENT

Hear from engine leasing experts including:

Romain Chambard
VP Marketing,
Rolls-Royce

Julie Dickerson
Managing Director,
Shannon Engine Support

Alexey Ivanov
Sales Director
Russia & CIS,
Magnetic MRO

Andrea Luebke
Managing Director,
MTU Maintenance Lease Services

Denise Mangan-Fahy
SVP, Portfolio Planning & Operations,
GECAS Engine Leasing

Brian Ovington
Director, Engine Services Marketing,
GE Aviation

Allan Rennie
Technical Director,
KV Aviation

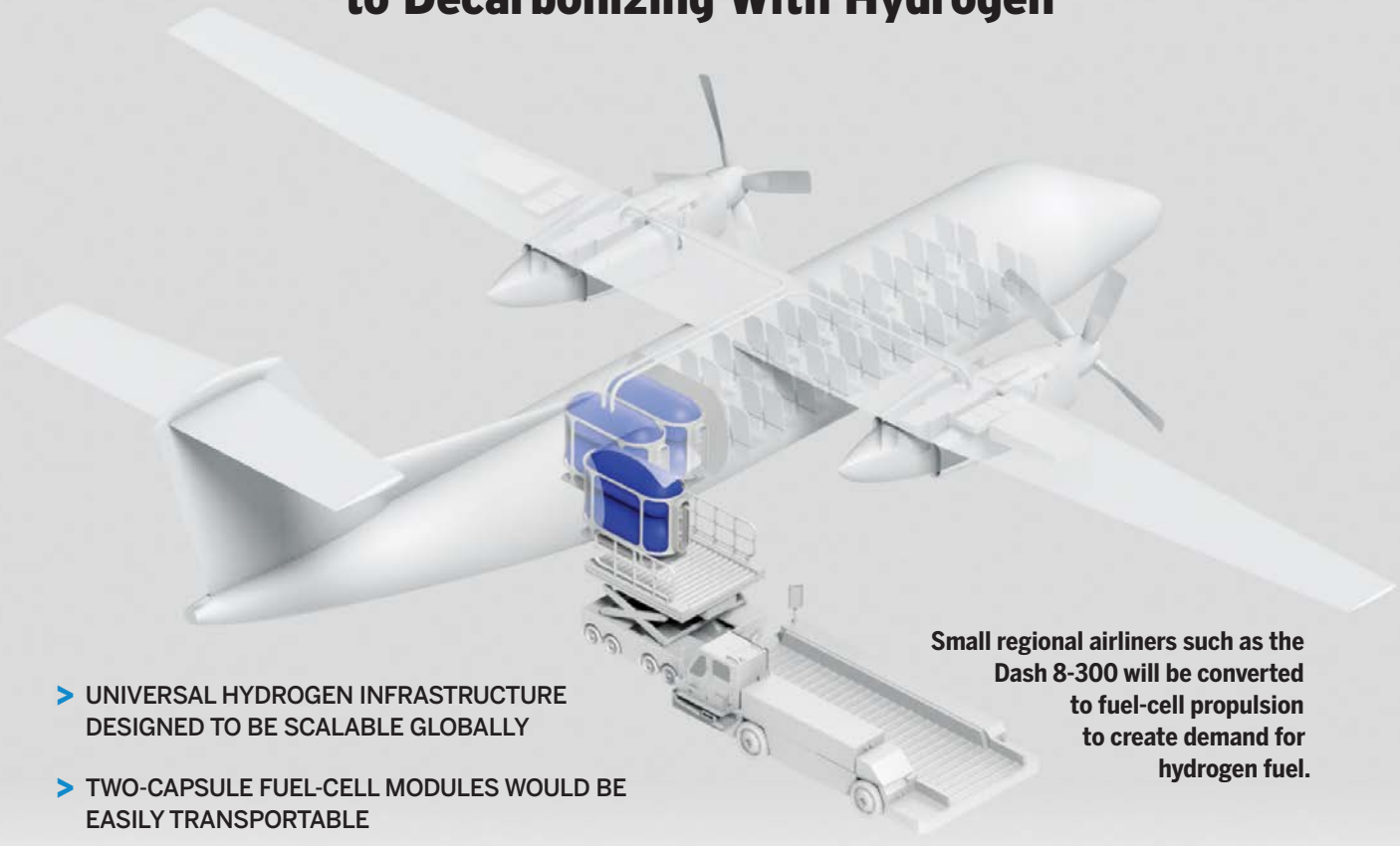
Eddo Weijer
VP, Head Engine Transactions,
GA Telesis

Host Sponsor
Engine Lease Finance

Sponsors
cfm The Power of Flight
SES Power to Fly Now

Official Publication
InsideMRO

Startup Tackles Infrastructure Barrier to Decarbonizing With Hydrogen



Small regional airliners such as the Dash 8-300 will be converted to fuel-cell propulsion to create demand for hydrogen fuel.

- UNIVERSAL HYDROGEN INFRASTRUCTURE DESIGNED TO BE SCALABLE GLOBALLY
- TWO-CAPSULE FUEL-CELL MODULES WOULD BE EASILY TRANSPORTABLE

Graham Warwick Washington

ONE IN A SERIES

Hydrogen is gaining attention as a means to deeply decarbonize aviation, with Airbus looking at the fuel as one way to meet its stated commitment to bring an aircraft with net-zero carbon emissions to market by 2035. But previous efforts to bring hydrogen to aviation have stumbled over the high cost barrier of the infrastructure required for production and distribution.

Now former Airbus and United Technologies Chief Technology Officer Paul Eremenko has launched a venture to build the infrastructure for hydrogen-powered commercial aviation.

To kick-start the market, startup Universal Hydrogen plans to convert ATR 42 and De Havilland Canada Dash 8-300 regional aircraft to hydrogen fuel-cell propulsion to pump-prime demand. But Eremenko's goal is to prove out the company's hydrogen infrastructure before Airbus and Boeing make technical decisions on the next generation of single-aisles in the latter half of the 2020s.

"If we want hydrogen aviation to happen, we need a much more capital-light approach," Eremenko says. "Our goal is to produce a minimally capital-intensive approach to building a hydrogen infrastructure that is scalable to global scale."

Universal Hydrogen is developing lightweight, modular capsules—"think of them as batteries," Eremenko says—that can be transported via the existing global intermodal container network and loaded with existing airport equipment into aircraft that have been minimally modified to operate on hydrogen.

"What we are trying to do is connect production to consumption, and allow them to take place in geographically disparate areas at temporally disparate times," Eremenko says. "We are not especially keen to do either production or play long-term in the consumption business, but we may have to do a little bit of both in order to get the aviation hydrogen market going."

Universal Hydrogen is developing both 850-bar high-pressure gas and liquid-hydrogen capsules in the same interchangeable form factor so an airline can choose between them for each flight. "For the Dash 8-300 with the gaseous capsules, we get 400 nm range. With the liquid capsules, we get 550 nm," Eremenko says. "The fleet-wide average stage length for these aircraft is about 300 nm. So even with the gaseous solution, you're going to be able to perform 75-80% of all missions flown."

The capsule is a cylinder with rounded ends, for more efficient packaging during transport and storage in the aircraft, Universal Hydrogen Chief

Technology Officer John-Paul Clarke says. One pair of capsules is mounted in a frame that provides structural support, plumbing and other systems. These two-capsule modules are then transported as dry freight in cargo containers by road, rail or sea. At the airport, they are loaded onto the aircraft using existing ground handling equipment—or a forklift at more austere locations, Eremenko says.

Insulated but uncooled, the liquid capsule has a maximum 40-hr. dwell time between production and consumption because overpressure builds up as the hydrogen evaporates. "As a result of that, and because liquefaction is a more energy-intensive process than compression, an airline would pay more for the liquid capsule. But they'd get a slightly better range," Eremenko says.

In the case of the Dash-300 retrofit, up to three modules—or six capsules—are slotted into the rear fuselage forward of the cargo area, which would be untouched. The service door is widened slightly as part of the supplemental type certificate modification. The hydrogen is plumbed through the dorsal fin, external to the fuselage pressure vessel, into the nacelles.

In each nacelle is a 2-megawatt hydrogen fuel-cell stack powering an electric motor—either a single motor of about 2 megawatts or around 1.6 megawatts, plus a smaller motor for auxiliary power. The existing propeller and controller are retained. A small lithium-ion battery handles throttle transients.

A fuel-cell's only emissions are warm air and water vapor. A thermal-management system including a P-51 Mustang-style zero-drag radiator on the nacelle cools the fuel cell and motor. The water is collected in the outer-wing fuel tanks and dumped at flight conditions when no contrails are produced.

"We've designed the retrofit so that it meets or exceeds the nominal aircraft performance, other than the change in range capability," Eremenko says. "We lose two rows of seats in the back. And we relocate the rear galley to the front, which causes us to lose two rear-facing seats in the front. So we lose a total of 10 seats, and the Q300 goes from a 50-passenger to a 40-passenger airplane."

Despite the loss of seats, operating economics in 2025—in terms of cost per available seat-mile—are estimated to be roughly equal between the modified and unmodified Dash 8. Hydrogen is projected to be more expensive than jet fuel in 2025, but that cost is expected to come down over time, he says.

"There will be a growing cost advantage to hydrogen. On top of that, the maintenance and overhaul costs for a fuel-cell-electric powertrain are quite a bit lower than for a turboprop engine. Our estimates for maintenance and overhaul costs suggest at least a 25% improvement," Eremenko says.

Interchangeable gaseous or liquid-hydrogen capsules will be transported and stored on aircraft in easy-to-handle modules.

Universal Hydrogen is working with partners to lighten a proven terrestrial fuel-cell and develop the motor. "These are fundamentally off-the-shelf technologies. I don't want to understate the challenge, but we think our plan is attainable on a three-year timescale," he says. "We're allowing some margin with a 2024 entry into service."

The startup has also engaged the regional airframers. De Havilland Canada has been "an exceptional partner to us thus far," Eremenko says. "ATR, which is starting to think about hydrogen, has also been positive toward the effort."

What would regional carriers have to pay in exchange for going green? "The value proposition that we offer is that we would subsidize the conversion to hydrogen for them, up to offering it as a no-cost conversion in exchange for a long-term hydrogen fuel contract," he says. The established renewable-energy project finance market would then be tapped to pay for the conversions.

"The regional aircraft fuel market is about $2 billion per year. So we might create a billion-dollar business by supplying the regional market if we get really good penetration," Eremenko says. "The huge opportunity in the 2030s is the single-aisle. And both Airbus and Boeing seem likely to make decisions on the technology base for the single-aisle in the mid-to-late 2020s, for an entry into service in the early 2030s. And we would like to de-risk the decision for them, as much as we can, to go with hydrogen."

Universal Hydrogen is six months into the initial design phase, self-funded to the tune of about $3-5 million if partner efforts are included, he says. "We're going into detailed design in the next month or two. And, by this time next year, we would expect to have an iron bird of the powertrain as well as an end-to-end demonstration of the full-scale capsule technology."

Experimental flight testing will follow, with one side of the aircraft converted to fuel-cell propulsion and the other left unmodified for safety of flight. "After experimental flight, we would go into certification flight test. And alongside that, we would mature the hydrogen logistics network and develop a low-rate initial production system for the capsules and the modules," he says. "To get us to market, we need an equity raise of about $300 million."

After kick-starting demand with its ATR and Dash 8 conversions, the startup plans to release its modification as an open-source reference design that can be customized by developers of commuter aircraft, single-engine turboprops or urban air mobility vehicles—Eremenko's eyes are firmly on decarbonizing the single-aisle sector.

Universal Hydrogen is already in discussions with both Airbus and Boeing. "They're both receptive and learning more about our approach and technology," he says. "But the proof will be when we are actually in operation at scale from 2024 onward showing that we have solved the infrastructure and logistics problem for hydrogen for them."

GE

AETP tests in 2021 will be the first chance to run complete engines through their full adaptive cycles.

ADAPTIVE AIMS

> GE XA100 AND P&W XA101 ON TRACK FOR 2021 TESTS

> ADAPTIVE FEATURES AND TECHNOLOGY STUDIED FOR FOURTH- AND FIFTH-GEN UPGRADES

Guy Norris Los Angeles

For more than half a century, U.S. air dominance has rested on generations of advanced combat aircraft powered by a succession of superior jet engines. But now, as adversaries threaten to close the gap, and significant improvements in turbine technology become more difficult to achieve, a U.S. Air Force-led test effort to maintain this crucial power advantage is approaching a key phase.

Flight-weight prototypes of adaptive, or three-stream, engines are entering assembly ahead of tests planned to start in 2021. The engines, General Electric's XA100 and Pratt & Whitney's XA101, are the forerunners of a new class of morphing propulsion systems that promise a step change in combat capability through the dynamic modulation of a third stream of air.

Running separately from the conventional core and bypass flows, the additional flow can be redirected to provide 10% increased thrust during combat or 25%-plus greater fuel efficiency during cruise conditions compared to a 2015 state-of-the-art fighter engine. Aside from increasing range, lower fuel burn will reduce the demand for tankers and allow those still needed to remain farther away from the combat area.

The third stream will provide extra cooling air for thermal management. This is becoming more challenging as aircraft designers make increasing use of composite materials, which in general have 40 times lower heat conductivity than aluminum. Compounding the problem is the growing use of power-hungry sensors and systems, including directed-energy weapons, all of which generate excess heat.

The XA100 and XA101 are the product of the Air Force Life-Cycle Management Center's Adaptive Engine Transition Program (AETP), an effort launched in 2016 to prepare demonstrator three-stream engines grown from earlier research efforts for full-scale development. These most notably included the Air Force Research Laboratory's Adaptive Engine Technology Demonstration (AETD) and Adaptive Versatile Engine Technology (Advent) programs, which over the previous decade helped usher in the era of practical variable-cycle propulsion.

"We aim to open up the technology S-curve," says David Tweedie, general manager of GE's Advanced Combat Engines, referring to the progress of innovation from slow beginnings through a steeper acceleration phase to a flatter period of maturation. "The turbojet got us so far, and then it was kind of running out of gas," he says. "Then investments were made to establish the turbofan, and we spent probably the last 40-50 years wringing out the efficiency and capabilities of that technology S-curve. And now what we're doing is inventing a third S-curve for jet propulsion."

"Really, our program over the last four years has been all about designing, fabricating and then testing the first-ever adaptive engines," says Lt. Col. James Rodriguez, materiel leader at the Life-Cycle Center's Propulsion Acquisition Division. "Both

Changing engines for attritable aircraft **p. 48**

GE and Pratt & Whitney completed the detailed design of their engines, which is the design that we use to go build a prototype," he says. "They both completed the detailed design phase within the last 18 months, and over the course of the last nine months or so both contractors have started building their prototype engines. We are on track now to test the first prototype engines in the next calendar year."

Each manufacturer is assembling two complete engines for testing at its own facilities and for simulated altitude evaluation at the Air Force's Arnold Engineering Development Complex in Tullahoma, Tennessee. "As we run these prototypes and try to burn down the risks for a future follow-on engineering and manufacturing development (EMD) program, we will prioritize those risks that we see across the engines," says Josh Mark, lead engineer for propulsion development at the Propulsion Acquisition Division.

"We need to get to altitude to do exactly those test activities as it relates to flying across the envelope," he adds. "This isn't a qualification program per se, but it poises us for entry into an EMD-type of program so that we can go do low-risk, high-confidence qualification testing."

The work builds directly on the AETD effort, which focused on proving the viability of the adaptive concept through a series of large-scale rig tests of compressors, core engines and fan modules, as well as a number of other rig tests for components such as turbines and combustors. "This is now putting all of those knobs and widgets, as it were, into one package to demonstrate capability for performance operability—whether it's for takeoff or the acceleration parameters we are going for," says Mark.

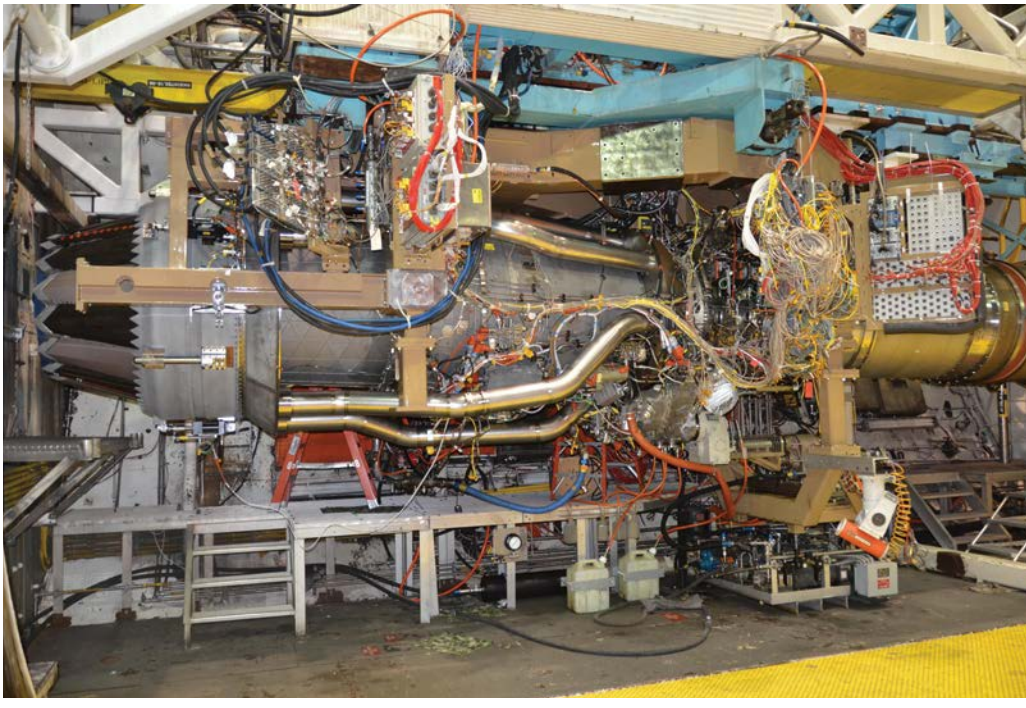
Testing will therefore focus not only on baseline engine performance in various adaptive modes across a matrix of altitudes and speeds but also on operability of the three streams and associated heat-exchanger configurations during dynamic transitions between cruise and combat modes. Operability evaluation using complete engines will also represent another first for the program, as previous tests of the engine core rigs were limited by having to adapt facilities to simulate inputs from the low-pressure system and other components.

Tests will focus on the operability and performance of variable geometry devices that dynamically alter the fan pressure ratio and overall bypass ratio—the two key factors influencing specific fuel consumption and thrust. Fan pressure ratio is changed by using an adaptive, multistage fan in combination with a variable-area nozzle, while the third stream, which is external to both the core flow and standard bypass duct, is used to alter bypass ratio.

The variable features in the adaptive fan control how the inlet airflow is split to meet the mass flow requirements of the specific mode—with more flow diverted into the bypass for cruise and more flow into the core engine for the higher-thrust combat mode. The variable-area nozzle, meanwhile, works in conjunction with the inlet system and back-pressures the fan to increase fan pressure ratio for higher thrust and to reduce it for more efficient cruise performance.

Although originally expected to begin as early as 2019 with three test units from each contractor, the full engine testing with just two units is now due to start in 2021 and will likely run into 2022. "We have a schedule laid out with the four engines that we're going to be testing that is still moving around a little bit," says Rodriguez. "After that, there's going to be a little bit of time when we will bring all that data in and really have an opportunity to analyze it and make sure that the results are telling us what we need. We will make sure that the capability benefits that we see are accurate. At that point we have to see what's next."

U.S. AIR FORCE



Prior to the XA101, Pratt & Whitney's adaptive fan was tested on an F135.

Lessons learned from the AETP will likely determine the future direction of U.S. jet engine development for several decades to come, with implications not only for the evolutionary path of sixth-generation combat aircraft but also for retrofits and upgrades of fifth- and even fourth-generation aircraft.

"The Air Force has some decisions to make there about what's next," says Rodriguez. "We would anticipate that at the end of AETP, we'd go into an EMD phase. We would go and actually put these engines through a more formal transition program, where we do more testing as well as any additional design iterations that would be needed to get these engines ready for flight.

"Our real desire is that the test provides the opportunity for Air Force senior leadership to define what's next. Everybody's looking at this program saying, 'Once we prove that this technology is ready, then we'll figure out where it goes next—whether that's the F-35 or other platforms,'" he says.

While it decides on where to go next for adaptive engine technology, the Air Force is meanwhile using the mechanism of the Life-Cycle Management Center and the AETP to bridge the infamous "valley of death"—the technology readiness level between the development of an innovative breakthrough and its successful adoption into service. "The Air Force has over the years struggled to transition programs. We are absolutely, firmly, on the middle of that bridge and trying to get across it," says Rodriguez.

In the meantime, the Air Force is "trying to keep our options open as much as possible," he notes. The AETP program is therefore structured to support three lines of effort, the first being a potential form, fit and function replacement for the Pratt & Whitney F135 engine in the Lockheed Martin F-35. Designed as a 45,000-lb.-thrust-class engine to meet potential growth requirements for the Joint Strike Fighter, the AETP engine is tailored as a drop-in unit for that platform. The program would be "a low-risk EMD, and we could transition that technology fairly easily," Rodriguez says. "So that's the first the first line of effort."

So will the AETP engines be ground-tested in an F-35? "That's something that we certainly have explored in the past, but it is not an activity that we currently have funded or that we are pursuing," says Rodriguez. "But it is certainly available as an option to consider as we continue engaging with the F-35 Joint Program Office and will continue to offer as a potential opportunity."

The second effort is focused on future air superiority applications after the F-35. "[It looks at] what those technologies would need to be to enable future platforms," he says. The initiative appears to be closely linked to the Air Force's Next-Generation Adaptive Propulsion (NGAP) program, under which GE and Pratt & Whitney are defining competing engine concepts for the Next-Generation Air Dominance program.

Details of both closely held initiatives were revealed for the first time in Air Force budget documents for fiscal 2021 and indicate the two engine-makers are set to complete initial design work by the second quarter of 2022 and finish tests of a full-scale engine in 2025. The timeline also appears to dovetail with the AETP schedule that is set to complete testing in 2022, clearing the way for the development of follow-on adaptive engines for initial applications.

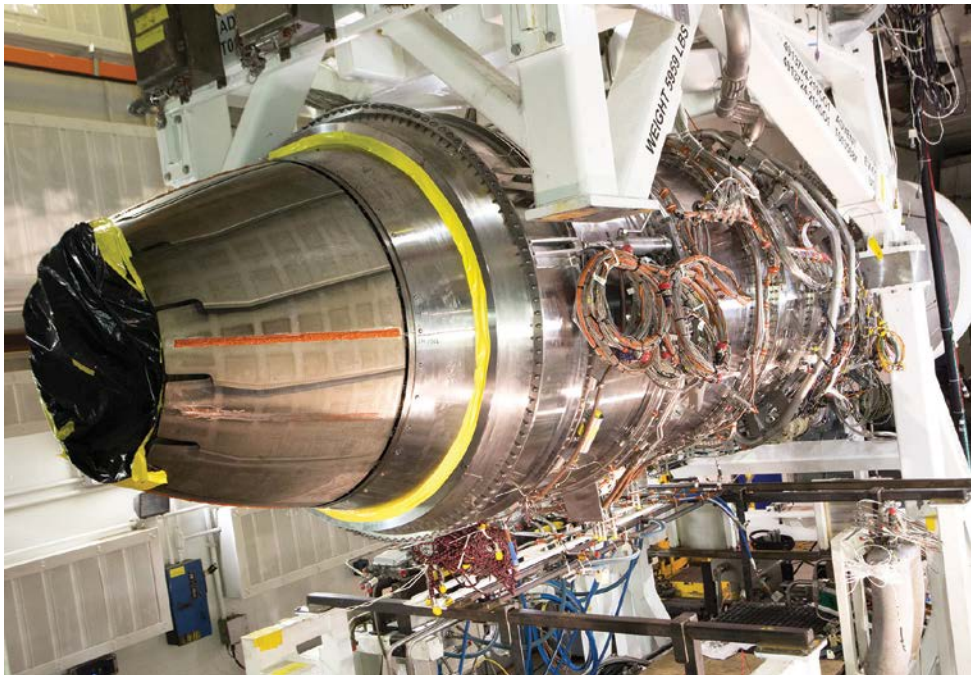
"[The] NGAP is our effort where we are looking at those features for priority applications and determining what changes in the design would have to happen in order to enable future aircraft," says Rodriguez. "We are actively looking at that right now, and both of the contractors are working [on] those designs. We're in the early stages of that effort."

The third line of effort is focused on ways of potentially incorporating AETP-related technology into legacy engine fleets. "While that could be whole engine replacements, that's probably not likely," says Rodriguez. "It's probably much more likely to be performance modifications to existing engines, like perhaps the F119 or the F100 or F110. We are looking at where you can take some of the components of an adaptive engine and some of the technologies and materials and incorporate those into those engines for performance benefits."

Key adaptive technologies such as advanced heat exchangers and higher-temperature-capable materials are therefore more likely to transfer as potential upgrades to fourth-generation combat engines than adaptive fans or third-stream ducting. "Many platform [programs] today are looking for how they can incorporate additional mission systems," says Rodriguez.

"Those mission systems take power and thermal capacity," he says. "It's all going to be very dependent on the individual aircraft designs as to how much the engine is incorporated into that. But we view that as a critical enabling technology of an adaptive engine, that it provides much greater power and thermal capacity than legacy engines. And so that's something that enables the aircraft to have more mission systems on board."

Pratt & Whitney, which eight years ago battled its way back into conten-



GE

GE's three-stream concept was initially tested during AFRL's Advent program.

tion for the AETD with a self-funded adaptive fan design after having lost earlier Advent award rounds to GE and Rolls-Royce, is determined to protect its pole position as the sole-source propulsion provider to the Air Force for both the F-35 and F-22. Today the engine-maker is assembling the initial XA101. "[It is] the future of fighter propulsion and the future of military engines," says Matthew Bromberg, president of Pratt & Whitney Military Engines.

"The question is just when, and we are laser-focused on our first engine to test and racing with our program office to that milestone," he adds. Bromberg says the adaptive concept—whether deployed as a stand-alone engine or as a wellspring for technology insertion across engine families—is a "win" for the U.S. "If I can provide an option that meets the needs in an agile fashion, that takes a subset of AETP technologies and creates an upgrade to an F135, or potentially even an F119 or an F100, that's a home run for the Department of Defense," he says.

"That's what they're asking us to do—be agile in how we think the technologies that we jointly develop are used to provide upgrades," says Bromberg. "We can tackle smaller, less risky, quicker-to-the-finish-line type projects, and that's what we think the engine enhancement packages do. We hope to provide similar solutions, both with an upgraded F100, which is an early conversation, and an F119, as people look at the F-22 in 2040, [asking]: 'What do we need out of the engine?'"

Pratt & Whitney's AETP-related upgrade studies are led by the company's GatorWorks division, a prototyping unit formed in 2018. Likening the potential improvement options to Lego interlocking toy bricks, Bromberg says: "My GatorWorks are the Lego builders, and I'm asking them how do they pull the best technologies off the shelf and do it in the most cost-efficient manner? That's what we're pitching right now to the government."

GE, which lost its bid with Rolls-Royce to develop the F136 alternate engine for the F-35 when that effort was canceled in 2011, sees the XA100 as both a potential gateway back into the F-35 as well as the basis for upgrades on other engines. "GE is very hopeful that when we get through engine-testing and we show that the data works, that when the Air Force looks at what they want out of the future of the F-35, [then] hopefully this is an opportunity for them to capitalize on the significant investment they've made to really provide transformational capability to that platform," says Tweedie.

Based on empirical data from component and rig tests, the company is confident the complete XA100 will meet performance goals. GE also continues to refine concepts "on how we could spin off component- and module-level improvements into our legacy fleet," Tweedie adds. "We continue to see interest from the Air Force in terms of [upgrades]. The F-15EX is a great example of them asking, 'What can you do to increase the capability?'"

Rotating Detonation Engines Are an Emerging Priority for U.S. Air Force

> PRESSURE-GAIN COMBUSTION RDEs OFFER KEY FUEL SAVINGS

> RDE CONTRACTS AWARDED TO GENERAL ELECTRIC, PRATT & WHITNEY AND AEROJET ROCKETDYNE

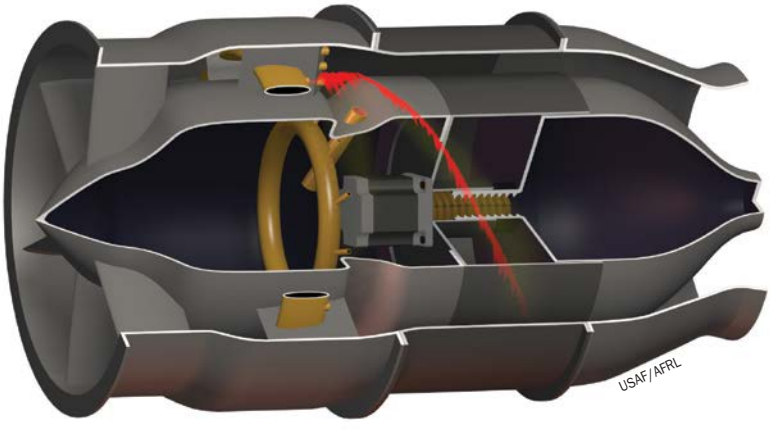
Guy Norris Los Angeles

With a technology development portfolio ranging from attritable engines to distributed propulsion, the Advanced Turbine Technology for Affordable Mission (ATTAM) capabilities initiative is a bellwether for future programs and an inside guide to the Pentagon's propulsion priority list.

But four years after the U.S. Air Force Research Laboratory (AFRL) formally rolled out ATTAM, the nation's newest military engine technology development plan—while continuing the overall quest for speed, range and lower cost—is already evolving in some surprising new directions in response to perceived emerging threats and urgent capability needs. Heading up the list of high-importance new engine architectures is, for the first time, the rotating detonation engine (RDE)—a pressure-gain combustion concept that until now has remained at a low-technology readiness level despite decades of research.

Alongside RDEs, other top ATTAM priorities include ultra-low-cost expendable or attritable turbine engines and hybrid-electric distributed propulsion systems of the type being evaluated for commercial urban air mobility platforms. Also on the list are reusable high-speed turbojets for use in hypersonic turbine-based combined-cycle systems. Work continues to focus on adaptive engines, both in the development of three-stream turbofans and advanced turboshafts. (See updates on adaptive, attritable and combined-cycle programs on pages 40, 48 and 46, respectively.)

"Sometimes the focus changes, and then sometimes potential adversaries change what you think you might want to do to stay ahead of them," says Daniel Thomson, ATTAM portfolio manager. One of the overarching changes adopted in the new program compared with its predecessor, AFRL's decade-old Versatile Affordable Advanced Turbine Engines (VAATE) program, was the inclusion of integrated power generation and thermal management. "ATTAM is attempting to go beyond VAATE, which was more closely focused on traditional turbine engines, and is looking at broader system capabilities to eke out everything we can from our future engines," he adds.



Air enters the RDE inlet and as it passes the isolator, it mixes with fuel injected in a sequential, circular manner and ignited at the detonation annulus. The notional detonation wave front is indicated in red.

ATTAM's broader research effort continues the trajectory established when VAATE took over in 2005 from the Integrated High-Performance Turbine-Engine Technology program, the first national propulsion-development initiative. Launched in 1987, that program was focused on flange-to-flange engine-performance improvement, including doubling thrust-to-weight ratios, and paved the way for the Pratt & Whitney F119 and F135 engines. VAATE's goals were widened to include affordability improvements as well as a 200% increase in the engine thrust-to-weight ratio and a 25% cut in fuel consumption.

Today, ATTAM's goals, which are closely aligned with the Defense Department's Energy-Optimized Aircraft sister effort in power and thermal management, are baselined against 2015 technology and include a 25% improvement in fuel efficiency and a 10% boost in thrust-to-weight ratio for both large and small turbofans and turbojets. For novel cycles, including RDEs, the goal is 30% better fuel burn, while for expendable systems the program is targeting 10% better fuel efficiency for supersonic engines and a 30% improvement for subsonic. Power and thermal management goals are at least a doubling of capability for expendables, an eightfold improvement for large turbofans and 20 times the improvement for small turbofans and turbojets.

Describing rotating detonation engines as "definitely our top priority," Thomson says AFRL's RDE research explores entire propulsion systems that would potentially provide nearer-term power options for high-speed cruise missiles or possibly even an element of a combined-cycle propulsion system for larger hypersonic vehicles.

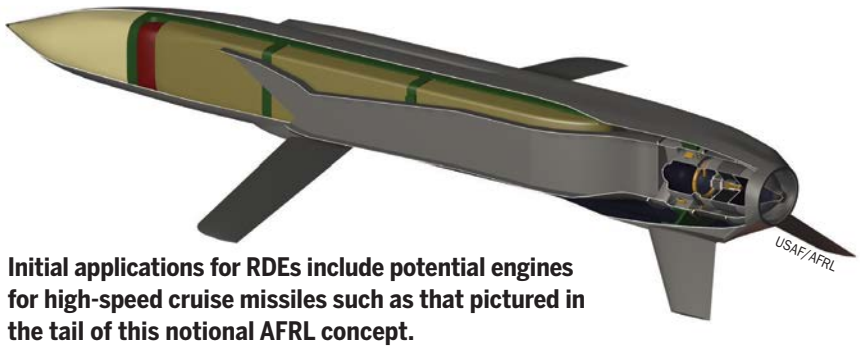
"At the same time, we are looking at where the rotating detonation might be used as an augmenter," Thomson says. "For a more traditional turbine-engine architecture, we would also look at just replacing the combustion systems within that turbine-engine architecture with RDE components. Those are the two main tracks that I would say we are on." In turbine engines, RDEs could replace combustors, saving weight and eliminating a compressor stage for a given overall pressure ratio and would also be shorter in overall length.

Building largely on earlier research into pulse detonation engines (PDE)

since the 1990s, AFRL's newly increased focus on RDEs is the latest sign of a gradual acceleration of interest in pressure-gain combustion and propulsion over the past two decades. RDEs offer a potential step change in thermodynamic efficiency because combustion takes place at constant volume rather than constant pressure, as in current engines. Combustion of the fuel-air mixture occurs at supersonic speed as a detonation rather than the subsonic deflagration seen in conventional combustors. The process results in a pressure gain—rather than loss—during combustion.

In an RDE, also known as a continuous detonation wave engine, the detonation wave travels around an annulus. As air and fuel are injected into the annulus, the mixture is ignited by the detonation of the previous wave and the process becomes self-sustaining. The concept is also mechanically simple, with few moving parts, and more efficient than PDEs, which require the detonation chambers to be purged after each pulse.

AFRL is concurrently working on an RDE rocket engine project that would use the pressure-gain combustion system in place of the conventional turbopump-fed rocket chamber. Also studied by NASA in the 2000s as a lightweight option for upper-stage engines as well as for lunar and planetary landers that require deep throttling capability, the AFRL rocket project began an initial ground test campaign in 2017. AFRL says an RDE-based rocket would have up to 15% better theoretical efficiency or up to five times lower initial combustion pressure.



Initial applications for RDEs include potential engines for high-speed cruise missiles such as that pictured in the tail of this notional AFRL concept.

As another sign of increased interest in RDEs, AFRL and the Air Force Office of Scientific Research also joined forces on a rocket RDE effort in 2014-15 to promote research into injector designs and modeling with multiple universities. One of the research teams at the University of Central Florida announced in May 2020 that the completed study presents "for the first time, experimental evidence of a safe and functioning hydrogen and oxygen propellant detonation in a rotating detonation rocket engine."

Other agencies are also exploring air-breathing applications, including DARPA, which in March 2020 awarded Raytheon a contract worth almost $1 million to study an RDE-powered long-range strike missile concept. Earlier research has shown pressure-gain combustion can be beneficial to ramjet system efficiency up to speeds of Mach 3.

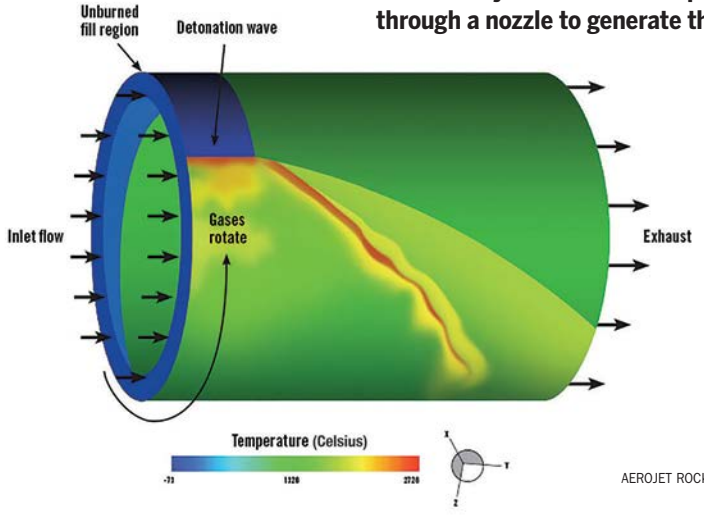
AFRL meanwhile has awarded three key RDE development contracts worth $520 million under the first phase of ATTAM. The bulk of the work is divided equally between General Electric and Pratt & Whitney, which have each been awarded a contract worth $250 million to develop, demonstrate and transition the technology; Aerojet Rocketdyne has signed a $20 million contract. Although details of the proposed work scope are sparse, all three companies are due to complete test and development work by September 2026.

"The intention, if everything goes well and priorities remain the same, would be to take those concepts and run them on a test stand for the propulsion system you would want to operate it on," Thomson says. "It might not look like a completely traditional engine test."

Work will focus on integrated designs with low loss inlets and efficient diffusers that can reduce the impact of the interaction of the unsteady flow from the RDE on the downstream turbine stages. Key challenges also include development and testing of nonmechanical, fluidic inlet valves with high-frequency response to prevent pressure pulses from detonations traveling upstream into the compressor. Other design challenges include advanced high-speed fuel-injection systems that avoid deflagration and development of practical combustion devices that use liquid fuels for all Air Force applications.

The designs will also tackle the issue of thermal management systems, which do not overpenalize performance with excess cooling bleed air. Other basic problems to overcome include development of new techniques to measure and verify RDE performance. Although researchers use mass flow rates and thrust to assess overall operation, the lack of means to measure internal conditions, mixing rates and injector performance means the reasons for good or poor performance levels can at the present time only be inferred.

Shock waves ignite hot gases that expand out of the cylinder and are expelled through a nozzle to generate thrust.



AEROJET ROCKETDYNE

U.S. Air Force Studies Rocket-Based Hypersonic Flying Testbed Plan

> MAYHEM IS AN EXPENDABLE AIR-BREATHING DEMONSTRATOR

> ROCKET-BASED CYCLE IS THE BASELINE, BUT THE DOOR IS OPEN TO A TURBINE OPTION

Guy Norris Los Angeles and **Steve Trimble** Washington

To fully exploit the military utility of hypersonic speed in roles beyond high-speed weapons, the U.S. Air Force is stepping up its decades-long quest to develop a combined-cycle air-breathing propulsion system as an enabler for reusable vehicles.

The plan promises to unlock the wider tactical potential of Mach 5-plus capability and fulfill the long-held ambitions of hypersonic proponents, who since the 1960s have envisioned high-speed vehicles for roles ranging from intelligence, surveillance and reconnaissance to multistage-to-orbit launch systems.

However, despite numerous studies and ground tests of scaled multicycle propulsion systems, two major questions still face developers: Which is the best propulsion system combination for the reusable hypersonic cruiser role? And how should the chosen concept and its mode transitions be flight-tested at a usefully representative scale?

Now, as the U.S. Air Force enters a fast-paced four-year flight-test program of rocket-boosted hypersonic weapons—both gliders and scramjet-powered—the service is quietly preparing to answer these questions by planning development of an air-breathing demonstrator vehicle. Dubbed Mayhem, the flying testbed plan came to light in August in Air Force Research Laboratory (AFRL) budget planning documents that describe a proposal to develop "multicycle engines."

First disclosed in a request for information published on Aug. 12 for an "Expendable Hypersonic Multi-Mission Air-Breathing Demonstrator," Mayhem is expected to be capable of hosting at least three different payloads on each flight. The vehicle was also known early in its inception phase as "a 'Multi-Mission Cruiser' due to the focus on sustained hypersonic flight capabilities independent of potential payloads," the AFRL says.

Although the choice of propulsion system has not yet officially been determined, the AFRL is believed to be leaning in favor of a rocket-based combined cycle (RBCC) over the alternative turbine-based combined cycle (TBCC). For hypersonic applications, rocket-based multicycle concepts have been studied principally for operation at speeds up to Mach 6-plus and altitudes of 100,000-200,000 ft.

The RBCC differs from the better-known TBCC configuration in that the initial acceleration to ramjet/scramjet takeover speed is provided by air-augmented or ducted rocket power rather than an air-breathing turbojet. At higher Mach numbers for vehicles designed for space access, the system would also transition to pure rocket propulsion for the final ascent.

Although the U.S. Air Force has studied RBCC systems for decades, including for multistage-to-orbit space launchers, no U.S.-developed vehicle using a rocket-based combined cycle is ever thought to have reached the flight-test stage. A larger-scale RBCC-powered version of the X-43 experimental hypersonic vehicle flown in the early 2000s was considered, but the X-43B—as it was later designated—was configured with a TBCC propulsion system by the time of its cancellation in 2004.

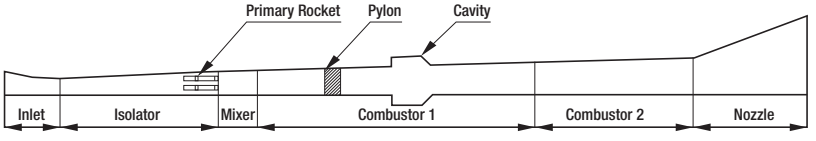
Another promising early U.S. project on which Mayhem could draw is a Mach 4.5 supercharged ejector ramjet (SERJ) developed in the 1960s by the long-vanished Marquardt Corp. as a proposed development for testing on the North American X-15 hypersonic research aircraft.

Considered as a potential high-Mach propulsion option for combat and reconnaissance aircraft of the 1970s, the SERJ-176E engine would have replaced the X-15's standard XLR-99 rocket in the tail and was fed by air through a 2D variable-geometry inlet. The ramjet incorporated a ring of internally mounted rocket engines inside the duct to generate a high-velocity exhaust and entrain air into the inner flow path.

To supercharge the system, some inlet flow was to be diverted to power a small gas generator enclosed in front of and beneath the SERJ. The gas generator powered a fan mounted in front of the ejector ramjet. The engine, which was designed to burn jet fuel and hydrogen peroxide as an oxidizer, was successfully ground-tested at subscale by Marquardt and Aerojet but never progressed to flight testing.

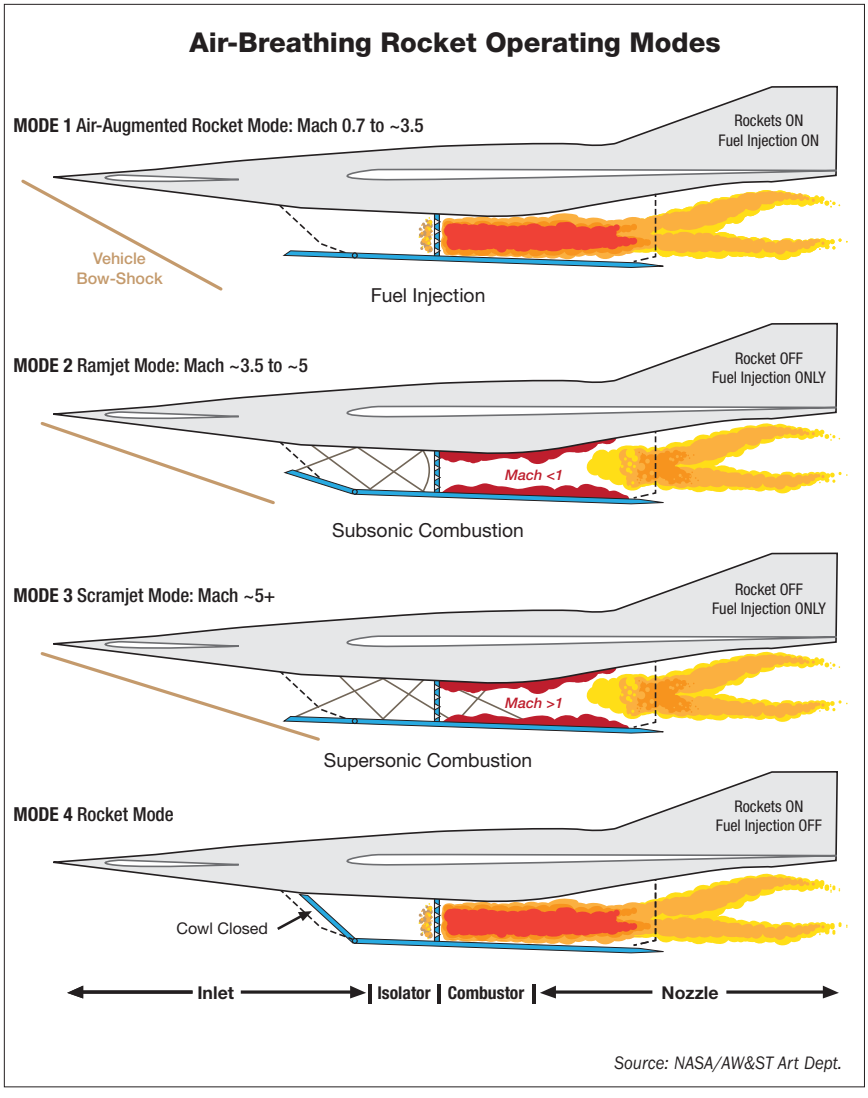
Since the 1980s, other proposed RBCC developments in the U.S. have traditionally focused on powering the first stage of two-stage-to-orbit (TSTO) launchers, although an RBCC that integrated a liquid rocket engine and a deep-cooled turbojet (DCTJ) was also initially proposed for the McDonnell Douglas DC-X Delta Clipper single-stage-to-orbit vehicle. RBCC systems were also baselined for the X-30 National AeroSpace Plane as well as NASA's Highly Reus-

China RBCC Engine Configuration



Source: Northwestern Polytechnical University/AW&ST Art Dept.

U.S. interest in RBCC is reviving as work steps up on international projects such as this combined-cycle concept now under development in China.



Although never flight-tested, the proposed X-43B ISTAR indicates how a typical RBCC propulsion system might operate.

able Space Transportation program.

More recently, in the early 2000s, NASA also began the Integrated System Test of an Airbreathing Rocket (ISTAR) RBCC demonstration program in support of the X-43B. The ISTAR effort was paralleled by NASA's Revolutionary Turbine Accelerator project for the agency's TBCC accompanying demonstration program. To develop the ISTAR RBCC, an industry team called the Rocket-Based Combined-Cycle consortium was created, which included what was then Boeing Rocketdyne, GenCorp Aerojet and Pratt & Whitney. Aerojet contributed the Strutjet, which was based on an earlier cooled strut design developed to inject hydrogen into the scramjet combustor on the X-30.

Other proposed RBCC concepts for TSTO launchers in the U.S. have included the Aspirating Rocket Engine, in which liquefied air taken from the atmosphere is mixed with liquid oxygen and burned with liquid hydrogen (LH2) in a conventional rocket engine. In this cycle, originally outlined by Vladimir Balepin of MSE Technology Applications, the LH2 would be used as a fuel, a coolant and to drive the turbine in the turbomachinery.

Another MSE RBCC concept that was studied in the early 2000s by the AFRL is the KLIN cycle, which proposes combining a thermally integrated DCTJ with a liquid rocket engine. In this cycle, LH2 fuel for the rocket and turbojet engines is used to deeply cool inlet air to boost the pressure ratio in the jet engine until shutdown above Mach 6, at which point a high-expansion rocket would take over.

Other related and more recent propulsion concepts include Reaction Engines' SABRE (Synergetic Air-Breathing Rocket Engine), which is in development for hypersonic and space access applications. The system is based on a precooler, which is also being offered separately to condition inlet air for boosting performance in modified turbojets—either in standalone engines or potentially as part of TBCC systems.

For RBCC applications, the integrated SABRE system operates in two modes: an air-breathing mode in which the precooler combines with a turbo-compressor to deliver chilled air directly into a rocket combustion chamber and, secondly, in a pure-closed-cycle rocket mode where LH2 is burned with an onboard load of liquid oxygen.

RBCC concepts have also been evaluated in Russia and China; the former include an air turbo rocket deeply cooled cycle developed by the Moscow-based Central Institute of Aviation Motors. The concept integrates a precooler and turbo compressor that supply chilled high-pressure air to a rocket combustion chamber, where it is burned with LH2. The hydrogen acts as a rocket fuel, while also being a coolant and powering the turbine. As the LH2 exits the turbine, it can then be used to potentially power a ramjet.

The status of China's RBCC developments remain obscure, although in late 2018 researchers from Northwestern Polytechnical University in Xian disclosed details of an ongoing program into a variable-geometry concept that appears aimed at a reusable hypersonic cruise vehicle rather than for access to space. Similar in concept to the early Marquardt ejector ramjet, the Xian RBCC incorporates a set of small bipropellant rockets integrated into the ramjet/scramjet duct. In this case, the rockets, which are RP-1/liquid-oxygen-fueled, are situated in the aft end of the isolator directly upstream of the mixer and combustor.

Although no details of the proposed application have emerged, researchers in China say the concept is designed to propel a vehicle from a standing start to high Mach numbers

and return it to landing. The program is targeting improvements in overall RBCC performance in ejector mode, and a version of the engine has been run through a series of direct-connect experiments to assess the effects on ejection of manipulating secondary fuel-burning and throttling the rocket in the duct. Other tests have also assessed the effects of a variable-geometry combustor and throat area. The testing also appears to have successfully demonstrated continued combustion during transition from rocket-ramjet to pure ramjet mode at Mach 3.

Chinese researchers in Beijing are also actively developing the turbo-aided rocket-augmented ram/scramjet combined cycle, designed to operate from a standing start to Mach 6, and from sea level to 33 km (20 mi.). The propulsion system, which is on track for flight tests in the mid-2020s, combines a turbine engine, rocket and ramjet with a common adaptable inlet and exhaust and is in the first of three planned development phases.

The AFRL says TBCC options will also be considered for Mayhem. Led by the Air Force, DARPA and NASA, TBCC technology development over the past two decades has focused largely on testing high-speed turbines to close the gap between jet and ramjet/scramjet takeover transition, as well as the control and mechanics of mode transition.

Testing of high-Mach engines, conducted over the past decade under the Air Force/DARPA High-Speed Turbine Engine Demonstration program and follow-on AFRL Supersonic Turbine Engine for Long-Range program, paved the way for the ongoing Advanced Full-Range Engine (AFRE) initiative. Led by DARPA, together with the Air Force, AFRE is testing elements of a TBCC system designed for future runway-based reusable hypersonic vehicles operating up to Mach 5. AFRE builds on previous Mode Transition and Falcon Combined-cycle Engine Technology efforts, the latter completed in 2009.

Combining an off-the-shelf turbine and dual-mode ramjet/scramjet (DMRJ), the AFRE engine uses mass-injection precompressor cooling to boost the maximum speed of the turbine. The water injection system, together with the common turbine/DMRJ inlet, combustor and nozzle, are due to be integrated later this year into the complete TBCC assembly. Freejet testing of the engine is set to occur in 2021.

NASA's long-running Hypersonic Technology Project, which included tests of a large-model TBCC under the Combined-Cycle Large-Scale Inlet Mode Transition program, also continues TBCC concept studies. Earlier this year, NASA announced it is working with GE Aviation to develop high-temperature ceramic matrix composite materials for component parts. NASA also selected GE's F101 turbofan for analysis as part of studies of a TBCC-powered concept vehicle.

Attritable Aircraft Prompt Changes in Jet Engine Designs

> ROLLS, PRATT AND KRATOS ENTER ATTRITABLE ENGINE MARKET

> AFRL SEEKS TO BREAK COST-RATIO PARADIGM FOR ENGINES

Steve Trimble Washington

As a boundary-blurring line of "attritable" aircraft gains interest, the U.S. Air Force is taking a new look at traditional principles of jet engine design with the goal of defining a propulsion system that falls somewhere between expendable and fully reusable.

A Williams International FJ33 turbofan powered the first flight of the Kratos XQ-58 Valkyrie in March 2019, but the Michigan-based maker of small turbofan engines can expect competition.

Rolls-Royce LibertyWorks announced in August the completion of rig tests on a small engine designed for the "expendable and attritable market for the Department of Defense," the company said. Rolls-Royce's release followed an announcement by Pratt & Whitney in 2019 that launched development of the FJ700 family of small turbofans for the same application. Finally, Kratos in March 2019 acquired Florida Turbine Technologies, a previous recipient of contracts from the Air Force Research Laboratory (AFRL), to design a low-pressure module for a "Low-Cost, High-Efficiency Attritable" turbofan.

All these industry projects are seeking to capitalize on the Air Force's plans to develop a family of low-cost unmanned aircraft systems (UAS) under the Digital Century Series initiative. With the latest generation of manned aircraft bristling with expensive capabilities—albeit in small quantities—the Air Force is seeking to rebuild mass and strike capacity in the combat fleet with hundreds, if not thousands, of attritable UAS priced between $2 million and $20 million.

A rule of thumb in the aircraft industry sets engine prices at around 15% of the overall cost of the aircraft. If that applies to the attritable aircraft category, the new class of attritable engines could result in a price range of about $300,000 to $3 million. However, the AFRL wants to break that 15% ratio for attritable engine prices.

"I think there's some opportunities to go much cheaper," says Daniel Thomson, the AFRL's portfolio manager for the Advanced Turbine Technologies for Affordable Mission (ATTAM) capabilities program, which includes an attritable engine component.

An attritable aircraft is defined as being affordable enough to be expendable on any mission yet capable enough to fly multiple sorties if called upon. Thomson acknowledges that sets up a tricky design requirement for an engine manufacturer.

"People say that if I just make it so it doesn't last as long, it's going to be cheaper," Thomson says. "As with many things, but especially with engines, that's not exactly true."

For example, a common temperature at the first stator outlet position of a combustor—one of the hottest parts of an engine—is above 1,000C (1,832F). Only a few costly materials can survive at such a temperature for any length of time.

"That temperature is going to drive you to make certain design and material decisions just [so it is] able to survive a few seconds even," Thomson says. "It's going to create basically an inherent life that might be longer than you think you really need in an application.

"What matters perhaps more is what you want to do with [the engine] as opposed to just [service] life in and of itself," he says. "So when we talk about targeted life, what we're really doing is coupling the [service] life as a requirement that's equal to other requirements."

If simply using cheaper, lower-temperature materials is not a panacea for the issues facing attritable engine design, the AFRL has other options. The AFRL fabricated an 11-ft.-long, S-shaped engine inlet duct for an attritable UAS this year with a new process. Instead of hand-applying composite prepreg to a steel mandrel, the AFRL used an automated system to apply dry fiber to a shape-memory polymer mandrel. The composite prepreg had to be cured in an autoclave, but the dry fiber was infused with a low-cost epoxy in a vacuum-assisted resin transfer-molding process.

U.S. AIR FORCE

The first generation of jet engines, such as the F-84's J35 (pictured), came with 100-hr. time-between-overhaul ratings. Attritable engines may come with a similar service lifetime to achieve affordability targets.

Another option is driving time-consuming processes out of the manufacturing process altogether. A jet engine for a manned aircraft is subject to continuous airworthiness reviews, with any new incident in service potentially adding time and cost to the production process.

"Every time we have an incident, we add a new step to the process . . . or another test or another analysis," Thomson says. "With attritable, I'm trying to think: 'Well, what exquisite things can we get rid of at the beginning?'

"So it's not really about, say, dialing in a number and then a design system cranks something out. It's really more about determining what my target is and then making design trades to meet that target," he adds.

HUNTER-KILLER II

> NORTHROP GRUMMAN UNVEILS ITS VISION FOR REPLACING MQ-9

> SG-2 IS PART OF A NEW FAMILY OF ADVANCED UAS

Steve Trimble Washington

Every age presents a new military challenge—and new ideas to solve it. A decade ago, the urgent problem facing the U.S. Defense Department was the scourge of improvised explosive devices (IED) planted beneath the uncontested skies of Afghanistan and Iraq.

Today, it is how to track the hundreds, if not thousands, of mobile missile launchers that rove freely deep behind the well-defended borders and coastlines of China and Russia.

To counter the IED problem, the defense industry proposed installing highly sophisticated, staring sensors onboard a set of relatively defenseless, ultra-long-endurance aircraft such as hybrid airships and hydrogen-powered unmanned aircraft systems (UAS). The concept produced a bevy of development programs such as the Blue Devil II, Long-Endurance Multi-Intelligence Vehicle and Orion UAS, but none came to fruition.

Northrop Grumman's operations planners are still in early discussions with the Air Force about the proper response to the mobile missile launcher threat, which, unlike the very real roadside IEDs of the last decade, remains theoretical.

As the Air Force starts to look for an MQ-9 replacement in 2030 now being called "MQ-Next," Northrop is ready to lift the veil on a potential option: the SG-2 UAS.

The SG-2, which Northrop detailed exclusively to Aviation Week, forms one of a new family of UAS that the company submitted in July to the intelligence, surveillance and reconnaissance and special operations directorate of the Air Force Life-Cycle Management Center.

With a fuselage based on the familiar cranked-kite platform of Northrop's X-47B, the SG-2 features an inboard wing section extended by a shallower angle along the trailing edge and an outboard wing section with a narrower chord. As proposed, the 20,000-lb. aircraft with 1,000-nm range is less than half the maximum takeoff weight and one-third the range of the carrier-based X-47B, says Scott Winship, Northrop vice president for advanced programs.

But the true breakthrough offered by MQ-Next proposals such as the SG-2 is not based on any dramatic new revelation in aircraft or jet engine design.

In Northrop's view, the replacement for the MQ-9 could be a meshed swarm of dozens of hunter-killer UAS stealthy enough to penetrate into defended airspace and collectively find, track and, if necessary, destroy a wide range of targets, including radar sites and mobile missile launchers. Alternatively, the aircraft's onboard jammers could clear a path through a gauntlet of enemy sensors, allowing the more valuable crews of fighters and bombers to reach targets farther downrange.

That vision seeks to capitalize on the promised power of a new generation of autonomous aircraft that no longer require the direct control of a human operator. These UAS would be able to dwell for long periods inside defended airspace, using automated functions to

NORTHROP GRUMMAN

Northrop's newly unveiled SG-2 concept relies on an automated command-and-control system to orchestrate the movement of a UAS swarm.

sense, understand and react to changes in the environment by themselves.

The heart of the capability is not the SG-2 or other members of the UAS family, but Northrop's Distributed Autonomy/Responsive Control (DA/RC) system. Northrop officially describes DA/RC as a joint all-domain command-and-control (JADC2) prototype, but Winship calls it a "battle manager on steroids."

To an outsider, observing the DA/RC system in action seems like watching a video game. A giant video screen set up in a Northrop facility shows a battle in process, with about a dozen X-47B-shaped icons in blue arrayed against an enemy's air defense systems on the ground in red.

To the untrained eye, the X-47B icons look like they are following a script. In virtual reality, they are acting out a sophisticated simulation. As each of the icons move, they are performing a role as part of a mission. The DA/RC software manages the X-47B assets in the simulation in the same way as a human battle manager on a Northrop E-8C Joint Stars, except much of the process moves at machine speed. A human staff monitors the operation, but the unmanned systems do not depend on continuous communication with a human controller.

Northrop began developing the software platform that evolved into DA/RC about 15 years ago. As the company was developing the X-47B for what was then the Navy's Unmanned Combat Air Systems (UCAS) program, the idea was to control five carrier-based aircraft in flight without dedicating a human staff to each, Winship says. The DA/RC software is now capable of running a simulation with about 100 constructed elements serving as aircraft.

The operational breakthrough posed by the DA/RC is not a new inspiration in aircraft design. Instead, it is a suite of computer hardware and software tools that can manage a complex air battle at a speed far beyond human abilities. Northrop portrays the system as a prototype of the Air Force's vision for JADC2, but the company's operations analysis, as informed by the DA/RC, suggests other elements of the military's modernization agenda—such as the low-cost attritable aircraft and loyal wingman concepts—may not work.

The concept for the SG-2 aircraft offers a case in point. The airframe design is informed more by Northrop's

experience with the X-47A Pegasus, Winship says, rather than the larger, more sophisticated X-47B. For both the X-47A and SG-2, Northrop leveraged the low-cost manufacturing expertise of its Scaled Composites subsidiary.

"When you talk with Northrop's [Aeronautics Systems division] about building something cheap, we default to the wrong answer," Winship says. "So we work really exclusively with Scaled Composites to try and understand how we can do these things cheaper but have the same smarts onboard. Northrop would bring the smarts, and [Scaled Composites] would bring the cheap manufacturing."

Despite Scaled Composites' participation, Northrop is struggling to fit an operational SG-2 into the Air Force's notional range of $2-20 million for an "attritable" aircraft system, Winship says.

"We tried to work very hard to get the air vehicle with a baseline load-out below $20 million," Winship says. "The difficulty is when you start to load it up with different kinds of sensors—[signals intelligence] or [electronic intelligence] or some of the other things they want to carry—you start to push the price. Then you think it's more valuable, and you want to bring it home."

A war against Russia or China could result in a lengthy campaign. An aircraft designed to be attritable could, by definition, sustain significant losses. Even if the costs remain a fraction of more survivable—and sophisticated—manned fighters and bombers, the losses in the attritable fleet may not be sustainable, according to Northrop's operations analysis.

"On a campaign that takes days, weeks, months, you can't just be dropping these things into the sea all the time," Winship says. "They just get really expensive."

Another aspect of the Air Force's attritable aircraft concept is runway independence. The Kratos XQ-48 Valkyrie, which was funded by the Low-Cost Attritable Aircraft Technology program, was designed to take off and land without using runways. Northrop's operations analysis has concluded that such a concept leads to a more expensive overall fleet than an aircraft designed with traditional landing gear.

"If you could turn the vehicle in 4 hr. and put it back in the fight, you could buy fewer vehicles and have enough to pay for the higher-end landing gear and maintenance equipment to turn the vehicle faster," Winship says. "Turning it around in 12 hr., you have to buy more vehicles to maintain orbits."

Another concept the Air Force is pursuing is the "loyal wingman," which allows a fighter pilot to control one or multiple low-cost, attritable UAS. The human pilot could use the potentially reusable aircraft as advanced scouts or, if the situation demanded it, cruise missiles. But Northrop's analysis suggests the loyal wingman concept is flawed.

"One of the things that a UAV hates is the burden of having a manned fighter with it, which doesn't have any persistence [or] any endurance," Winship says. "Those are the two things that a UAV does well. Why would you burden it with being with a fighter?"

LOCKHEED MARTIN

Lockheed Martin Unveils Details of MQ-9 Replacement Offer

- THE U.S. AIR FORCE WANTS TO REPLACE THE MQ-9 BY 2030
- OFFERING COMBINES ELEMENTS OF THE RQ-170 AND LOCKHEED'S SEA GHOST CONCEPT

Steve Trimble Washington

Lockheed Martin Skunk Works has revealed new details of the company's vision for a U.S. Air Force MQ-9 fleet replacement on the eve of 2020's Virtual Air, Space & Cyber Conference.

The company responded to a request for information released by the Air Force in June for an MQ-9 replacement in 2030 with a family of unmanned aircraft systems (UAS), including both advanced and inexpensive platforms.

"Our operational analysis shows that the future UAS force structure can be optimized with a mixture of high-end systems and low-end (low-cost) expendable systems," Lockheed says in a statement to Aviation Week.

An illustration of the high-end Next-Generation UAS (NGUAS) concept released to Aviation Week by Skunk Works displays yet another evolution in Lockheed's stable of stealthy, flying-wing aircraft. Lockheed also showed a similar image of the NGUAS concept in August to media in Poland, which was aimed at the Polish Ministry of National Defense's Harpy Claw program.

The frontal aspect rendering of the NGUAS recalls the isosceles trapezoid inlet style of the RQ-170 and Lockheed's original Sea Ghost concept, which was tailored for a carrier-based surveillance and strike UAS. The Navy's requirement change to a carrier-based, unmanned tanker prompted Lockheed to submit a new design for the MQ-25 contract, with an aircraft featuring a rounded inlet and almost triangular planform.

The new NGUAS concept reveals a planform that falls between the sharper, sawtooth angles of the trailing edge for the Sea Ghost and the softer swept trailing edge of Lockheed's MQ-25 bid.

The concept builds on Lockheed's decades of experience in UAS design, a Skunk Works spokeswoman says.

"While the MQ-25 and Next-Generation UAS share some of this common heritage, including visual similarities, they are in fact two very different vehicles designed for two very different missions," the spokeswoman adds.

The NGUAS (pictured in flight with an F-35A) reveals a sophisticated-looking aircraft as a replacement for the turboprop-powered, medium-altitude MQ-9 fleet.

"The Next-Generation UAS includes specific features for survivability, enhanced mission radius, and advanced ISR [intelligence, surveillance and reconnaissance] capabilities that are not part of the MQ-25 program," Lockheed's spokeswoman says. "Our intent for the Next-Generation UAS is to develop a smart, stealthy unmanned ISR system to enhance the capability of existing assets across all domains, while helping to protect our warfighters from direct exposure to threats."

The company has released a rendering of its Next-Generation UAS concept, in flight with an F-35.

The Air Force has defined a challenging requirement for the still-nascent MQ-9 replacement program. As the service prepares for a future conflict with a great power: The so-called MQ-Next program seeks to introduce a capability that can persist and be effective within a defended airspace, yet remain affordable enough to meet the Air Force's definition of "attritable." One Air Force briefing to industry in May defined a price range for an attritable aircraft as falling between $2-20 million.

If the NGUAS falls on the high-end of that spectrum, Lockheed's proposal for the low-end aircraft avoids the Air Force's "attritable" term. Instead, Skunk Works describes the low-end member of the UAS family as simply "expendable." In the same briefing to industry in May, the Air Force defined expendable as cheaper than $2 million per unit.

SOFT POWER

- B-21 AND F-16 LABS INTEGRATE SOFTWARE CONTAINER
- OPEN ARCHITECTURE PROCESSORS COMING FOR F-22 AND F-15EX
- USAF OFFICIAL SEES OPPORTUNITY TO DISRUPT DEFENSE INDUSTRY

Two F-22s assigned to the Edwards AFB test fleet are among the first to receive new processors that are compliant with the Open Mission Systems architecture.

CHAD BELLAY/LOCKHEED MARTIN

Steve Trimble Washington

Secrecy surrounds nearly every detail of the U.S. Air Force's new stealth bomber. Analysts seeking an estimate of the Northrop Grumman B-21's takeoff weight are forced to scrutinize the two released renderings for possible clues such as the size and shape of the landing gear. Other fundamental features—like the number and size of the engines, the capacity of the weapons bay and even the aircraft's unrefueled combat radius—remain shrouded in classified mystery.

A consistent and surprising exception to the Air Force's tight-lipped discretion, however, comes with the B-21's software.

Even as the results of ground-based testing for the engines, structural materials and sensors remain a closely guarded secret, Air Force leaders feel free to boast about the lines of software code embedded in the B-21's computers and running as applications on an open architecture processing system. While the rest of the aircraft's development systems are described broadly as progressing on schedule, the secretive program's managers slip in specific details about the pace of software updates to the bomber's systems integration laboratories.

"We're not doing what was termed a normal OFP [operational flight program] drop every year or two," says Randall Walden, director of the Air Force Rapid Capabilities Office (RCO). "We're seeing it, like, every month or two. So that level of compression of time gets after those typical errors that take a long time to fix."

The B-21, according to Walden, is participating in a dramatic shift in software development within the military and the defense industry. It began a few years ago with a move to an agile software release schedule, with small capability increments released every few months instead of every few years. Over the next several years, multiple aircraft, including the B-21, Lockheed Martin F-22 and F-35 and Boeing F-15EX, will be fielded with architecture compliant with open mission systems (OMS).

Once the agile software method and OMS-compliant systems are in place, Air Force officials are preparing for even more profound changes. As software updates rather than new hardware begin to drive new combat capabilities, a powerful set of tools already used by commercial industry potentially becomes available to combat systems. The tools may allow developers to untangle the software code

for a specific application from a military jet's operational flight program (OFP), which would markedly reduce the cost and schedule for introducing new, software-driven capabilities on the combat fleet.

The implications for the defense industrial base could be dramatic. If the technology survives the technical, regulatory and cultural challenges that still lie ahead, some Air Force technical leaders, including Chief Software Officer Nicolas Chaillan, will seek to disrupt a pillar of the defense industry's business model, with the government taking ownership of the valuable intellectual property (IP) embedded in the source code OFP. Instead of controlling the life cycle of a franchise weapon system, the industry's revenues would come from developing the most valuable software-driven applications, which would generate licensing fees based on the government's usage.

The B-21 program guards many secrets, but not its role in the shift to a new software development model. As Northrop continues assembling the first flight-test aircraft in Palmdale, California, the systems integration laboratories for the B-21 are receiving new containerized applications orchestrated by a Google-derived tool called Kubernetes.

"Kubernetes allows us to reduce the regression time because not all of the software is in this spaghetti-code makeup," Walden says. "It's broken up into [discrete applications] and allows us to do a much better job of . . . getting [the applications] on the airplane."

Software development in U.S. defense programs has been a problem for decades.

In modernization programs, the pace of upgrading existing aircraft such as the F-22 has been partly driven by a software development method known as "waterfall." Software developers divided the code into separate applications, with each developed and tested separately. At the end of a usually two-year development cycle, the individual software modules would be integrated and tested together for the first time as a complete system.

Inevitably, the testers would find numerous deficiencies, which could take months or even years to resolve. The Increment 3.2A upgrade for the F-22 OFP suite, for example, fell a year behind schedule under the waterfall method, according to a 2018 report by the Defense Department Inspector General.

NORTHROP GRUMMAN CONCEPT

The avionics on the future Northrop Grumman B-21 have validated the ability to run software containers in ground testing.

The same waterfall method also has sometimes partly dictated the pace of software development for new aircraft. Prat Kumar, Boeing's F-15 program manager, says the typical program would begin with Air Force development requirements. At some point, a request for proposals would be released. Months later, a company would be awarded a contract, launching the software development process. A final bundle of software would finally be released to a testing organization, which would reveal deficiencies that need to be fixed. Half a decade could pass between the requirements being set and the capability being delivered.

"It could be a 3-5-year time frame, broadly speaking," Kumar says.

The commercial industry largely moved toward agile software development methods over a decade ago, and the defense industry is now starting to come along. In an agile process, the goal is to deliver new capabilities in smaller increments, which can then be tested at the integration level much sooner. The agile process does not eliminate software bugs, but in theory the method simplifies the resolution.

In many cases, some form of agile development method is already the norm for the Air Force's most advanced combat aircraft. The F-35 adopted the Continuous Capability Development and Delivery process for Block 4 modernization, although the Government Accountability Office recently noted that the method fell short of expectations during the first full year of production in 2019. The F-22 program, meanwhile, has adopted the Raptor Agile Capability Release process, which broke up the Tactical Mandates upgrade program into a series of smaller capability insertions delivered more rapidly.

Though in production for nearly a half-century, Boeing's F-15EX also is making a similar transition. The Air Force plans to order a minimum of 144 F-15EX aircraft, and the first lot of eight aircraft will be delivered with Block 9.1X software for the OFP. Starting with Lot 2 aircraft deliveries in 2023, the Air Force has contracted Boeing to deliver Block 9.2 software, which will set a new fleet-wide baseline, Kumar says. That means new F-15EX and older models, including the F-15C and F-15E, will use a common software suite.

At the same time, Boeing is working on a new Phantom Works-developed mission systems processor for the F-15EX. The new computer hardware is compliant with the Air Force's OMS architecture. As the processor enters service beginning in 2023 on Lot 2 jets, the possibilities for new upgrades will change. Applications developed by vendors outside Boeing's proprietary software standards will have an easier path to integration on the F-15EX. The OFP will continue to be updated in roughly yearly intervals, Kumar says.

The OMS architecture also is spreading to Lockheed's stealth jets. A new, OMS-compliant processor has been installed on the first five F-22s for development testing at Edwards AFB, California, and Nellis AFB, Nevada, says O.J. Sanchez, Lockheed's vice president for F-22 programs.

"We'll start to see that retrofitted in the fleet after it's approved for release next fall," Sanchez says.

Beyond agile development and OMS-compliant architectures, the

CAPT. JUSTIN MARSH/U.S. AIR FORCE

U.S. Air Force Chief Software Officer Nicolas Chaillan (center, in purple tie) in front of an F-16 SIL with the Hill AFB software team during a Kubernetes demo.

Air Force's next push will be to containerize new software capabilities. To software developers, the idea of using virtual containers to deliver new applications is nothing new. Containers are commonly used for the software that runs applications for consumers and even information technology services in the defense industry.

A container allows a computer processor to run a new application without entangling the source code of other systems on the jet. A cottage industry of containerizing tools, such as Docker and OpenShift, allows developers to create the new applications. Depending on the number and complexity of containers involved, the developers can use Google's Kubernetes automated orchestration tool.

For now, containers do not yet exist on flight-certified applications for any aircraft—much less the Air Force's most advanced combat jets. But that could begin to change.

On Nov. 7, 2019, Chaillan and Will Roper, the Air Force's assistant secretary for acquisition, technology and logistics, met at Hill AFB, Utah, to attend a major milestone: For the first time, an internal Air Force software factory inserted a new containerized application into flightworthy hardware. In this case, the hardware belonged to the F-16 systems integration laboratory (SIL), a ground-based testing rig.

The Air Force integrated new map and sensor applications into the display of the F-16 SIL purely as a proof-of-concept demonstration, Chaillan tells Aviation Week. Roper and Chaillan had challenged Hill's software factory to develop the code, integrate Kubernetes and run the application on the F-16 SIL's existing computers within 45 days. Using a traditional, noncontainerized approach, the same upgrade could require additional weeks or months of regression testing to verify that the software would not interfere with other systems on the jet.

As the RCO's Walden confirms, the Air Force later performed the same demonstration on the B-21, although further details have not been released.

"People were always saying: 'Well, you know we can do all this stuff on business systems, but, we cannot do it on weapon systems. And we knew [that] was wrong and was completely possible," Chaillan says. "We wanted to demonstrate that in 45 days, so we picked the F-16 to show it could be done on legacy hardware, and it's not required to replace any component."

Following the proof-of-concept demonstrations on the F-16 and B-21 SILs, the Air Force is seeking to obtain flight certification for containerized software updates, allowing the mission systems for jets to be updated wirelessly during flight. Aircraft certification standards for software now require extensive validation and verification for every line of software code before they can be installed on a jet on the ground, so the new approach represents a significant change. The Air Force is now seeking to approve the new certification policy and achieve safety-of-flight certification, Chaillan says, but he cannot offer a timeline for completing the process.

Chaillan considers containerization critical to the future of combat aircraft technology. If future fighter and bomber pilots want to stay relevant, they cannot wait for software developers to complete the same level of regression and security testing used today for new updates, he says.

"I don't think we have a choice," Chaillan says. "I think if we don't do it, China and Russia are going to be 20 years ahead. The last 30 years of innovation was driven by hardware. The next 50 [years of innovation] are going to be software-defined. It's going to be artificial intelligence software that's going to be able to make decisions before you even have the time to touch the button."

If flightworthy software containers become reality, Chaillan foresees profound changes for the defense industry. Upon entering U.S. government service after a successful career as a technology entrepreneur in France, Chaillan found the military's relationship with defense contractors over the rights to software source code backward compared to the commercial industry. The government pays defense companies to develop the source code for an aircraft OFP, but industry keeps the IP rights to the code. Chaillan wants to reverse that approach.

"We paid for the software and yet we didn't own the IP. That will never happen on the commercial side," Chaillan says. "On the commercial side, if you go to a company, and you say, 'I'm going to hire you to build whatever capability, and I'm going to pay 100% of the cost of developing it,' well, guess what, you better own the IP."

Defense companies could still make money, but the business model would change. Instead of basing a business case on owning rights to the OFP source code, defense companies could develop new, containerized software applications, Chaillan says. Each application could be licensed by the company to a military, government or even a commercial customer, with fees paid for how often the application is used.

"It's a recurring revenue model," Chaillan says. "You can sell the same piece of software as a monthly fee or a consumption-based fee."

As the OMS architecture and software containers replace proprietary OFP source code on military aircraft, the new model also could lower barriers to entry for traditional technology companies to develop new applications for the military. Chaillan acknowledges the transition is likely to take several years.

"It's not going to happen in a year; it's going to happen in 10 years," Chaillan says. "If we don't do it, we're going to get behind."

Reforging of USAF Pilot Training Hits New Complications

> AIR FORCE CANCELS SOLICITATION FOR LEASING DEAL

> QUESADA AVIATION EMERGES TO LEAD T-50 BID

Steve Trimble Washington

In June 2019, U.S. Air Force Gen. James Holmes strapped into an Israeli Air Force M-346 Lavi advanced jet trainer and flew off to attack a ship in the Mediterranean Sea.

"We fought our way through air threats and ground threats; we did a simulated attack on a target; we came off and fought through air threats and then [returned to base]," recalls Holmes, who retired last month as head of Air Combat Command (ACC).

Of course, the attack was simulated: The threats and target appeared as constructed elements on the sensor displays inside the cockpit. The purpose of the exercise was not to defend the Israeli coastline but instead to show Holmes a new way of training pilots as the Boeing T-7A enters service within three years.

The U.S. Air Force pilot training curriculum is almost as dated as the 60-year-old Northrop T-38Cs the T-7As will replace. New fighter and bomber pilots spend two years mastering basic skills at bases focused solely on training new pilots; then they move on to fighter training units (FTU) at operational bases. When Holmes entered the Air Force in 1982, FTU pilots still flew about 250 hr. each year. With flight-hour costs for F-15Es, F-22s and F-35As now over $25,000 per hour, FTU pilots today on average log about 150 hr. annually, contributing to a four-digit backlog of pilots certified for combat.

But Holmes' experience with the Israeli Air Force has inspired a new approach to changing U.S. Air Force training. Unlike the T-38C's limited computing power, the M-346's embedded simulation system allows pilots at FTUs to fly realistic combat scenarios. As the T-7A enters service with similar technology, the Air Force is considering a broad shake-up of its pilot training system. The end result would be streamlining the curriculum by teaching fundamental skills and shifting earlier to combat training with T-7As instead of F-35s, F-22s or F-15Es.

"One option might be to take those T-7s and put a mix of them at [training] bases to teach people how to fly them and do advanced bomber training and then put some portion of them out at the fighter wings," Holmes says. "One option might be to do that training at training bases."

ISRAEL DEFENSE FORCES

A June 2019 ride in an Israeli Air Force M-346 trainer persuaded Gen. James Holmes to reconsider the U.S. Air Force's pilot training system before the Boeing T-7A enters the fleet.

To determine the best approach, Holmes' ACC launched Project Reforge. The original idea outlined in May 2019 called for leasing eight Korea Aerospace Industries (KAI)/Lockheed Martin T-50 jets from Hillwood Aviation for five years. ACC hoped to use the jets to understand how embedded training systems in the T-50 cockpits could allow the Air Force to streamline the pilot training system.

The ACC is still pursuing Project Reforge, but the acquisition process has been trickier than expected. Mission Systems Solutions (MSS), which has partnered with Leonardo to offer the M-346, objected to a plan from ACC to sole-source the lease deal to Hillwood's T-50s. Ultimately, the Air Force agreed to open the lease deal to competition and released an "invitation to propose" to industry in June.

As the bidding deadline passed on Aug. 17, however, ACC changed course again. The invitation to propose for the lease deal was canceled for unknown reasons. Instead, ACC is continuing to accept proposals under a less formal process called a Commercial Solutions Opening (CSO). The CSO allows ACC to accept proposals for providing advanced jet trainers through means other than a leasing arrangement.

Meanwhile, a new company called Quesada Aviation Holdings has emerged to submit a proposal with the KAI/Lockheed T-50, replacing Hillwood.

"Quesada is fully prepared to support the [Air Force] and Air Combat Command," says Seth Downing, the CEO. "We are pleased to see the CSO open and look forward to working alongside the [Air Force] and ACC in structuring a mutually beneficial and commercially viable alternative."

MSS also remains active in the Reforge project as the Air Force shifts to the CSO process.

"We began conversations with the Air Force about the Reforge training concept more than a year ago," says David Nichols, CEO of MSS. "We are continuing discussions with them to better understand their requirements and provide innovative solutions."

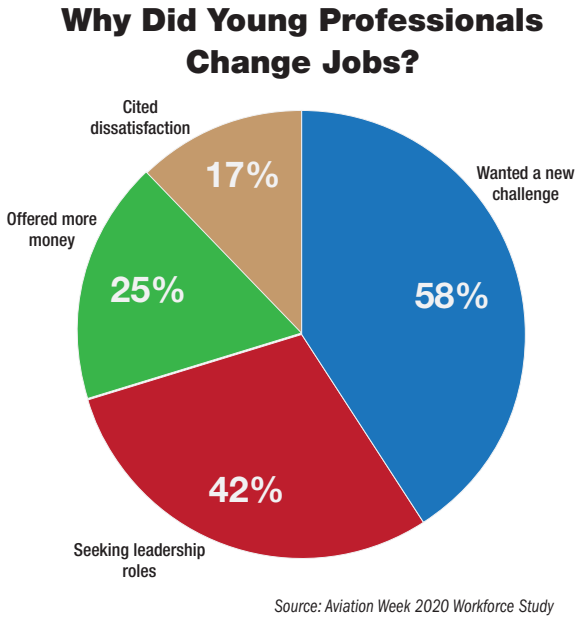
The final decision on the acquisition path for Project Reforge will be made by Gen. Mark Kelly, now the head of ACC, and will determine how to move forward with pilot training reform.

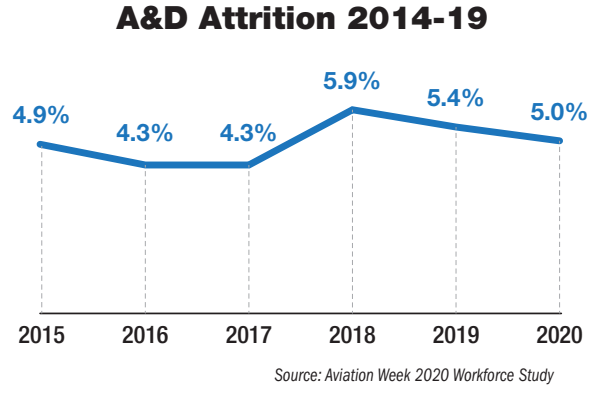
A&D'S BRAIN DRAIN

> OEMS AND TOP-TIER COMPANIES STRUGGLE TO RETAIN TALENT AMID LAYOFFS

> KEEPING A&D ATTRACTIVE MAY BE EVEN HARDER WITH MASSIVE CUTS AND A SLOW RECOVERY

Michael Bruno Washington





When Rolls-Royce on Aug. 27 unveiled a goal to divest £2 billion ($3 billion) of corporate assets, revealed pretax losses of £5.3 billion for the first half of 2020 and announced cuts of 9,000 workers by year-end, no one was surprised.

What startled many was the revelation that, among the thousands to leave Rolls was Stephen Daintith, its chief financial officer since 2016. Daintith is punching out of the embattled aero giant to take the same job at skyrocketing online supermarket Ocado. As trade journal *The Grocer* noted, "For Daintith, the appointment takes him from one of the worst-performing companies in the [Financial Times Stock Exchange] 100 to one of the best-performing."

Add brain drain to the list of challenges facing Western aerospace and defense (A&D) in the post-pandemic era. According to comments by industry managers and consultants during recent Aviation Week conferences and interviews, OEMs and top-tier companies are worried about losing too many talented workers as industry sheds tens of thousands of employees—maybe hundreds of thousands over the coming years—due to the impact of COVID-19.

Also, on top of what could be one of the worst manufacturing contractions in A&D history and the largest workforce reduction since the end of the Cold War, industry leaders are concerned about not being able to recover.

"We're having a lot of layoffs, but we're seeing a lot of people jump ship," says an executive at a leading OEM. "Really good, qualified people," he adds. "It's not just the millennial groups; it's across the board—jumping ship to a safer industry."

Some of the safer industries attracting aerospace talent include information technology along the West Coast, especially marquee names such as Amazon, Apple and others. The executive says more talent is leaving commercial OEM operations, but even defense is seeing talent leakage.

"Retention has always been an issue for us, especially in Southern California," echoes an executive at another top-tier A&D company. "It's not that we can't get good people again, but you'd like to keep the people you've trained, and we do have some issue with people bouncing around."

Announcements of major workforce reductions come out weekly. On Sept. 3, Embraer said it was laying off 900 employees in Brazil, about 4.5% of its global workforce. In August, Boeing said it was expanding its own reductions to more than 10% of its workforce. Rough counts of planned and announced layoffs across aerospace amount to more than 100,000 workers, and many more have been furloughed as manufacturers rightsize to 30-50% lower production needs as well as elevated aircraft retirements in coming years. And if Washington fails to provide another bailout for airlines by Oct. 1, the U.S. could see as many as 225,000 additional airline workers lose their jobs, consultancy Oliver Wyman said in August.

"I've never seen anything as bad as this," says a worker departing from Spirit AeroSystems, which has announced a 28% force reduction. "What is humbling is listening to workers who have been here for 35, 40 years and them also saying, 'I've also never seen anything like this.'"

Companies across A&D need to cut costs, and consolidating footprints and cutting workers are popular maneuvers. But humans are a more complicated asset. "The easier part is preserving the physical capability; the more challenging

part is going to be the workforce," says Scott Thompson, U.S. A&D leader at PwC. "If you have a hard time retaining the workforce during the sharp downturn, those specialized skills are not going to be available when the volumes return.

"Companies need to take a very strategic look at the critical skills they need to retain and come up with strategies . . . to preserve that workforce over the next 3-5 years," Thompson adds. That includes unavoidable demographic changes, such as already expected retirements.

"What we have is a large change for the aircraft industry in terms of expectations with regard to hiring, retaining and training," agrees Cliff Collier, a principal at Charles Edwards Management Consulting, which specializes in aerospace.

While voluntary attrition across industry was low before the pandemic (see chart on facing page), A&D has struggled to attract enough desirable talent. As the Aviation Week Network Young Professionals Study has documented for years, A&D companies have complained about competition for technologically savvy, younger candidates from Silicon Valley, gaming, health care services and others. One side effect has been how "old" A&D continues to look compared with other industries; the average age of an A&D worker has hovered in the mid-40s for years despite the entry of post-baby boomer Generations X, Y and Z into the wider workforce.

"The workforce has aged," says Ernst & Young Americas A&D leader Paul Feeko, compared with its Apollo heyday. "That's probably the most long-term and critical challenge the sector faces. There is already a significant shortage of tech-savvy workers in core areas like engineering, but even the more digitally savvy workforce required across all corporate functions is [lacking]. There are so many places that have become more attractive environments for the younger end of the workforce."

For sure, A&D had strong points compared with other industries. Higher levels of job security and self-declared passion among its workers were key recruiting strengths through the late 2010s, as well as a better-than-average work-life balance. But the fallout from COVID-19 is attacking the heart of what made A&D attractive.

"One of the attractive reasons that young people would want to come to the company—job security—is gone," says a younger industrial engineer at a Tier 1 supplier, who is leaving her employer to pursue an MBA. That is compounded by the fact that layoffs at unionized sites are guided by seniority and tenure, which leaves younger, newer workers at greater risk, the engineer notes.

Another brewing challenge for A&D companies, according to a human resources leader at a major aerostructures provider, is that aerospace may lag automotive and other industries in its recovery, perhaps by years, making it less attractive for new talent. "I do think that is a very real concern for our industry," the executive says. "If people think the recovery is too distant, or the current environment is too unstable, it certainly is very natural for them to think about who else might appreciate the talents and skills that [they] bring."

Others agree. "We believe the automotive industry may be well-positioned for growth in fiscal 2021," say A&D talent placement specialist Samantha Foster and her colleagues at ZRG Partners. "Simply put, aerospace talent will likely be more open to opportunities in which they can use their specialized skills in new and unique ways, within industries that they perceive as having greater near-term stability."

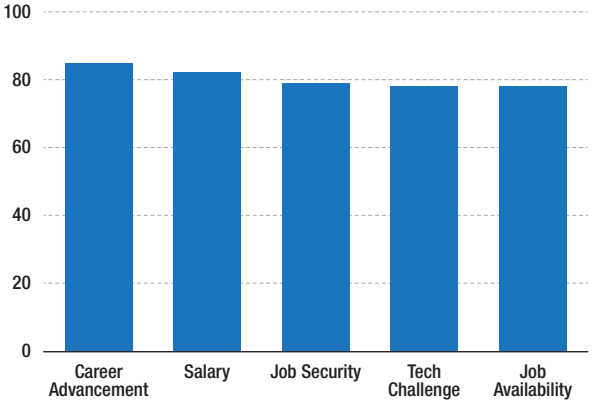
What is more, the short-lived hiring spree of the last half-decade could be quickly forgotten among communities where A&D was beginning to form pipelines of manufacturing and maintenance, repair and overhaul talent. According to the Aerospace Industries Association, the A&D industry supported 2.5 million jobs in 2018, the last full year of data. That included 881,000 direct jobs and another 1.6 million in the supply chain, which often serves multiple industries.

But 2018 could serve as the high-water mark. Long before the COVID-19 pandemic and even before the Boeing 737 MAX was grounded last year and production halted this year, industry was consolidating at a rapid pace. Each merger or acquisition deal brings more workforce reductions as managers take out costs and divest what they deem as noncore assets.

To be sure, the swelling available talent pool due to the pandemic is a "temporary reprieve," says Feeko, from past sourcing difficulties. And some smaller companies are capitalizing on the suddenly expanded pool. "We are seeing a better quality of candidates coming through," says Brian Neff, CEO of A&D-focused additive manufacturing provider Sintavia.

ETI Tech, which provides design, manufacturing and finishing of parts and specialized test equipment for A&D, is

A&D's Most Attractive Factors



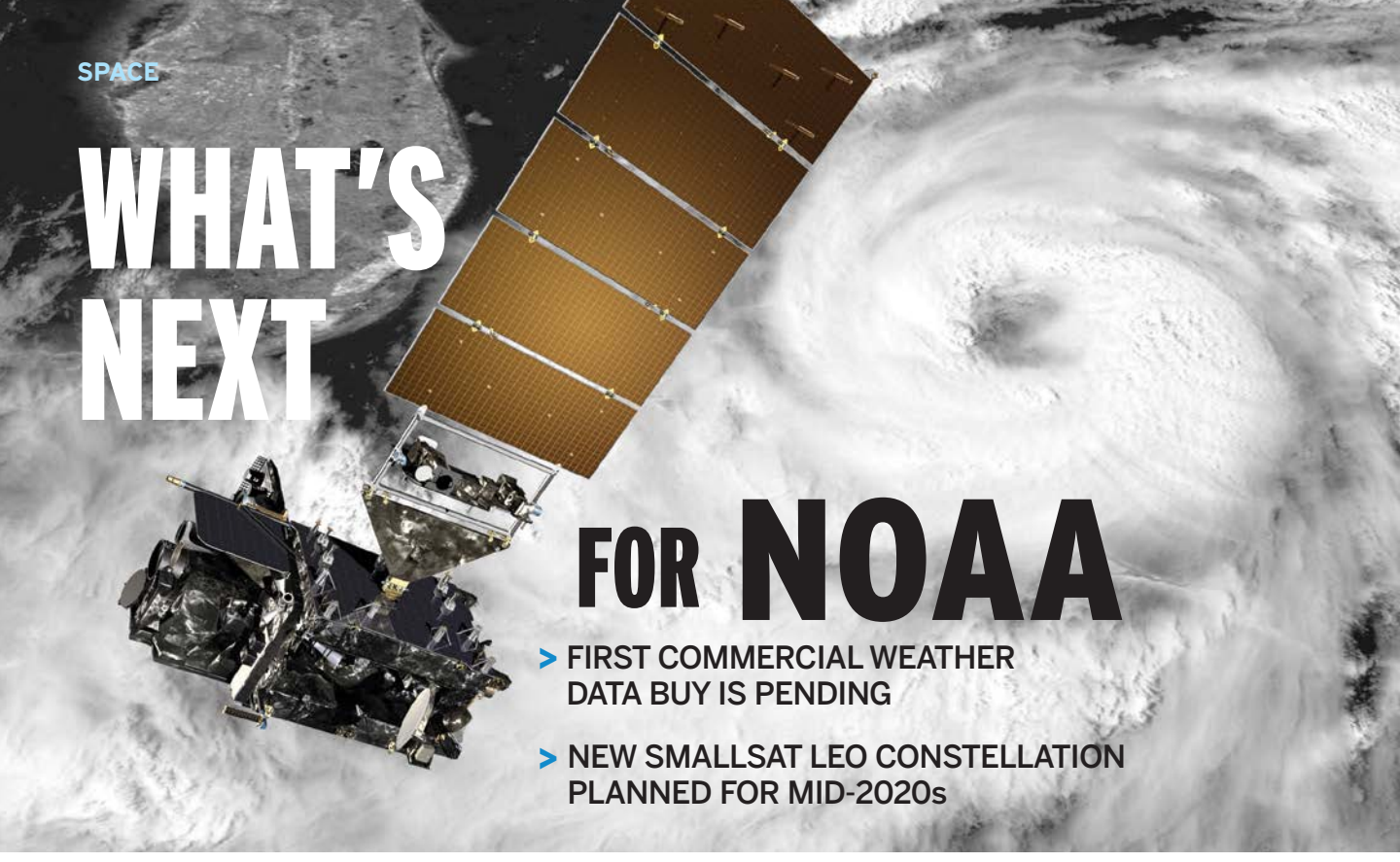
Source: Aviation Week 2020 Workforce Study

run by two young professionals with a self-described Silicon Valley mindset looking for like-minded employees. This summer, ETI's private equity owner Simon Group installed Chief Operating Officer Eric Lewandowski, 37, and Chief Financial Officer Kevin Moyer, 33, and infused the Dayton, Ohio, provider with $2 million to rebuild the decades-old company with new talent and technology. The 60-person firm aims to double or triple in size through acquisitions—ETI is looking to roll up other Midwest machining shops with at least $2 million in pretax earnings, especially those with commercial aerospace end-markets—and by hiring more personnel.

"We're looking to find like-minded individuals who want to join a company that wants to grow quickly, [with] ambitious growth goals," says Lewandowski. "One thing that is nice is that as a younger leadership team, we've really been able to connect with the younger side of our workforce, as well."

The growth plan existed before the novel coronavirus, but the pandemic's effects are feeding into it. Says Lewandowski, "A lot of the companies around us have had huge staff reductions, and just being able to execute that strategic plan has helped with recruiting."

WHAT'S NEXT FOR NOAA



- FIRST COMMERCIAL WEATHER DATA BUY IS PENDING
- NEW SMALLSAT LEO CONSTELLATION PLANNED FOR MID-2020s

Irene Klotz Cape Canaveral

Since its formation, the U.S. National Oceanic and Atmospheric Administration has set the bar for gathering and distributing data about the planet for weather prediction, storm tracking and meteorological research. Now, faced with increased demand for its services and with new Earth-observing technologies and systems emerging, the agency is charting a very different path for its future.

"This is a significant transformation," Stephen Volz, assistant administrator for the agency's Satellite and Information Service, tells Aviation Week. "It's not just a flip from Category A to Category B amongst selectable options in what we could do."

Traditionally, the National Oceanic and Atmospheric Administration (NOAA), which marks its 50th anniversary in October, operated two primary constellations of environmental satellites, one in geostationary (GEO) and the other in polar orbit.

The Geostationary Operational Environmental Satellites (GOES) series, now in its fourth iteration, fly 22,243 mi. above Earth's equator at speeds equal to the planet's rotation. From that perch, a pair of satellites provides continual views of the continental U.S., the Pacific and Atlantic oceans, Central and South America and southern Canada.

The current GEO system, GOES-R, consists of two operational spacecraft and two on-orbit spares. The operational birds are GOES East, launched in 2016 and located at 75.2 deg. W. Long., and GOES West, launched in 2018 and positioned at 137.2 deg. W. Long. Two more GOES-R series satellites are in development and scheduled to launch in late 2021 and in 2025.

NOAA's GOES-East satellite captured this image of a hurricane off the coast of Florida.

Fully fueled, the Lockheed Martin-built GOES-R satellites weigh 11,446 lb. and host six suites of instruments. The primary payload is the Advanced Baseline Imager, built by L3Harris Technologies, which views Earth in 16 spectral bands, covering visible, near-infrared and infrared portions of the electromagnetic spectrum. The camera features configurable, customized scanning and an interleaved swath design that enables simultaneous hemispheric image collections every 10 min., regional images every 5 min. and severe weather images every 30 sec.

Since GOES-1 reached orbit in October 1975, a total of 18 GOES satellites, developed in partnership with NASA, have been launched, all but one successfully.

The total cost to develop, launch, operate and eventually decommission the four-satellite GOES-R Series is $10.2 billion, NOAA says. The budget also funds the Environmental Satellite Processing and Distribution System and a Comprehensive Large Array-data Stewardship System to process and archive GOES-R Series data and ultimately make it available to end users.

The satellites, built on Lockheed's A2100 bus, are designed to last 15 years. The constellation is expected to remain operational through the mid-2030s.

Complementing the views and data from GEO are four NOAA polar-orbiting satellites, including NOAA-20, which launched in November 2017 to become the first member of the new Joint Polar Satellite System (JPSS) constellation. The polar birds fly in sun-synchronous orbits 500-540 mi. above Earth, circling the planet nearly 14 times per day to provide global weather coverage.

Three more JPSS satellites are expected to be added

Concept Studies

The National Oceanic and Atmospheric Administration has awarded 32 study contracts to 17 companies and agencies to develop mission concepts, spacecraft and instruments for future weather constellations. The projects are:

(Blue: Geostationary and Extended Orbits)
(Green: Low Earth Orbit)

Astra
- GEO Utilization of Common LEO Architecture for Weather (G-CLAW)

Ball Aerospace
- Ball Operational Weather Instrument Evolution (BOWIE) Geostationary Infrared (IR) Sounder Study for Compact Hyperspectral IR Observations (CHIRO)
- Dedicated Auroral Imager for a Tundra Satellite
- Ball Operational Weather Instrument Evolution-Microwave (BOWIE-M) Sounder Study
- Ball Operational Weather Instrument Evolution (BOWIE) IR Sounder Study

BAE Systems
- Infrared Sounding Instrument Constellation Study

Brandywine Photonics
- MetNet Small Weather Satellite Network Mission Concept

Colorado State University
- Tempest-based CubeSat Microwave Sounder for Temperature and Moisture Profiling

GeoMetWatch
- Global HyperSpectral Atmospheric Sounding Capability Commercial Fee-for-Service Option

GeoOptics
- Cicero-X: An Alternative Mission Concept For Global Atmospheric Sounding

Laboratory for Atmospheric and Space Physics
- Space Weather Architecture Trade Studies

L3Harris Technologies
- Advancing Today's ABI Foundation into the Next-Gen GEO Imaging Solution
- Hyperspectral GEO Sounder Study
- Infrared LEO Sounder Instrument Study
- Joint LEO Sounding Mission Study

Leidos
- GEO Earth Multispectral Mapper (GEMM) for Terrestrial Weather Imaging

Lockheed Martin
- Flexible Hosted Imager (FHI): Advancing Today's ABI Foundation into the Next-Gen

NASA Jet Propulsion Laboratory
- GEO IR Sounder
- GeoSTAR: A Geostationary Microwave Sounder for NOAA
- Developing Microwave Sounders for NOAA Users in 2030

Northrop Grumman
- Geostationary Microwave Sounding Unit (GEMSU)
- Photonic Imaging Spectrometer Instrument Concept Exploration
- Alternative LEO Small Microwave Sounder (ASMiS)
- Microwave Reference Radiometer (MIRER) Constellation Architecture
- Next-Gen MW/IR/RO Sounder Sat Evaluation
- Small Satellite Constellation

Raytheon
- Real-Time Imager
- LEO Sounding Satellite (SounderSat) Concept Exploration (HIRIS)

SSL
- Commercial Hosting Service for Sustained GEO Weather Missions
- Common Bus for Sustained Hosting of LEO Weather Missions

Xplore
- Panorama – Commercial Earth-Sun L1, L4 and L5 Missions

York Space Systems
- Gaea – LEO SounderSat Mission Concept Study

Source: NOAA

L3HARRIS TECHNOLOGIES

to the constellation, launching about every five years in 2022-32. Ball Aerospace built JPSS-1 (renamed NOAA-20 upon reaching orbit) and Northrop Grumman is prime contractor for JPSS-2, -3 and -4.

Satellites in the JPSS constellation are designed to operate for at least seven years and host five primary instruments, including the Advanced Technology Microwave Sounder, Cross-Track Infrared Sounder, Visible Infrared Imaging Radiometer Suite, Ozone Mapping and Profiler Suite and an instrument to measure the Earth's energy budget.

Together, the instruments gather global measurements of atmospheric, terrestrial and oceanic conditions, including sea and land surface temperatures, vegetation, clouds, rainfall, snow and ice cover, fire locations and smoke plumes, atmospheric temperature, water vapor and ozone. The data is key for forecasting hurricanes, tornados, blizzards and other severe weather and for assessing droughts, forest fires, air pollution and other environmental hazards.

The data is used in a wide variety of industries and applications including: agriculture, aviation, maritime transportation, commercial fishing, shipping, recreational boating, land transportation, defense, coastal community preparedness, land and ocean tourism, energy, construction, insurance, emergency management and conservation.

The cost to develop, build, launch, operate, maintain and sustain the NASA/NOAA Suomi-National Polar-orbiting Partnership (NPP) spacecraft, four JPSS satellites and the JPSS ground system from 1995 to 2038 is estimated to be $18.8 billion.

NOAA also owns the Deep Space Climate Observatory, which is located at Lagrange point 1 (L1), a gravity-neutral orbit between Earth and the Sun approximately 1 million mi. from Earth. From L1, the satellite serves as an early-warning buoy for potentially hazardous space weather, providing about 1 hr. advance notice of geomagnetic storms.

The agency operates, but does not own, seven additional satellites including Suomi-NPP, France's Jason-3, the four-member U.S. Air Force Defense Meteorological Satellite Program (DMSP) constellation and the recommissioned GOES-13 satellite, now owned by the Space Force and renamed Electro Optical/Infrared Weather System-Geostationary 1 (EWS-G1).

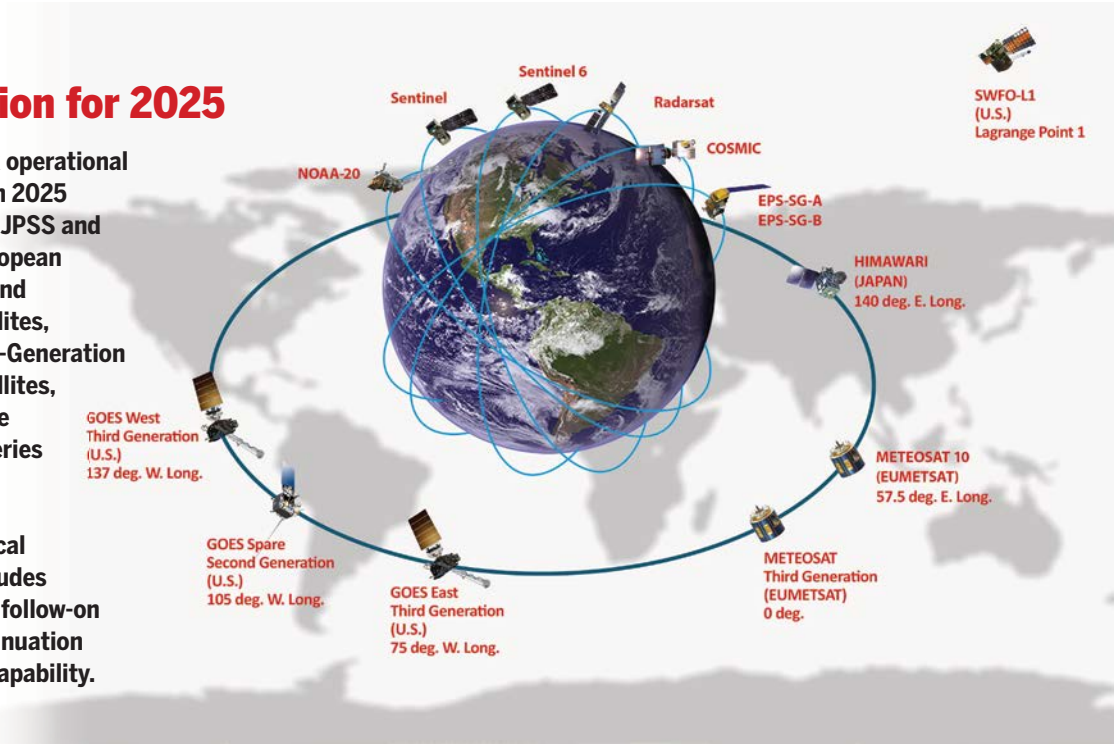
Positioned in GEO over the Indian Ocean, EWS-G1 is associated with a new U.S. Space Force program to replace the aging DMSP network. In June, the Space and Missile Systems Center announced Other Transaction Authority agreements, worth a combined $309 million, for EWS prototypes to Atmospheric and Space Technology Research Associates, General Atomics Electromagnetic Systems Group and Raytheon Technologies.

What the NOAA fleet will look like, including who owns and operates the satellites, will be far less important in the future. "We are placing equal importance on user engagement and understanding the use of the data as we have on developing the observation systems themselves," Volz says.

"We've already invested billions in GOES-R and JPSS, and those are essential to the models and the system that we have," he says. "But when it's time to refresh that system, what do we do next? Do I do a JPSS-Next and a GOES-Next and just replicate the path? Or do I take advantage of all the systems advances to produce a much richer spectrum of data to improve weather forecasting, environmental forecasting and ecosystem modeling?"

NOAA's Vision for 2025

NOAA's benchmark operational satellite program in 2025 includes the NOAA JPSS and GOES-R series, European Eumetsat METOP and EPS-SG polar satellites, the Meteosat Third-Generation geostationary satellites, the European Space Agency Sentinel Series and geostationary satellites from the Japan Meteorological Agency. It also includes two space weather follow-on satellites and continuation of Cosmic-2 level capability.



Source: NOAA

NOAA already taps data collected by the European Organization for the Exploitation of Meteorological Satellites, Indian Space Research Organization, Japan Meteorological Agency, Japan Aerospace Exploration Agency and NASA, among other partners.

"But what we didn't have 10 years ago, and which we do have now, is the ability to bring this data together," Volz says. "The best benefit for NOAA is to extract the maximum value from the global observation system through collaborations, partnerships, coordination with our interagency and international partners and developing the ground systems interfaces and the IT [information technology] systems, which allow for near-real-time integration of these data and does all the software and the algorithm to onboard all these different data together."

The availability of diversified data is coinciding with the miniaturization of satellite technology, easier and less expensive access to space and growing commercial interest and expertise.

"What's important is continual improvement," says Rob Mitrevski, L3Harris vice president and general manager of Spectral Solutions, Space and Airborne Systems. "The question is: Can you augment that capability with something affordable that might give you another advantage, like revisit time?"

L3Harris is among 17 companies and agencies awarded a total of 32 NOAA study contracts to develop mission concepts, spacecraft and instruments for future weather constellations. The projects address not just imagery and data traditionally collected from GEO and low Earth orbit (LEO) but also new orbits, which NOAA refers to as Extended Orbit.

The agency also is looking to take advantage of cloud-based services to integrate, process and distribute its massive datasets in near real time. "We're talking about petabytes of data a day. This is a processing beast for us, historically done with our on-premises hardware," Volz says.

"We're looking at how and where we migrate . . . to cloud providers so that we can have much more scalability—particularly as we're bringing on new hyperspectral and synthetic aperture radar imagery datasets that are much more data-intensive—to develop the products and services without having to buy whole rooms and buildings full of processors," he adds. "The cloud is the place to make this possible and to be scalable into the future."

NOAA's first next-generation satellite is expected to launch in 2025-26. It will be part of a still-to-be determined constellation of smallsats in LEO outfitted with microwave infrared radio occultation sounders to complement data collected by JPSS spacecraft.

A solicitation for LEO sounder satellites is expected in the summer or fall of 2021. "These are going to be 3-5 year [design life] satellites, not 10-year, which means more rapid replenishment—ideally with different technologies as they become available," Volz says.

NOAA also is making its first commercial weather data buy, following a pair of pilot programs. On Aug. 4, the agency released a request for proposals (RFP) for space-based commercial radio occultation (RO) data for use in NOAA's operational weather forecasts. RO provides atmospheric profiles by measuring distortions in GPS and other navigational satellite signals as they pass through the limb of Earth's atmosphere, relative to an observing satellite's point of view.

NOAA intends to award a two-year indefinite-delivery, indefinite-quantity contract to one or more vendors. "You have to give NOAA credit for the speed at which it is moving," says Peter Platzer, CEO of San Francisco-based Spire Global, which participated in both rounds of NOAA's commercial RO data pilot program. "This is a pretty rapid adoption timeline."

Later this year, NOAA plans to release a draft RFP for GEO imager study contracts, followed in 2021 by additional LEO satellites outfitted with microwave, infrared and RO instruments, depending on budget. The agency also is developing follow-on missions for space weather at L1.

NOAA, which currently receives about $5 billion a year, will need more money as it reinvests in new systems, but the amount will be nowhere near as much as what it would cost to build another JPSS and another GOES constellation.

"It is a cultural change," says Platzer. "But the benefits for the customer are substantial."

ASK THE EDITORS

Do hypersonics invalidate and effectively defeat the mutually assured destruction concept of the nuclear triad? It seems the capability of a hair-trigger response with a hypersonic weapon is an incredibly destabilizing situation.

U.S. ARMY

Defense Editor Steve Trimble posed that very question earlier this year to Mike White, the director for the hypersonics portfolio in the Pentagon's research and engineering branch. White's reponse: I think that it's more destabilizing if our adversaries have them and we don't. So, in order for us to be able to remove that, we have to be able to counter with similar capabilities when the time comes.

And then, there are a set of targets and missions that you really need these systems to be able to accomplish. And if you can't accomplish those missions, then you lose the deterrence of our broader forces. . . . I believe that's more destabilizing.

So, the first real objective is to make sure that we are holding adversary capabilities at risk while maintaining our military deterrence and our strategic deterrence with our warfighting capability.

AIRMAN 1ST CLASS BRYAN GUTHRIE/U.S. AIR FORCE. INSET: MASS COMMUNICATION SPC. 2ND CLASS DOUGLAS PARKER/U.S. AIR FORCE

Has radar stealth been fatally compromised? With "Future Shock" *(July 27-Aug. 13, p. 52)* you show an F-35A with six external pylons and two laser-guided bombs (above left); page 54 shows two F-35As each carrying an AIM-9 on the left wing (above right). We have been told that the next conflict could be with a "near-peer" nation with real air combat capability. So why then is the F-35 being flown as if its next opponent will have the air-to-air capabilities of the former Islamic State group?

Steve Trimble responds: When minimizing radar cross section (RCS) is not required for a mission, the F-35 can carry weapons externally. Not every mission requires minimizing the RCS profile. It is true that the F-35 would be unable to use AIM-9s in stealth mode, but it can carry four (and after 2023, six) Amraams internally on such missions.

Yes, AIM-120s are medium-range missiles. But, as the F/A-18E shoot-down of a Syrian Su-22 in 2018 showed, they are also capable of short-range intercepts—if necessary. The F-35 also has demonstrated the ability to employ laser-guided bombs from inside the weapons bay, so that is not an issue in stealth mode.

F-35 pilots have to train to be proficient in all potential air combat scenarios, which include operations against lightly defended or undefended targets.

The Aviation Week Network invites readers to submit questions to our editors. Answers are published online at AviationWeek.com. To access our answer archive or post a new question, go to: **AviationWeek.com/asktheeditors**

CABIN HYGIENE

Waypoint Interiors

UV Lighting Solutions, Germ-Free Airline Travel

- Long-term solution for COVID-19 and future viral threats!
- 99%+ effective
- Disables virus or bacteria
- Disinfects surfaces and airborne germs
- No harsh chemicals
- Latest LED UV light technology
- Permanently installed

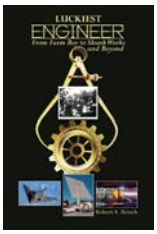
www.waypointinteriors.com

https://marketplace.aviationweek.com/product/uv-lighting-solutions-germ-free-airline-travel

MEDIA

Luckiest Engineer

An Aerospace Engineer's Memoir



Available in print and as an ebook, *Luckiest Engineer* is a memoir about the work of a farm boy turned engineer whose involvement working on unparalleled aerospace vehicles and systems of the last 50 years makes for some great stories. *Luckiest Engineer* also shows the humorous side of aerospace engineering, highlighting many hilarious personal anecdotes.

luckiestengineerbook.com

https://marketplace.aviationweek.com/product/luckiest-engineer

ORIGINAL EQUIPMENT

Greene Tweed

EPM 953--The Ultra-Low Temperature Hydraulic System Seal

Greene Tweed has created the new EPM 953 elastomer for phosphate ester hydraulic systems in aerospace applications. EPM 953 was developed to perform at ultra-low temperatures; it will maintain an excellent seal at temperatures as low as -85°F (-65°C) or below. It is also compatible with phosphate ester hydraulic fluids and outperforms existing EP elastomers with improved elasticity in static and dynamic seals in hydraulic actuation systems.

www.gtweed.com

https://marketplace.aviationweek.com/product/epm-953-ultra-low-temperature-hydraulic-system-seal

TRAINING

Abaris Training

Advanced Composites Training and Services

Abaris Training offers over 23 different intensive courses in engineering, manufacturing, and repair of advanced composite structures. All courses are a mix of classroom and hands-on lab exercises designed to provide students a thorough learning experience.

abaris.com

https://marketplace.aviationweek.com/product/advanced-composites-training-and-services

TEST EQUIPMENT

Matec Instrument Companies, Inc.

Ultrasonic Testing Systems

Matec Instrument Companies is an industry leader in providing superior nondestructive conventional and phased-array ultrasonic testing solutions. Our systems range from small laboratory tanks to complex, multi-axis, immersion and gantry systems capable of scanning large parts and complex contour geometries.

Matec provides a full range of in-house services including mechanical and electronic design, machining and fabrication, instrumentation and control, applications testing, and data acquisition and analysis software.

Matec's support services include installation and start-up, commissioning, training, instrument calibration, and repairs to ensure proper system alignment and calibration, and to deliver optimum performance and value.

Matec Instrument Companies

Northborough, MA - Banning, CA | 508-393-0155 | sales@matec.com

www.matec.com

https://marketplace.aviationweek.com/product/ultrasonic-testing-systems

Contact Us

President/Publisher: Gregory D. Hamilton;
+1 (212) 204-4368; hamilton@aviationweek.com

Managing Director, Global Media: Iain Blackhall (UK);
+44 (0)20 7975 1670; iain.blackhall@aviationweek.co.uk

U.S. Sales Offices

Managing Director, Americas: Beth Wagner;
(202) 517-1061; beth.wagner@aviationweek.com

Director, Commercial Sales: Tom Davis;
(469) 854-6717; tom.davis@aviationweek.com

International Regional Sales Offices

Publisher, Defense, Space & Security:
Andrea Rossi Prudente (UK); +44 (207) 182 4524;
andrea.rossiprudente@aviationweek.co.uk

Marketing Services

Director, Digital Customer Solutions: Jason Washburn;
(216) 931-9161; jason.washburn@informa.com

Sales Team Listings: @AviationWeek.com/sales-contacts

Business/Production

Senior Manager, Ad Production: Jim Heffron;
(630) 524-4552; jim.heffron@informa.com

Ad Operations Specialist: Kara Walby;
(913) 967-7476; kara.walby@informa.com

Advertising/Marketing Services

Media Kits, Promotions or Custom Media:
www.aviationweek.com/mediakits or Elizabeth Sisk;
(860) 245-5632; elizabeth.sisk@aviationweek.com

Business and Finance Manager: Gabriel Balmes;
+44 (0) 7881-010660; gabriel.balmes@informa.com

Subscriber Service

U.S.: (877) 369-3767

Outside the U.S.: +1 (913) 850-6931

Manage Your Subscription (and Claim Digital Edition) at:
aviationweek.com/awstcustomers

Conferences/Exhibitions

www.aviationweek.com/events:

To Sponsor/Exhibit: Beth Eddy;
(561) 279-4646; betheddy@aviationexhibits.com

To Register: Virginia Gongora;
(212) 204-4202; virginia.gongora@aviationweek.com

AW&ST Mailing List Rental and Sales

Mary Ralicki: (212) 204-4284; mary.ralicki@informa.com

Reprints, Photocopies and Permissions

Custom Reprints: informa@wrightsmedia.com

Wright's Media, 2407 Timberloch Place, Suite B
The Woodlands, Texas 77380
Office: (281) 419-5725
Toll Free: (877) 652-5295
Cell: (713) 724-6987
Fax: (281) 419-5712
wrightsmedia.com/sites/aviation-week/contact.cfm

Social Media

Join the conversation. Follow us at:

linkedin.com/company/aviation-week
Twitter.com/AviationWeek
Facebook.com/AvWeek
YouTube.com/AviationWeek

Aviation Week & Space Technology is published biweekly, with one issue in August by Informa Markets, a trading division of Informa PLC, 22701 W. 68th Terrace, Ste. 100, Shawnee, KS 66226-3583. Member of Audit Bureau of Circulations and Magazine Publishers of America. Periodicals postage paid at Kansas City, MO and additional mailing offices. Canadian GST #R126431964. Title reg.® in U.S. Patent Office.

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
SEPTEMBER 14-27 2020 VOL. 182, NO. 18
(ISSN 0005-2175)

Aerospace Calendar

To submit Aerospace Calendar Listings
email: aero.calendar@aviationweek.com

Sept. 14-Oct. 30—RTCA Plenary Sessions/Committee Meetings. Virtual or various locations. See rtca.org/content/upcoming-committee-meetings

Sept. 14-16—CareFlite Emergency Care Update Conference. Virtual event. See careflite.org

Sept. 14-16—Air Force Association Air, Space & Cyber Conference. Virtual event. See afa.org/events/calendar/2020-09-14/air-space-cyber-conference

Sept. 15-17—Commercial UAV Expo Americas. Virtual event. See expouav.com

Sept. 22-24—Full Spectrum Air Defence Digital Conference. Virtual event. See asdevents.com/event.asp?id=22269

Sept. 28-29—Global Aerospace Summit. St. Regis Saadiyat Island Resort. Abu Dhabi. See aerospacesummit.com

Sept. 28-29—UAV Technology 2020 Conference. Virtual event. See asdevents.com/event.asp?id=22251

Sept. 28-30—European Space Agency EO (electro-optical) Phi Week 2020. Virtual event. See phiweek.esa.int

Aviation Week Network Events

+1 (800) 722-6344 or Events.AviationWeek.com

Sept. 14-16—Commercial Aviation Industry Suppliers Conference-Europe. Virtual event.

Sept. 16-17—Aero-Engines Europe. Virtual event.

Sept. 22-24—Aero-Engines Asia-Pacific. Virtual event.

Sept. 23-24—MRO Asia-Pacific. Virtual event.

Oct. 14-Jan. 13—CAPA Live. Virtual event, every second Wednesday of the month.

Oct. 19—Aviation Week Laureates Awards. McLean, Virginia.

Oct. 20-21—Aviation Week DefenseChain Conference. McLean, Virginia.

Oct. 21—Aviation Week Program Excellence Awards and Banquet. McLean, Virginia.

Oct. 26-27—Routes TakeOff North America 2020. Denver.

Oct. 27-29—MRO TransAtlantic. Virtual event.

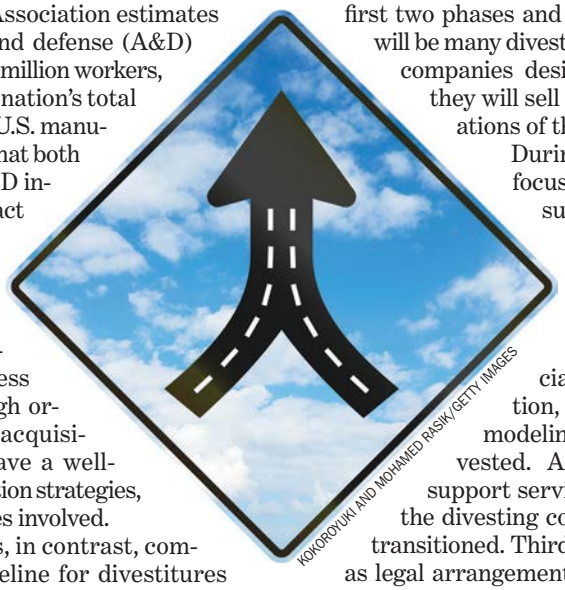
Nov. 10-11—Engine Leasing, Trading and Finance. London.

ADVERTISERS IN THIS ISSUE

A Primer for Acquisitions and Divestitures

By **Alex Krutz**

The Aerospace Industries Association estimates that the U.S. aerospace and defense (A&D) industry employs about 2.5 million workers, which is approximately 2% of the nation's total employment base and 20% of the U.S. manufacturing workforce. This means that both growth and contraction in the A&D industry can have a significant impact on the U.S. economy.



KOKOROYUKI AND MOHAMED RASIK/GETTY IMAGES

In previous decades, times of growth in the A&D industry were steady and extended over many years. During growth periods, A&D manufacturers' business transformation happened through organic growth and mergers and acquisitions. These events typically have a well-planned timeline and strong execution strategies, and they create value for all parties involved.

During economic contractions, in contrast, companies usually have a short timeline for divestitures because they must take quick and decisive action due to cash shortfalls and the need to finance ongoing operations. Since 2000, there have been three contractions due to exogenous events: Sept. 11, 2001; the financial crisis of 2008; and the novel coronavirus in 2020. These shocks have significantly affected the A&D industry.

In response to these events and after economic downturns start, there are multiple paths companies can take to improve financial conditions. The commercial airlines and auto industry during contractions generally take the path of restructuring through Chapter 11 reorganizations. A&D companies usually take a more complex transformation path of downsizing through divestitures to generate cash to survive until the next growth cycle begins.

The impact of the 2001 and 2008 events forced many A&D manufacturers to transform their businesses through divestitures. Those companies had to choose this path because of poor planning, ineffective execution or cash disbursements to shareholders during years of growth, which led to the need for cash infusion and financial restructuring during the contractions after the economic downturns.

Once a contraction starts in the A&D industry, three phases ensue. First come significant expense reductions such as cuts in discretionary spending, business travel and research and development programs. Second, workforce reductions such as furloughs and layoffs are made. Third, financial restructuring such as plant rationalization, consolidations and business unit divestiture is undertaken. Due to the sudden contraction caused by the COVID-19 crisis, the A&D industry has moved swiftly through the first two phases and is now entering the third. There will be many divestitures of business units that larger companies designate as noncore assets, which they will sell to generate cash to support operations of their core assets.

During all divestitures, three areas of focus should be addressed to ensure successful execution. First are operational considerations such as culture and employees, environment, physical asset reviews and product delivery commitments. Second are financial considerations of the transaction, including appropriate financial modeling for the business units being divested. Also, cost allocations, transition support services and creditor relationships of the divesting company need to be identified and transitioned. Third are commercial obligations such as legal arrangements with customers and suppliers. These contracts should be reviewed to ensure they are appropriately novated and transferred.

These three areas of focus often are not diligently followed in challenging times of contraction, and there is usually a rush through this third phase of divestiture. This can be damaging to both companies involved.

MANY COMPANIES MISS THE CHANCE TO REINVENT FOR THE FUTURE AND LEAPFROG THE STATUS QUO.

Philip Vaillancourt from Accenture's A&D practice points out that many companies fold an acquired company into their existing inefficient processes, systems and operating model—missing the chance to reinvent for the future and leapfrog the status quo. The result is usually weak bottom-line synergies and anemic topline growth.

Accenture Strategy analyzed 800 global merger and acquisition transactions, and just 27% resulted in both operating-margin improvement and revenue growth. Accenture noted two main factors in long-term success stories for deals. First, prior to the close of the deal, leaders created a long-term blueprint for the intended synergies and the operating model. They seized the opportunity to create an intelligent enterprise, reimagining the way work is done, and they transformed their workforce. Second, they ensured that an executive with financial expertise remained involved after the deal closed to see that the company achieved the expected financial value from that blueprint.

These steps are especially critical during these challenging times so that the divesting company is ready to grow again and the acquiring company is well-positioned and organized with its newly added business unit.

Alex Krutz is managing director at Patriot Industrial Partners.

AVIATION WEEK
Intelligence
NETWORK

Stay **Informed.** Stay **Connected.** Stay **Engaged.**

Access authoritative market insights and analysis along with company, program, fleet and contact databases covering the global aviation, aerospace and defense communities with an **Aviation Week Intelligence Network (AWIN) Membership**.

120,000 industry personnel

26,000+ global organizations

Details on 150,000+ commercial, business and military aircraft

16,000 suppliers of more than 175,000 products and services

Become a member today.

Visit **aviationweek.com/AWINinfo** to schedule your demo.

Or call **Anne McMahon at +1 646 291 6353** or
Thom Clayton +44 (0) 20 7017 6106

AVIATION
WEEK
NETWORK

Constantly evolving technology, for a constantly evolving world.

The U.S. Air Force's F-35A was designed to integrate and command a complex, multi-domain battlefield against highly capable adversaries – and win. It was designed with the understanding that every single sortie is an expedition of the greatest importance. With stealth, advanced sensors, networked data links, supersonic speed, fighter agility and flexible weapons capacity, the 5th Gen F-35 delivers on that vision. The F-35 redefines multi-role airpower and everything that comes with it. It gives the men and women of the U.S. Air Force a decisive advantage today, and for decades to come.

Learn more at lockheedmartin.com/f35

Lockheed Martin. Your Mission is Ours.®

LOCKHEED MARTIN