STARTS AFTER **PAGE 34**

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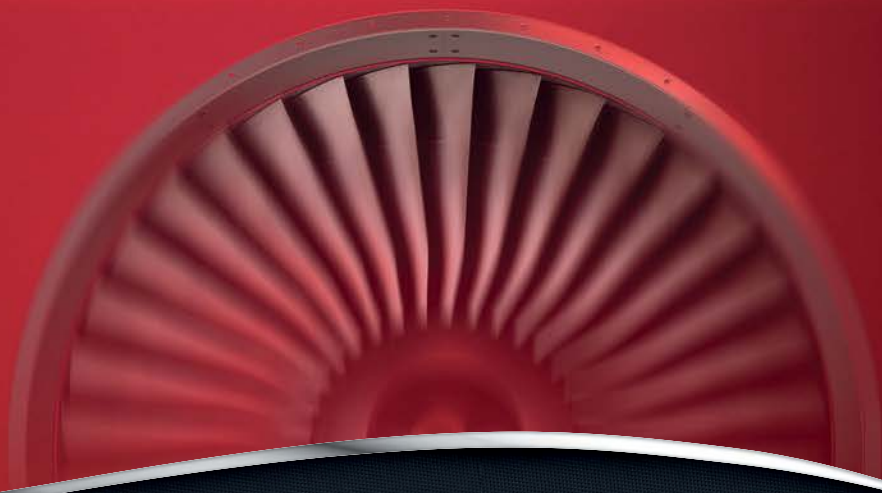

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AVIATIONWEEK & SPACE TECHNOLOGY

April 20-May 3, 2020 · Volume 182 · Number 8

JESSE H. NEAL AWARDS Est. 1955 2019 Winner

60 | *Testers with the Virginia Tech Mid-Atlantic Aviation Partnership carried a Titan X8 multirotor drone equipped with the Echodyne EchoFlight metamaterial electronically scanning array radar, the small white panel fitted below its front, during NASA's Raavin project.*

DEPARTMENTS

FEATURES

DEFENSE

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AIR TRAFFIC MANAGEMENT

ROTORCRAFT

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SPACE

FAST FIVE

AUTONOMY

HYPERSONICS

AVIONICS

VIEWPOINT

ON THE COVER

A new delta wing, revised engines and an improved empennage are hallmarks of a finalized AS2 supersonic business jet design that Aerion believes is not only sustainable but also lays a solid foundation for a follow-on family of high-speed commercial and military derivatives. Senior Editor Guy Norris' report begins on page 50. Aerion concept.

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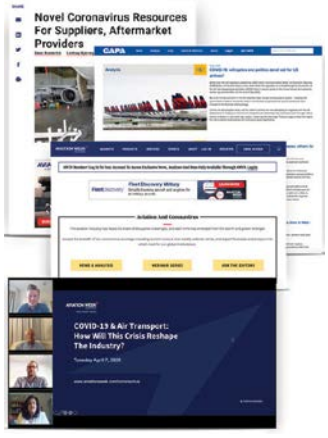
AVIATION WEEK NETWORK
By Informa Markets

Doing Our Part With Crisis-Focused Content

Now that we are all engaged in unprecedented efforts to contain the spread of COVID-19, I'd like to update you on actions that the Aviation Week Network has taken since my last letter a few weeks ago.



Our goal from the beginning of this crisis has been to deliver high-quality, reliable and actionable information. We want to help you maintain situational awareness, see forward and connect with experts and each other to navigate the risks, plan for the recovery and return to growth.

Here are initiatives we have already launched to make "know-predict-connect" a reality for you:

- **Some 8,000 COVID-19-related articles,** more than 1,000 of them analytical, opinion or feature pieces aimed at sharing best practices, solutions and forecasts.
- **A coronavirus portal,** curated daily and free to all, that provides convenient access to the above content.
- **Three webinars and two podcasts per week** that address the challenges across aviation and aerospace and especially in our niche communities of Air Transport, MRO, Defense, Space, Business Aviation and Aerospace, featuring our leading editors, analysts and guest experts.
- **Expansion of Route Exchange,** which connects airline network planners and airports in the absence of live Routes events.
- **Ask the Editors,** another free service offering that provides an opportunity to reach out to our editors and the experts with whom they consult for answers to your questions.
- ***SpeedNews* COVID-19 Manufacturer and Supplier Services** connecting industry players who are stepping in to play a role in addressing medical shortages.
- **New features for our premium subscribers,** such as an AWIN coronavirus portal, The Daily Memo and a new monthly COVID-19 key indicator report.
- **CAPA** country-by-country Air Transport COVID-19 analyses.
- **A new Air Transport group on WeChat** to help members make new connections and share best practices with their Chinese counterparts. Visit **https://youtu.be/ZJBXXnCWqnQ** for a video on how to join the group.

Visit the landing page: **AviationWeek.com/COVID19**

Register for our webinar series: **AviationWeek.com/COVID19/webinar**

Ask the Editors: **AviationWeek.com/ask-the-editors**

From the engagement we are seeing on our websites (22% traffic growth since January) and webinars (over 10,000 have registered so far), it is clear that our information is being consumed and used all over the world.

We will continue to do our part to help the industry move to the other side of the pandemic and begin growing again. Until then, if there is anything you think we could do better and to be more useful, please contact me or anyone on our global team.

Greg Hamilton,
President, Aviation Week Network

hamilton@aviationweek.com

FEEDBACK

'BALANCED CAPITALISM'

Kevin Michaels' recent Up Front, "Rethinking 'Shareholders First'" *(March 23-April 5, p. 10)*, is the most important thing you have published in years.

In law school, in our first course of business law, the professor asked: "By what principle does a Corporation have the rights and protections under law of a natural individual? How is it that owners (shareholders) are granted no liability and limited risk (they can only lose their investment, not be further held responsible for actions of the corporation)? What does the corporation owe in return?"

It owes service to customers, the community, employees, suppliers and shareholders. Since these constituencies are all essential to the economic success of the enterprise, this is a practical as well as moral imperative. There is a mutual benefit, a mutual interest and a mutual responsibility.

Later, in study of organizational behavior, we were asked how we expect managers to behave if they are compensated with shares or options of ownership? They will behave in their own interests as stockholders, not as professional managers responsible to their ethical and legal calling to serve customers, the community, employees, suppliers and shareholders.

In so doing, they are no longer loyal employees serving the best interest of the corporation in the largest sense. As ably discussed by Michaels, shareholders, boards and managers have stolen "the corporation" from the customers, community, employees and suppliers.

Even disregarding ethics and honorable participation in the national commonwealth, it is fundamental good sense that a return to a balanced capitalism is essential to long-term prosperity of all the industry

Eric E. Dirats, Westfield, Massachusetts

ADRIAN825/ISTOCK

'THIS TOO SHALL PASS'

The advice offered by the editorial in the March 23-April 5 issue *(p. 66)* should not only resonate among the airlines or even just within the aerospace industry but among every publicly traded company. Our once-precious "free enterprise" system has seen too many corporations morph into ones driven strictly by shareholder value as the most acceptable business model. But they've also been encouraged by added incentives and safety nets, because Washington thinks they are "too big or critical to fail." Taxpayers are fed up.

Your editorial has prioritized what needs to be done and is actually what Capt. Crozier of the USS Roosevelt's actions were all about: The mission and the crew always come before any personal consideration.

Angus Macaulay, Kennebunk, Maine

The financial and viral malady facing the commercial aviation industry should be renamed "MAXCorona," a systemic illness that should cause the death of the weaker carriers and bring financial responsibility to the major U.S. carriers.

The U.S. taxpayers do not want another high-billion-dollar bailout giveaway to the domestic airline industry when the taxpayers are getting only $1,200 each at best and may shortly be unemployed.

The day of reckoning has arrived for this industry, and the cure will be painful. Sweep the airline CEOs and chief financial officers from their lofty offices and cease building those new corporate headquarters that are glass castles in the sky. The future is about prudence with your operations and balance sheets, saving for the hard times and making customer service your mantra.

James H. Sherrard, Plano, Texas

MISSIONS OF MERCY

In response to Aviation Week Network President Greg Hamilton's letter in the April 6-19 issue *(p. 5)*, as a professional UAV operator in South Africa, I believe it is time for all UAV pilots to step up and help the world and the aviation industry by delivering goods and supplies to otherwise inaccessible regions in order to help those struggling to get them. Long-range UAV technology has come a long long way, and there is no better time to implement it than now to safely complete missions of mercy.

Janus van Zyl, Springs, South Africa

CLEANING THE AIR

Your fine article "COVID-19 Outbreak Ushers in New Cabin Cleaning Techniques" *(March 23-April 5, p. 24)* on the improved procedures and expected new requirements for aircraft cabin cleaning will, no doubt, improve hygiene on aircraft. But it might have included one more area requiring urgent attention, especially in today's climate: the proportion of stale, possibly bacteria-/virus-laden recirculated air on commercial aircraft.

Several hours of inhaling other passengers' exhaled air is unquestionably a bigger threat to health than simply cleaning surfaces. Surely it is time for a substantial increase in the percentage of fresh air being circulated during any flight. A focus on this might achieve even better results.

Kenneth O.J. Harmon, Ancaster, Ontario

ONLINE, in response to "Possible New 'Engine War' Recasts Pratt As Champion Of Competition" *(March 23-April 5, p. 41)* GERARDFK writes:

One point is forgotten here. The USA needs two viable military engine manufacturers and giving this engine buy to Pratt & Whitney could have a detrimental effect. Losing a capable engine manufacturer, the cost of this will be immense.

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

Vytis Zalimas has been hired as CEO of *Jet Maintenance Solutions*, a provider of aircraft maintenance, repair and overhaul. Zalimas was head of corporate customers at Telia Co.

Raines International has hired **Patrick Gray** as managing director of its aerospace and defense industrials sector. Gray was Heidrick & Struggles' Americas practice leader for aviation, aerospace, defense and government services and is a former U.S. Army intelligence officer.

SES has hired **Sandeep Jalan** as chief financial officer. Jalan was chief financial officer of Aperam. He succeeds Andrew Browne.

Bye Aerospace has named U.S. Air Force Col. (ret.) **Rod Zastrow** to its board as a strategic advisor for its electric aircraft program. Zastrow is chief operations officer and president of Spartan Air Academy Iraq.

AsBAA, Asia's aviation industry organization, has hired **Jeff Chiang** as chief operating officer, a new position.

Grove Resource Solutions (GRSi) has promoted **Billy Burnett** to vice president of defense programs in addition to his role as general manager of Naval Information Warfare Systems Command operations. The new appointment expands Burnett's NIWC responsibilities across the entire GRSi defense business.

Woolpert, an architecture, engineering and geospatial consultancy, has promoted **Chris Snyder** from aviation design practice leader to aviation market director. He will focus on unmanned aircraft systems infrastructure in his new role. It also has hired **Jeff Mulder**—former director of airports in Florida, Oklahoma and Wisconsin—as a senior infrastructure consultant.

Professional Aircraft Accessories has hired **Keith Johnson** as director of materials and production control. He was Citadel Completions senior director of operations and held leadership roles at Delta Air Lines, Commercial Jet Services and AAR Corp., among others.

FLIR Systems has hired **Paula M. Cooney** as senior vice president and chief human resources officer. Cooney was vice president of human resources and communications at H.B. Fuller specialty chemicals.

Duncan Aviation has promoted **Tyler Spurling** to assistant manager of its maintenance, repair and overhaul rapid response teams for facilities in Lincoln, Nebraska; Battle Creek, Michigan; and Provo, Utah. It also added a new position at its Lincoln headquarters, naming **Robert Montano** as engine tech representative for Rolls-Royce support.

Par Avion Ltd. has hired **David Wyndham** as executive sales director and acquisition specialist. Wyndham, an industry veteran with more than 36 years in aviation, is a former U.S. Air Force C-130 instructor pilot.

Controp Precision Technologies has promoted **Guy Oren** to vice president for international marketing and sales from vice president of business operations, North America.

HONORS AND ELECTIONS

U.S. Rep. **Brenda Lawrence** (D-Mich.) has received the *Aeronautical Repair Station Association's 2020 Legislative Leadership Award*. Lawrence cosponsored a bipartisan bill establishing a collaborative grant program to address the aviation workforce skills gap and helped ensure the program's funding for fiscal 2020. Michigan's aviation maintenance industry supports more than 7,700 jobs and contributes $1.6 billion a year to its economy.

Adam Pilarski of Avitas has received the *ISTAT Award for 2020*. The award recognizes individuals who have made lasting contributions to the aviation industry over a significant period of time and is bestowed at The International Society of Transport Aircraft Trading yearly conference.

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
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DEFENSE

Boeing on April 13 conducted the first flight of the F-15QA ordered by the Qatar Emiri Air Force, scheduled for first delivery next year.

The Russian Navy should deploy the Zircon hypersonic missile in 2022 on the frigate Admiral Gorshkov, reports the state-owned TASS news agency.

The head of U.S. Air Force Global Strike Command has outlined a new concept for the Arsenal Plane as a clean-sheet aircraft to fill a gap in long-range strike capability even after the Northrop Grumman B-21 enters service.

A once-crippled B-1B bomber force has recovered significantly since structural and egress system problems grounded all but a handful for nearly a year, the U.S. Air Force says.

Boeing's Airpower Teaming System unmanned aircraft is on its landing gear and powered up as the loyal wingman demonstrator progresses toward a first flight planned in Australia this year.

BOEING PHOTOS

COMMERCIAL AVIATION

Ten U.S. airlines have agreed in principle to participate in a $25 billion payroll support program under the government's CARES stimulus package, despite the surprise disclosure that 30% will have to be repaid (page 21).

Boeing delivered only 50 commercial aircraft in the first quarter, down from 149 a year earlier, and saw 333 cancellations, but only 26 new orders, for a net orderbook reduction of 307 (page 21).

Airbus has decided to cut commercial aircraft production by roughly a third, including reducing the A320neo family output to 40 per month on average from a previous near-term target of 63.

The International Air Transport Association has further downgraded its 2020 forecast for the global airline industry and now believes revenue passenger kilometers will be down 48%, for a $314 billion revenue shortfall.

Business jet deliveries in 2020 could drop by between 12.5% and 40-50%, with recovery unlikely before 2023, forecasts JetNet IQ. Jefferies analysts expect a decline of 20%, while JP Morgan forecasts a 37% drop.

Eurocontrol's member states have agreed to let airlines and private jet operators defer payment of up to €1.1 billion ($1.2 billion) in air traffic control fees.

The International Civil Aviation Organization is consulting with global public health authorities on a "prototype" process that would validate flight crews—and, potentially, passengers—have been screened for COVID-19.

Space-based surveillance provider Aireon and the Civil Air Navigation Services Organization are to analyze the impact of the COVID-19 pandemic on air traffic flows of essential goods and services.

Aerospace and defense suppliers Woodward and Hexcel called off their planned merger due to the COVID-19 pandemic.

Airbus will continue investing in urban air mobility despite shutting down Voom, its on-demand helicopter booking service, citing the pandemic's impact.

Unmanned aircraft system test sites in New York and Virginia have been chosen to participate in the second phase of the FAA's unmanned traffic management pilot program.

Leonardo has completed its $185 million takeover of Switzerland's Kopter Group and its SH09 light single-turbine helicopter from private equity firm Lynwood.

VIEW FROM WASHINGTON

COVID-19 Concerns Reach Orbit

Space may seem well-removed from the pandemic gripping the world, but, citing the bankruptcy of satellite operator OneWeb, an industry trade group is asking the U.S. government to add $2.5 billion in funding for space programs

OneWeb declared bankruptcy on March 27, after the assets of primary shareholder SoftBank collapsed amid the novel coronavirus pandemic. The U.S. military draws heavily on commercial satellite communication and Earth-observation services. Given that dependence, the National Security Space Association (NSSA) is asking the government to help companies survive this downturn.

"From dramatic disruptions to existing contracts and critical production lines, to the shrinking of capital markets that fuel the new space economy, the economic and national security threats to the space industrial base from the pandemic are clear and present," says the NSSA.

The group is seeking $1 billion for unfunded U.S. Space Force requirements in fiscal 2021, $500 million to accelerate existing programs and $500 million to protect commercial communication and remote-sensing capabilities. It is also seeking $500 million for launch service providers.

SPACE

Nonignition of a third-stage engine caused the failure of a Chinese Long March 3B rocket on March 9, according to a part-owner of the Indonesian customer that lost its satellite.

VIRGIN ORBIT

Virgin Orbit completed a major dress rehearsal for its LauncherOne air-launch system on April 12, clearing the way for the first demonstration launch.

The Ozone Monitoring Instrument on NASA's Aura satellite has shown a 30% drop in air pollution over the Northeast U.S as a result of lockdowns to contain the COVID-19 pandemic.

A small autonomous helicopter flying as a technology demonstration on NASA's Mars 2020 mission has been attached to the Perseverance rover in preparation for launch this summer.

The European Space Agency's BepiColombo probe, launched in 2018 to study Mercury, completed a flyby of Earth on April 10 as a gravity-assist maneuver on its seven-year journey.

A NASA astronaut and two cosmonauts docked to the International Space Station April 9, prepared, if necessary, to continue minimal staffing through October.

Boeing is to conduct a second uncrewed flight test of its CST100 Starliner crew capsule, expected in October, following a flawed orbital debut in December.

60 YEARS AGO IN AVIATION WEEK

Our cover of April 25, 1960, showed early astronaut and U.S. Air Force Capt. Donald K. "Deke" Slayton sliding into the side hatch of a boilerplate Project Mercury capsule to begin training for maritime escape techniques. Slayton, a World War II fighter pilot and Air Force test pilot, was chosen by NASA as one of the original Mercury 7 astronauts. Scheduled to fly on the second orbital Mercury mission in 1962, following John Glenn, he was grounded after doctors detected a slight irregular heartbeat. Determined to be restored to flight status, Slayton undertook a rigorous health routine that eliminated the fibrillation.

He finally made it to space at the age of 51 in 1975, flying on the U.S.-Soviet Apollo-Soyuz docking mission and logging 217 hr. 28 min. 24 sec. on his only spaceflight. Slayton retired from NASA in 1982 and became president of Houston-based Space Services Inc., which successfully launched a Conestoga rocket in September 1982, becoming the world's first privately funded rocket to reach space. Slayton died of brain cancer in 1993 at the age of 69.

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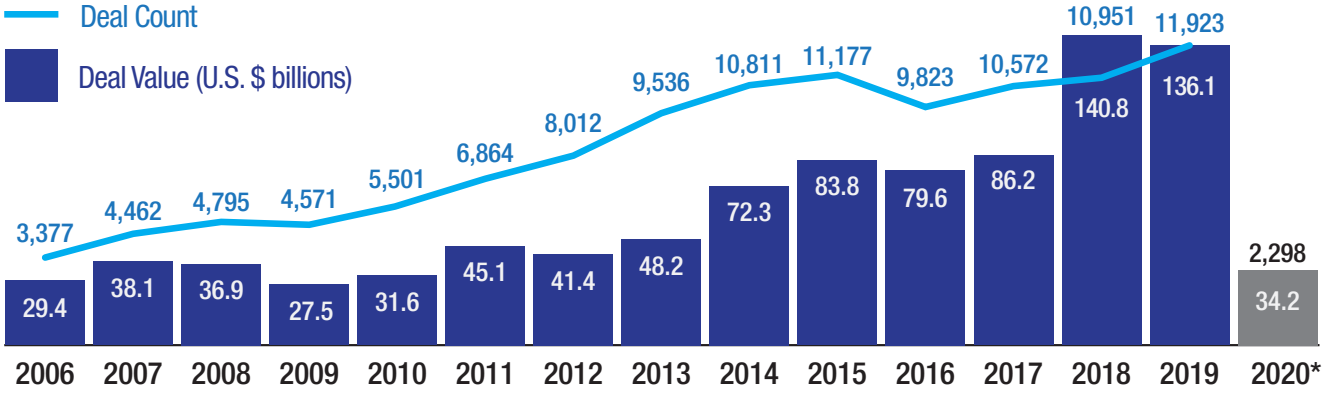
VENTURE CAPITAL Lessons From the Last Recession

U.S. venture-capital funding declined 28% during the 2007-09 recession. A similar decline from 2019 funding levels of $136 billion implies the industry could shrink by about $39 billion in 2020—more than the size of the entire market in 2007—forecasts capital markets research company PitchBook.



Source: PitchBook

*as of March 31, 2020

GOING CONCERNS

MICHAEL BRUNO

High Stakes, Deep Cuts

Giving equity to Uncle Sam **may be the least of Boeing's worries**

APRIL IS THE CRUELEST MONTH for Boeing. As of April 6, the aerospace and defense giant's Puget Sound, Washington, sites were closed indefinitely for deep cleaning, and Boeing is trying to convince workers to come back after at least one local death from the COVID-19 pandemic was reported in late March. That same day, the company announced that work at its factory in Charleston, South Carolina, was suspended, too.

Meanwhile, Boeing is asking if there are some workers who do not want to come back at all.

On April 2, Boeing announced voluntary layoffs, and CEO and President David Calhoun acknowledged there likely will be changes coming to its product lines. But as monumental as those changes might be, they are not the biggest concern. Instead, the OEM first must figure out how to finance itself through the rest of the year.

The numbers were well-publicized in March as the U.S. Congress raced to pass its multitrillion-dollar stimulus and relief bill in response to the coronavirus pandemic, the CARES Act. Jaws dropped when Boeing sought a $60 billion aid package for itself and its suppliers as part of the legislative sausage-making.

But it is easy to see why it did so: Short-term commercial paper financing is frozen as a recession suddenly grips the U.S. and likely the world. Boeing Chief Financial Officer Greg Smith said access had dried up, at least temporarily. Calhoun tried to offer a brave face and said Boeing has access to $15 billion in cash and another $9.6 billion revolving credit line.

So why would Boeing seek government aid? The company ended 2019 with more than $27 billion in debt, doubling the red ink from the year before. By mid-March, before credit markets froze, it had newly opened and then fully drawn down a credit line totaling nearly $14 billion. Boeing Commercial Airplanes alone is burning through more than $4 billion a month to bankroll itself and some suppliers, starting with Spirit AeroSystems and General Electric Aviation, and it faces other big bills such as the $4.2 billion acquisition of most of Embraer's commercial division and $4 billion in debt repayments. Analysts say Boeing could have to nearly double its debt again this year, especially if the grounded and halted 737 MAX is not recertified until late this year due to further delays caused by the COVID-19 pandemic.

Boeing wants either no strings attached on direct U.S. aid or government guarantees that back its loans from other financiers. Calhoun tried swatting down the idea of giving Washington outright equity in what is the country's biggest exporter and second-biggest defense prime.

But that is likely easier said than done. "There aren't many options to explore for Boeing without a guarantee from the government," says Dhierin Bechai, an investment advisor with the Aerospace Forum whose Boeing analyses are widely followed on Seeking Alpha. The commercial aviation outlook has turned so bad so rapidly that newly minted airliners are being flown to storage. Even if commercial credit markets thaw enough for new debt to be taken on, Boeing could get hammered on the terms of that debt. "Doing the math, you can conclude rather quickly that Boeing can sustain a couple of months, but if this is going to last well into late 2020, then this is not sustainable," Bechai said March 31.

But there probably will be less work in which to be involved. Any day now, Boeing is expected to announce new, lower production rates for 2020 and perhaps for the longer term.

Analysts are lowering their expectations for future production. Rob Stallard and Karl Oehlschlaeger of Vertical Research Partners on March 30 said they envision a revised requirement for 6,300 new airliners over the next five years, compared with their previous forecast of 8,300. By type, they foresee 1,540 fewer narrowbodies and 380 fewer widebodies, both roughly 25% cuts versus their prior demand model.

AIRCRAFT DELIVERIES ARE FORECAST TO FALL ABOUT 70% YEAR-OVER-YEAR IN 2020.

Analysts Sheila Kahyaoglu and Greg Konrad of Jefferies on March 31 forecast that aircraft deliveries will fall about 70% year-over-year in 2020, and they reduced their 2020-23 cumulative delivery estimate by around 60%, as airlines continue to defer deliveries with a significant portion of the widebody fleet parked.

The Jefferies duo assume Boeing will produce its 787 widebody at an average rate of four a month this year, stepping up to six in 2021 and 2022. They also forecast 777X deliveries at a rate of one per month, "which is quite pessimistic relative to [an] assumption of three a month."

Similarly, Manfred Hader and Robert Thomson of Roland Berger say a recovery to overall 2019 production rates will take two years, albeit faster for Airbus and longer for Boeing, given the MAX situation.

The new normal for Boeing (and Airbus) is lower for longer when it comes to large commercial aircraft demand. With the MAX already putting it behind, Boeing may become eager for any American to boost his or her stake in the company, even Uncle Sam.

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GRAHAM WARWICK

THERE ARE SOME WHO BELIEVE advanced air mobility is about more than urban air taxis and vertical takeoff and landing. John Langford, founder and former CEO of Aurora Flight Sciences, is one.

Langford, who finally left Aurora in January after selling the company to Boeing in 2017, has formed a new company, Electra.aero, focused on applying hybrid-electric propulsion to regional mobility. Now in the initial design phase, the company is looking at aircraft ranging from 4-6 to 35-40 seats that are able to fly 50-500-mi. stage lengths.

The Aurora founder's new vision is to use powered lift enabled by distributed hybrid-electric propulsion to achieve extreme short-takeoff-and-landing performance, or super-STOL. Capable of taking off or landing

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

"within a couple of hundred feet," the aircraft would be able to operate from small, local STOLports, yet fly intercity distances.

Langford is working with Mark Drela and John Hansman, professors in the Massachusetts Institute of Technology's (MIT) department of aeronautics and astronautics. With Aurora's support, the MIT team has already flown a one-third-scale model of a super-STOL concept using distributed electric propulsion to blow the wing and flaps, increasing lift at low airspeed.

If successful, Electra will help a class of aircraft return to the skies that has not been seen for a generation, Langford says, pointing to previous powered-lift STOL designs including the 1960s' Breguet 941 and NASA's Quiet STOL Research Aircraft of the 1970s. At that time, he notes, both NASA and the FAA forecasted that STOL airliners would be the future of short-haul air transportation.

But extreme STOL performance requires multiple turbine engines to blow the wing and flaps, which means high maintenance costs, so the idea never took off. Now, the low energy and maintenance costs of distributed electric propulsion are making powered lift attractive again.

While Langford is a believer in electric vertical takeoff and landing (eVTOL) and urban air mobility, he sees economic advantages to STOL. "When you look at the energy costs of doing VTOL versus some kind of super-STOL concept, super-STOL has a large advantage and almost as good a balanced field length," he says.

Super-STOL aircraft could operate from the same vertiports as eVTOLs and also provide services to connect cities. Compared with short intracity hops, regional super-STOLs flying longer distances could offer greater door-to-door time savings that passengers may be more willing to pay a premium for, Langford says.

Also, Langford believes urban air taxis can only be economically viable with full autonomy replacing the pilot. "Economically, you can't operate at scale with pilots when you are carrying two people." And certifying full autonomy "is very much, in my belief, a job for a big company" like Airbus or Boeing.

Electra plans to use autonomy to augment—not replace—the pilot. "If you are operating into very small

Short-Field Short-Haul

Aurora founder **eyes hybrid-electric super-STOL regional mobility**

AW&ST ARCHIVE

fields you have to be very precise," he says. "repeatable landings on very short fields needs some autonomy."

Another piece of Electra's offering will be an Uber-type mobile app to enable on-demand booking and manage the switching between transportation modes to enable seamless regional travel. "One of the big questions is going to be the mixture in demand between scheduled and on-demand," he says.

Planned to launch this summer, Electra is initially funded by Langford from money he received for selling Aurora to Boeing. But he says the company will have to raise "many hundreds of millions, probably approaching $1 billion" through a couple of investment rounds to take the aircraft through certification, which is expected to take about five years.

Electra hopes to fly a full-size, two-seat demonstrator, designed by the MIT team, within a year of the COVID-19 novel coronavirus restrictions lifting. For now, it is a virtual endeavor with a team of about 10 people working from home. But Langford's goal is to build a company similar to Pilatus Aircraft—"high quality and highly regarded in a meaningful niche in the market, but not trying to do everything."

THE LAUNCHPAD
IRENE KLOTZ

THE LAST TIME A ROCKET LIFTED OFF from Florida to put a satellite into a polar orbit, the booster failed, raining debris over Cuba. Engine parts were reportedly handed over to Russia and China for analysis, and a story circulated about a not-so-proverbial sacrificial cow being felled by a falling piece of wreckage.

"Havana charged that a cow was killed in a deliberate U.S. action," George Tenet, former director of the Central Intelligence Agency, said during a speech at the National Reconnaissance Office 40th Anniversary Gala on Sept. 27, 2000.

"The Cubans soon paraded another cow through the streets with a placard reading: 'Eisenhower, you murdered one of my sisters.' It was the first—and last—time that a satellite has been used in the production of ground beef," Tenet quipped.

The incident spurred the U.S. to abandon polar launches from Florida and shift those missions instead to Pacific Coast launch sites in California and Alaska. But the restriction, which has remained in effect for nearly 60 years, is about to be lifted.

A new generation of rockets outfitted with automated flight safety systems is once again making the polar corridor an option for Florida launches, says U.S. Air Force Brig. Gen. (ret.) Wayne Monteith, who now serves as associate administrator for the FAA's Commercial Space Transportation Office.

In 2016, when Monteith was the director of the Air Force's Eastern Range at Patrick AFB, Florida, and the commander of the 45th Space Wing at Cape Canaveral, widespread fires in California temporarily shut down operations at Vandenberg AFB.

"The fires were so intense they took down power lines, and as I recall they melted some of the fiber-optic backbone," Monteith tells Aviation Week. "There was a lot of consternation about what would happen if we needed to support . . . something into polar or sun-synchronous orbit and Vandenberg was unavailable."

Monteith directed his team to start researching polar orbits from Cape Canaveral. "We really started it out as a sort of science project: Is it something that's even possible, given the last anomaly?" he says.

In addition to the famed failed flight over Cuba, Monteith's team found a few examples of rockets heading north from Florida to reach polar orbits. However, the problem with that trajectory is that vehicles have to dogleg around the Canadian province of Newfoundland to avoid first-stage flight over populated areas. "You lose a lot of energy when you go north," says Monteith.

At the time, the Air Force was also working with SpaceX to test and certify an autonomous flight safety system (AFSS) for its Falcon rockets. The AFSS would alleviate the need for downrange tracking systems to relay a destruct signal in case the booster veered off course and posed a threat to populated areas.

"SpaceX at that time supplied us with notional flight data [for polar trajectory from the Cape], and we did the initial safety analysis," Monteith says. "I say 'initial' because there was no projected mission at that time."

There is now. SpaceX plans to launch Argentina's Earth-observing Saocom 1B satellite from Cape Canaveral into a near-polar, sun-synchronous orbit about 390 mi. above Earth. The flight, originally targeted for late March, was postponed due to travel restrictions imposed to help combat the spread of COVID-19. The company also has not yet received its FAA license to fly.

"We are in the throes of doing the actual analysis, based on a launch that has been submitted for a license," Monteith says. "It's really pretty exciting if you think about it—for the first time in what would be 60 years doing this flight trajectory," he adds. "What is allowing that to occur [are] the advances in technology."

The SpaceX mission, which has not yet been rescheduled, will still overfly Cuba, but by then its first stage will have separated, leaving powered flight to the second stage. It will pass over Cuba at an altitude of about 300 mi., the FAA says.

Rockets flying east from Cape Canaveral typically have second-stage flight over Europe or Africa, so the polar trajectory is not considered any higher risk to public safety, the FAA analysis shows.

SpaceX is planning to fly up to seven polar missions from Florida a year, according to a draft environmental impact analysis posted on the FAA's website. And it is not the only one looking at polar trajectories from the Cape.

"Once you had a company that could successfully demonstrate it, then you would anticipate that other companies may follow suit," says Monteith. "You're looking for that trailblazer to go through any regulatory and safety hurdles."

Cape Goes Polar

Saocom launch will be first polar flight from Florida in **60 years**

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DIGITAL DRAGON

- AVIONICS TECH REFRESH INCLUDES NEW MISSION COMPUTER AND COCKPIT DISPLAYS
- UPDATE PROVIDES BRIDGE TO FOLLOW-ON UPGRADES PLANNED UNDER DRAGON STAR
- THE ATR-CONFIGURED U-2S MAY BE USED AS A TESTBED FOR ABMS, LOCKHEED SAYS

Guy Norris Los Angeles

After shrugging off the recurring threat of replacement by unmanned systems, the U-2S is poised for a comprehensive avionics upgrade that Lockheed Martin says will position the spy plane for follow-on capability enhancements and a new lease on life at the heart of the U.S. Air Force's ambitious Advanced Battle Management System (ABMS) command and control plan.

The Air Force's $50 million investment in Lockheed Martin Skunk Works' Avionics Tech Refresh (ATR) upgrade forms the latest part of a broader update plan funded through fiscal 2025 and underpins the service's renewed intent to grow the strategic and tactical roles of the venerable intelligence, surveillance and reconnaissance (ISR) platform. It also confirms Air Force plans to keep the U-2S in service as a complement to the unmanned Northrop Grumman RQ-4 Global Hawk, reversing earlier moves to sunset the fleet.

"We're really breathing new life into the capabilities of this platform," says Irene Helley, U-2 program director for Lockheed Martin Skunk Works. "Most of these jets were being built in the late 1980s and '90s and have only averaged about 17,000 flight hours, so [they] have about 80% of their airframe life remaining and still have so much more to give."

The upgrade is "about growing the mission," Helley adds. "We are revamping all of the avionics [in a] system [that] really hasn't been revisited since the early 2000s."

Lockheed says the updated avionics system provides the backbone for enhanced mission capabilities and will build a bridge to a wider series of follow-on upgrades. Internally called Dragon STAR (Sensors Technology and Avionics Refresh), this broader long-term initiative also includes additional sensor technology and systems updates.

The core of the avionics suite update is "a replacement for the existing avionics processor, which is experiencing a lot of diminishing manufacturing sources," says Sean Thatcher, U-2 modernization program manager. Finding a replacement "is really the genesis from where the 'tech refresh' components came in for the aircraft," he adds.

Other key elements include a mission computer, which "is actually a new addition to the U-2, and that's really what starts to grow the mission itself," Thatcher says.

The mission computer is designed to the Air Force's open mission systems (OMS) standard, which will enable the aircraft to integrate at various security levels with systems across air, space, sea, land and cyber domains. "We're taking the OMS standard throughout the entire suite, so everything will be able to ride within the same network. Instead of being federated and their own little system, they'll now be able to communicate with one another to allow that broader system to be much more capable."

Lockheed confirms the upgrade incorporates the Enterprise Mission Computer 2 (EMC2), a company-devel-

LADY

The first ATR-configured aircraft will have initial capability in 2021 with upgrades to other aircraft to follow from 2022 onward.

LOCKHEED MARTIN CONCEPT

oped system nicknamed the "Einstein Box" that first publicly emerged in mid-2017, when it was tested on a modified U-2 taking part in demonstrations of advanced battlefield communications systems during a training exercise. Originally described as a "plug-and-play" system that bolts on to the avionics processor, the EMC2 also incorporates wider capabilities including dynamic mission replanning, ISR and electronic warfare capabilities.

The update also includes modern touch screen cockpit displays. "We are making those displays higher resolution for the pilots to see more and do more within the same physical area," says Thatcher. "They will have a higher pixel resolution as well as add some touch playing abilities. And we are also looking at upgrading other cockpit systems, to bring it up to a more modern standard."

There also will be a focus on software-driven display changes, he adds. "Pilots will be able to have more interaction with maps and other information that you would see in a modern jetliner." The provider of the display system has not yet been announced.

The U-2S cockpit was last modernized under the Reconnaissance Avionics Maintainability Program, which was completed in 2007. As well as providing a new main avionics processor, three 6 X 8-in. multifunction displays and a secondary flight display system, the upgrade also included a BAE Systems ALQ-221 advanced defensive system that incorporated both electronic countermeasures and radar warning receivers.

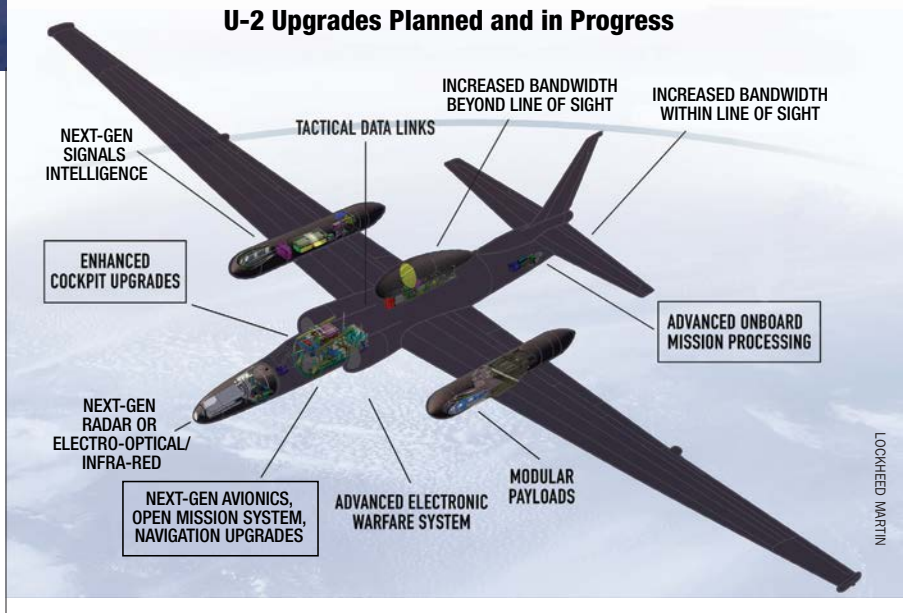
Helley says the enhanced displays will enable pilots to "collect data and respond faster" as well as "allow them to make better and [more] informed decisions." Part of this will include communicating and connecting with both fourth- and fifth-generation aircraft via multiple tactical data links such as Link 16, the F-35's fast-switching narrow directional multifunction advanced data link and the F-22's low-probability-of-detection and low-probability-of-intercept inflight data link. Given that none of these data links are compatible, the U-2S will communicate with all versions through the EMC2.

The ATR upgrade puts the high-altitude-capable U-2 on the path toward providing the Air Force with a key node in the service's ABMS network construct, a vision that Lockheed Martin has been steering the aircraft toward for several years. Originally conceived as the Airborne Battle Management System, the "A" now stands for "Advanced" and embraces a more comprehensive Air Force ambition to share data with and between Army, Navy and Marine Corps assets across land, sea, air and space domains. Now, as the Skunk Works begins funded work on the initial U-2 avionics modification, Lockheed also believes the company's ability to fast-track development efforts could play a key role in early test and deployment of the ABMS.

"There's so much talk about what the future holds for JADC2 (joint all-domain command and control)," Helley says. "Because of our ability to take the concept straight to demonstration—and then to have the capability in the field in months, rather than years—the U-2 has really become the perfect testbed to prove out those capabilities. With this avionics tech refresh effort, we're looking to be the first fully OMS-compliant fleet out there in the Air Force today."

The upgraded U-2 "really is going to be kind of a testbed truck for whatever those future platforms of 2030 will look like," Helley says. "It will be able to buy down the risk of those technologies and also serve the warfighter in today's mission abroad." Lockheed aims to field an interim capacity beginning as early as mid-2021 and hopes to begin the whole fleet modification effort in early 2022.

Looking further ahead under the Dragon STAR plan, the ATR "bridges



Avionics upgrades (marked in squares) will enable a raft of follow-on system updates that dovetail with others already underway.

the way for the U-2 mission to add in next-generation sensors such as a radar or electro-optic/infrared sensor up in the nose," Thatcher says. "We are also looking at opportunities for Sigint [signals intelligence] to be able to come in rapidly." In addition to providing a "gateway in the sky" for tactical data links, he adds the upgrade plan "will also look at increasing the bandwidth that can go over some of the existing links as well, both on the line-of-sight and beyond-line-of-sight links."

Many of these elements are either already underway or in planning. Flight tests of the first production version of the upgraded Raytheon ASARS-2B primary surveillance radar are due to start in 2021, although the Air Force is expected to issue a request for proposals for the follow-on ASARS-2C upgrade in fiscal 2022. The move to the -2C standard will involve upgrading the radar processor to exploit the full potential of the active, electronically scanned array antenna being introduced with the -2B.

The Air Force, Lockheed and Collins Aerospace also announced in February that flight testing and deployment of the latest variant of the Senior Year Electro-Optical Reconnaissance System (SYERS) sensor, SYERS-2C, has been completed. Meanwhile, Northrop Grumman is upgrading the Airborne Signals Intelligence Payload system that flies on the U-2 to provide cybersecurity and systems enhancements. Improvements to the BAE Systems ALQ-221 advanced defensive system are also included in the upgrade.

"We are talking about being able to host agile pods that give new mission capability at a rapid pace to support any given warfighter needs that come up," Thatcher adds, referencing systems such as the recently developed Air Force Research Laboratory Agile Pod—a reconfigurable sensor and communications payload system.

LOCKHEED MARTIN

The rebuild of damaged U-2S 80-1099 is underway following loading of the fuselage into the RF50 tool.

The overall upgrade plan also addresses improvements to the aircraft's future precision navigation and timing (PNT) capability. U-2 pilots are now being given Garmin D2 Charlie wristwatches that provide location and waypoint positioning information based on GPS and Global Navigation Satellite System signals to augment the aircraft's navigation systems. However, for the near term, navigation enhancements will include improved map displays as part of the cockpit avionics upgrade.

Other, longer-term changes are planned, including adding a star-tracking system and replacing the current inertial navigation and GPS system. "We are definitely looking at being able to provide that [capability] into the backbone of the aircraft, too, and to not have the pilots need that reliance upon other technologies," Thatcher says. "That's not to say that they would ever get rid of [the wrist watch] or not want to have it as a comfort zone. But we ultimately want to have [enhanced navigation capability] baked in as the ultimate PNT source for the U-2, and also to have the ability to share that data with the other systems that are onboard the aircraft."

Along with these operational improvements, other upgrades are in the works to address obsolescence concerns with airframe sustainment, the helmet and full-pressure suit, and Universal (formerly Unmanned) Aerospace Systems Command and Control Standard Initiative standards compliance. Beyond this, more upgrades—some of them secret—are planned, says Helley. "There are a number of other refresh modernization efforts that we are working on with our affiliates, but right now we're still in the early planning phases of those efforts. We are not quite to the place where we can talk about them in greater detail, and a number of those items will probably remain on the classified side of the fence," she adds.

Expanding U-2S mission capability forms one of three strategic program goals for the airframe, Helley says. "For the modernization, we've been growing our engineering and manufacturing team." Another is growing the fleet. "So we've been working in ways to increase the rate at which we do PDM [programmed depot maintenance], as well as introducing another tail number back into the fleet," she adds, referring to the refurbishment of tail number 80-1099. That aircraft is a single-seat model that was damaged in an August 2008 ground accident at Al Dhafra airbase, in the United Arab Emirates. Together with the rebuilt aircraft and four two-seat trainers, the planned upgraded fleet will number 31 aircraft.

"They recently loaded that tail [1099] into the main tool, which begins the main rework on the areas that were damaged," Helley says. "So the restoration processes will be worked on over the next year. It will be immediately followed by program depot maintenance, and they're anticipating a return to service as early as 2022."

Digital Extras *Read then-Editor-In-Chief David M. North's 1999 U-2 pilot report in the AW&ST* **archive.aviationweek.com/issue/19990412#!&pid=60**

See Guy Norris' gallery on the Dragon Lady at 65: **https://aviationweek.com/defense-space/lockheed-martins-dragon-lady-65**

Defense Primes Still Working Amid Uncertain Long-Term Budget Outlook

> PENTAGON LOOSENS CONTRACT PAYMENT RULES

> WITH FEW EXCEPTIONS, DEFENSE PRODUCTION IS ON TRACK

Steve Trimble Washington

Elbit Systems of America had everything set up on April 10 to publicize a self-defense system upgrade for the Air National Guard and Air Force Reserve Command F-16 fleet—except one last detail.

Internal social-distancing directives—due to concerns about the COVID-19 coronavirus pandemic—ruled out an in-person signing ceremony between the U.S. military and Elbit, so Air Force and company officials instead met virtually on the Zoom videoconferencing application. The U.S. subsidiary of the Israeli contractor announced the deal minutes after the ceremony ended.

"It's just to demonstrate to everybody that even with this pandemic we can get things done and moving forward," says Raanan Horowitz, CEO of Elbit Systems of America.

For the most part, the U.S. and global defense sectors continue to move forward with few operational disruptions reported through mid-April. Nevertheless, executives and defense officials remain wary of the spread of the COVID-19 illness and the long-term effects on spending priorities and available resources.

In the U.S., Boeing shut down assembly of the KC-46 and P-8A commercial aircraft derivatives in the Seattle area for three weeks. The manufacturer resumed operations for both defense programs on April 13 even as commercial aircraft production remained on indefinite hiatus. In a parallel development, a two-week production stoppage for Boeing's H-47 and V-22 fuselage lines in Philadelphia is expected to be lifted on April 20.

Elsewhere, the defense supply chain remains active. Although Boeing stopped work in Seattle and Philadelphia, the company's fighter production lines in St. Louis continued operating (the Qatari Air Force F-15QA achieved a first flight on April 13). The military's sprawling network of aircraft repair depots and the Defense Logistics Agency's parts distribution hubs also continued operating without any stoppages.

However, the defense sector is not immune to all maladies. A Lockheed Martin employee in Fort Worth died on April 11, six days after reporting COVID-19 symptoms to a supervisor. Lockheed also advised any colleagues who might have had contact with the employee in question to self-quarantine, but operations continued.

A different set of challenges has affected the defense sector's teams of engineers and office workers. With many working from home or in offices rearranged to accommodate social distancing guidelines, program officials are scrambling to develop workarounds for routine activities such as in-person design reviews.

In Washington, Pentagon officials have loosened certain federal acquisition regulations in order to allow the government to reimburse contractors—even if precautions for COVID-19 meant work was delayed. But the U.S. military's leadership has struggled with basic operational issues, including how to evacuate virus-stricken naval ships.

Additionally, the economic impact of the pandemic has prompted some governments to delay scheduled procurements. Argentina, for example, indefinitely deferred a planned order of Korea Aerospace Industries/Lockheed Martin F/A-50 light attack aircraft. In Europe, Croatia suspended the procurement process for a long-awaited replacement to the Balkan country's Soviet-era MiG-21 fleet.

U.S. defense spending was already expected to peak under the $712 billion budget alloted for fiscal 2020. As the Pentagon continues to defend a $705 billion spending request for fiscal 2021 and begins compiling the fiscal 2022 spending plan, the proposals face a new economic future. The Pentagon released the fiscal 2021 request on Feb. 10, only six weeks before the global pandemic prompted Congress to pass the $2 trillion CARES Act and the Federal Reserve to take steps to provide up to another $2.3 trillion more in loans.

During defense spending downturns, military suppliers often look to the commercial sector for growth. With the airline market facing an uncertain long-term recovery, some defense contractors are seeking refuge in other markets, such as healthcare. Horowitz notes that one of Elbit's subsidiary companies based in New Hampshire makes devices used for blood testing. Hospitals have started to convert the devices to test for COVID-19 infections, he says.

The subsidiary specializes in "high-volume, very capable diagnostic test equipment that's exactly fit for anything to do with blood analysis," Horowitz says. "As we speak, we definitely see that area growing significantly."

LOCKHEED MARTIN

Lockheed Martin's mile-long F-35 assembly line, pictured here in 2012, is continuing to operate. An employee died several days after entering quarantine and complaining of virus symptoms.

Airlift Initiative Propels NATO COVID-19 Efforts

> RAPID AIR MOBILITY FLIGHTS USE THE TRIGRAPH "OAN"

> NATO WANTS DIPLOMATIC CLEARANCES FAST-TRACKED IN 24 HR.

Tony Osborne London

Just a few weeks ago, the idea that a Turkish military aircraft would perform a medical aid flight to the UK would have seemed extraordinary.

The April 10 mission from Ankara to RAF Brize Norton, England, flown by an Airbus A400M not only demonstrated Turkish president Recep Tayyip Erdogan's soft power but also tested for the first time a NATO crisis-intervention initiative to speed up airlift missions across Europe.

The activation of NATO's Rapid Air Mobility (RAM) capability by the North Atlantic Council on April 2 to help alliance members deal with the novel coronavirus pandemic removed the constraints associated with moving military airlifters across Europe.

Although the Turkish A400M carried much-needed medical protective gear destined for the UK's National Health Service, RAM was originally developed so that NATO members could quickly reinforce their garrisons on the outer edges of the alliance, such as the Baltic States, with personnel and equipment at a time of growing crisis to support NATO's Very High-Readiness Joint Task Force (VJTF).

The initiative achieved an initial operating capacity last October. "We decided there might be moments in this crisis for which this proves useful to move around medical supplies, patients or medical teams," Camille Grand, NATO assistant secretary general for defense investment tells Aviation Week.

In peacetime or during emergencies, military aircraft have to compete for airspace with commercial traffic and may not get the most efficient routings or slots. But in wartime, NATO would likely own the skies over Europe.

"COVID-19 is a different scenario to what we had anticipated [for RAM]," Grand says. "The airspace is not exactly crowded, but on the other hand there are fewer air traffic controllers than in normal times. So it is not absurd to suggest that military flights should get priority."

When activated, the plan—a collaboration between NATO and air traffic management agency Eurocontrol—prioritizes flight routings and fast-tracks the diplomatic clearance process.

A military flight from Spain to Poland, for example, may normally have to secure diplomatic clearance from 5-6 different countries before the departure date. Such clearances can take days or even weeks to acquire.

Nations that request a RAM flight, however, receive a special call sign with the trigraph "OAN" from Supreme Headquarters Allied Powers Europe (SHAPE). With an OAN call sign, diplomatic clearances are fast-tracked, and the flight can be waved through the airspace of different countries by air navigation service providers.

The Turkish Air Force flight used the call sign OAN2901. Under OAN, the allies have agreed to fast-track clearance in 48 hr., with the aim of reducing that to 24 hr.

NATO is also taking steps to request blanket diplomatic clearances so that OAN flights can receive automatic diplomatic clearance. This is in part driven by the need to reduce delays for flights, but it is also in recognition that the COVID-19 crisis has shut down government ministries that would normally supply such approvals.

The initiative was developed primarily for military aircraft, not for aircraft chartered by governments. But the alliance is "looking into whether it could be extended to other governmental or government-chartered aircraft," Grand says. This would allow types such as the Antonov An-124 airlifters operated by Ukraine's Antonov Airlines through the Strategic Airlift International Solution initiative also to use the OAN call sign.

The COVID-19 pandemic presents one of the biggest crises the alliance has faced in its 70-year history, as it battles to help countries fight the virus but also remain at readiness. NATO has already seen several major exercises canceled, including the pan-European Defender-Europe exercise, which was due to test U.S. capabilities to rapidly deploy 20,000 troops and 13,000 pieces of equipment from the U.S. to Europe. It would have been the largest U.S. force to deploy to Europe in 25 years. SHAPE has established a COVID-19 Task Force to coordinate logistical, transport and medical support.

NATO's Euro-Atlantic Disaster Response Coordination Center has been receiving requests for assistance. So far, nine countries, including alliance members and partner nations, have made requests for assistance to NATO as a result of the COVID-19 crisis.

SGT. MATTY MATTHEWS/ROYAL AIR FORCE

The Turkish aid flight carried 250,000 items of personal medical protection equipment.

> Air travel after COVID-19 p. 24 Small narrowbody promise p. 55

H. GOUSSE/AIRBUS

Airbus is reducing A350 production from as many as 10 aircraft per month to just six.

IN DISTRESS

> COVID-19 CRISIS TO LEAD TO LOWER PRODUCTION RATES LONG-TERM

> AIRBUS CUTS OUTPUT BY ONE-THIRD

Guy Norris Los Angeles, **Jens Flottau** Frankfurt and **Michael Bruno** and **Sean Broderick** Washington

Just a short time ago, Airbus could not expand fast enough. Given the strength of demand, the manufacturer planned to add another final assembly line for narrowbodies in Toulouse, even though its global industrial system was already complex—because maximum deliveries were what mattered.

Now, as aircraft manufacturers begin to assess the medium- and longer-term impact of the COVID-19 pandemic, the Toulouse project and many others are on hold or at least substantially slowed down. And if the revised projections for future aircraft deliveries are only roughly accurate, that additional assembly line will not be needed for a very long time. Airbus in early April became the first OEM to announce new production targets, around one-third below previous assumptions.

At this stage, trying to figure out aircraft demand and future production rates is a matter of likelihoods and scenarios covering a wide range of outcomes. In many cases, the most optimistic scenarios already look outdated, leaving those indicating a deeper and more lasting impact on the table—a grim outlook for Airbus, Boeing, Embraer and their suppliers.

Consultancy Roland Berger has attempted to define three possible outcomes. Its "rebound" scenario is modeled around two months of air travel restrictions, a full recovery to a precrisis air travel level by next winter and a compound annual growth rate (CAGR) of 4.6% thereafter. In that case, OEMs would lose only 790 deliveries over 10 years vis-a-vis the precrisis outlook. It is already clear that the short term will be much worse, although a steep recovery in later years remains a possibility.

If restrictions stay in place for four months, the new normal would be at 90% of precrisis levels and would be reached in the summer of 2021. Airlines would defer aircraft replacement for 18 months and future growth rates average 4.1%. Under this "delayed cure" scenario, the industry would lose almost 6,000 deliveries between now and 2030.

Unfortunately, the worst Roland Berger scenario may now be the most likely, at least in its short-term elements: Six months of severe travel restrictions, demand recovery to only 80% by the summer of 2022, extended deferrals and lower growth for the long term at 3.6%. In that circumstance, airlines would accept 10,460 fewer aircraft over the next 10 years. For context: Airbus delivered 863 aircraft in 2019, and Boeing sent out 380 (affected by the 737 MAX grounding). In 2019, Boeing led with 806 deliveries, and Airbus handed over 800 aircraft.

If the worst-case scenario comes to pass, the industry will deliver only 11,280 aircraft in the next 10 years; the more positive assumptions of the "delayed cure" model leave that number at 15,840. This would essentially put the industry—on average and very roughly—at the 2017 delivery levels of a combined 1,600 commercial jets above 100 seats for Airbus (now including the A220), Boeing and Embraer. Of course, new players such as Mitsubishi's SpaceJet, the Comac C919 and the United Aircraft Corp. MC-21 will fill (small) amounts of the demand as well.

Airbus' decision to cut production by one-third would, if continued, leave it with around 570 annual deliveries, close to 2011 levels. CEO Guillaume Faury points out that it is "not unlikely" that the new rates could go back up in 2021 as the situation improves, but he says it is too early to make firm commitments. The decisions made now reflect the "best knowledge" today and "many conversations with airline CEOs and [chief operating officers]."

The production reduction will be implemented over the coming weeks. "This crisis will probably be a long one," says Faury. "Our industry is one of the most impacted. . . . [The production rates are] the result of the best matching between the downturn and the remaining commitments. We needed to have a plan. We will review it probably on a monthly basis."

The manufacturer plans to produce 40 A320neo-family aircraft per month on average, down from a previous near-term target of 63 and a planned increase to 67 or more. Airbus will also reduce A330/A330neo output to two aircraft per month from the pre-crisis production level of 3.5. A350 deliveries are being reduced from 9-10 aircraft per month to just six.

Airbus delivered 122 aircraft in the first quarter, 36 of them in March. That month included two A220s, 19 A320neos, one A321ceo, 10 A321neos, one A330-200 and three A350s, according to the company's latest order and delivery figures. Airbus produced 60 more aircraft that were not delivered in the quarter because customers said they were unable to accept them.

The A330 will remain a profitable program, says Faury, but the A350 will face "more headwinds," having just moved into profitability in 2019.

Boeing's recently updated commercial airliner figures for 2020 through March reveal dramatic cuts in orders and deliveries as the air transport market continues to nosedive in the midst of the COVID-19 pandemic.

The beleaguered company, which is due to release its first-quarter financial results on April 29, saw net orders for the year plummet by 307 aircraft, putting it on track for its worst period since the mid-1990s. Despite picking up 24 new orders for the 787 and two additional 767 orders, the bulk of the damage was caused by losses to the 737 MAX orderbook.

According to many financial analysts, Airbus' rate cuts set a floor for similar action by Boeing.

"We believe similar cuts from Boeing are likely," Ken Herbert of Canaccord Genuity said April 14. His team assumes MAX deliveries will not restart until at least the third quarter, with just 36 to be delivered this year. It will take "several quarters" for MAX new order activity to pick up. Production next year could average 21 new narrowbodies monthly, and perhaps around 40 per month by the end of 2022. But some of that depends on how much government aid and commercial-sector funding Boeing ultimately receives.

"We believe the updated production forecasts are alarming, but not surprising," Herbert added.

"The coronavirus is likely to become a significantly greater pressure point on Boeing than the long-running 737 MAX crisis," says Jonathan Root, Moody's Investors Service senior vice president and lead analyst. "We now estimate external funding needs in 2020 to at least double—to $30 billion—compared to our precoronavirus expectations," he says. Boeing already funded about half of this need with the $13.8 billion delayed-draw term loan facility arranged in February and drawn down by mid-March.

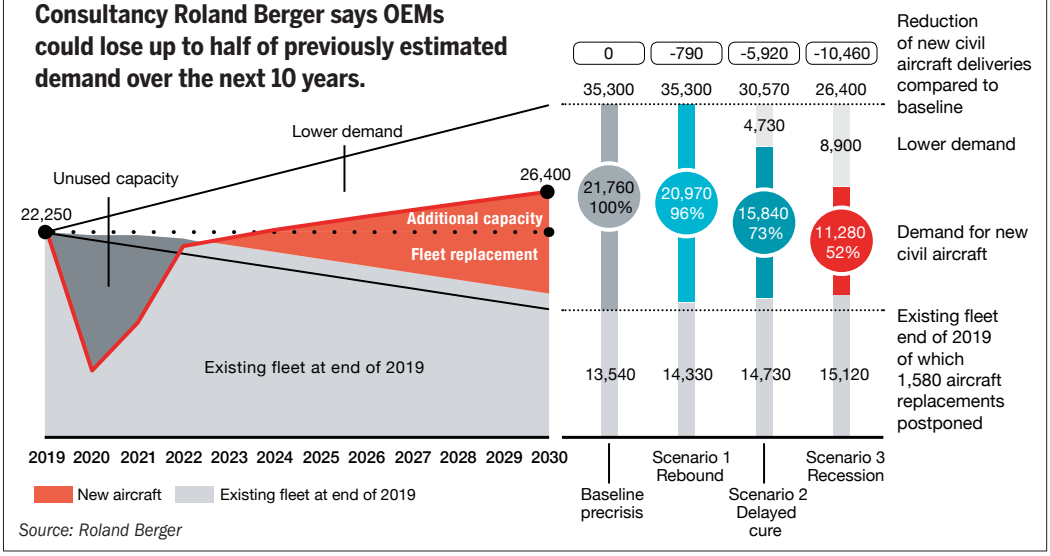
In the long term, Root's team does not envisage a return to 2019 delivery numbers before the end of 2022. Many other analysts such as Herbert and consultants such as Roland Berger's group agree.

Grounded since March 2019 following two accidents, the 737 MAX lost a further 150 orders in March 2020, half of which were cancellations from aircraft lessor Avolon. Other operators included Brazilian carrier Gol, which cut 34 aircraft from the backlog as part of a compensation deal for nondelivery of 25 MAXs in 2019. Overall, net 737 orders for the first quarter have been reduced by 314 aircraft, some 173 of which are listed as cancellations or conversions to other models, and another 141 lost because they no longer meet Boeing's firm contract revenue accounting standard.

Deliveries were also significantly down. Just 50 aircraft of all models were delivered through March 31, representing the lowest number of quarterly deliveries since the end of 2008. By comparison, Boeing delivered 149 aircraft in the same period in 2019, and 184 were handed over to customers in the first quarter of 2018. The falloff in deliveries primarily reflects the continuing impact of the 737 MAX grounding, which last year more than halved the company's overall delivery target. Boeing says delivery numbers have been also affected by logistical challenges, as some opera-

FUTURE AIRCRAFT PRODUCTION Possible Scenarios

Consultancy Roland Berger says OEMs could lose up to half of previously estimated demand over the next 10 years.



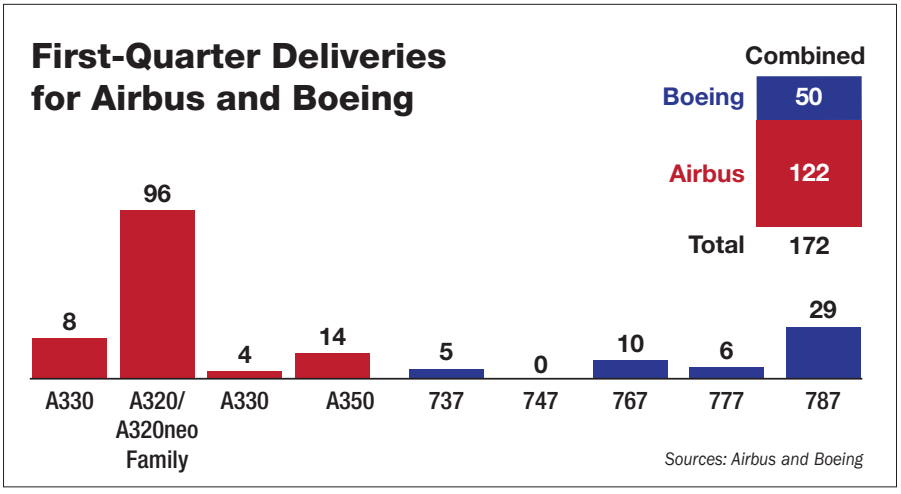
Source: Roland Berger

tors have been unable to bring flight crews to the U.S. to accept the new aircraft owing to travel restrictions.

The restrictions are also hampering the MAX's return-to-service effort. The final FAA certification flight to put the software through its paces, the next major step in the return-to-service process has not taken place. The subsequent milestone, work by the Joint Operational Evaluation Board (JOEB), a multi-regulatory group that will evaluate the MAX training recommendations in simulator sessions, has not been scheduled and is not likely to happen until international travel restrictions are eased. The MAX will not be approved for service until the JOEB's work, including a written report, is done. Boeing has not wavered from its projection that a mid-2020 FAA approval is in the cards, but the lack of progress on key milestones makes this increasingly unlikely.

In 2019, Boeing completed the year with 380 deliveries, 127 of which were 737s and 158 787s. The previous year, with production of the MAX ramping up and manufacture of the final 737NGs still being phased out, the single-aisle models accounted for 580 of the record-breaking 806 deliveries the company racked up for the year.

Military deliveries accounted for eight of the 50 (five KC-46A/767-derivative tankers and three P-8A maritime patrol 737NG derivatives), while the 787 contributed to the bulk of the tally with 29 aircraft.



Boeing has meanwhile announced it will begin a phased return to production of commercial aircraft models—including the 737MAX—at its Puget Sound, Washington, and South Carolina plants starting as early as April 20 after suspending activity on March 25 due to the COVID-19 outbreak. It is, however, widely expected to announce rate reductions for the 737, 777 and 787 shortly after manufacturing resumes. The adjusted numbers, using Boeing's own accounting standards on firm contracts, now show the overall firm backlog for all models has been reduced to 5,049—4,079 of those are for the 737. The 747-8F backlog is now reduced to 13, while the 777 orderbook has shrunk to 356 and the 787 to 515.

Business aviation fares no better than civil, with an expectation that the business jet market will see deteriorating demand. "Though we expect demand for smaller and midsize jets will see a greater decline in demand than larger jets, there will still be a negative impact to the large-cabin segment that includes Bombardier's Global family," Moody's analysts say.

In turn, credit rating agencies such as Moody's, S&P Global Ratings and Fitch Ratings are downgrading debt rankings of OEMs and suppliers across the board. "The downgrades reflect Moody's expectation that 2020 will be a very challenging year for commercial aerospace suppliers, with double-digit earnings declines stemming from a significant reduction in commercial aerospace production by Tier 1 OEMs and suppliers," the Moody's analysts say. "Stress on the supply chain will result in unprecedented deterioration in earnings and cash flows, resulting in key credit metrics that will remain strained for some time."

"Many suppliers are distressed," Spirit AeroSystems said in a regulatory filing.

How Air Travel Might Look After the COVID-19 Crisis

> IATA IS HOLDING A SERIES OF MEETINGS TO DISCUSS NEXT STEPS

> ICAO IS LOOKING INTO THE HEALTH VALIDATION PROCESS

Sean Broderick and **Bill Carey** Washington, **Jens Flottau** Frankfurt and **Helen Massy-Beresford** Paris

The COVID-19 pandemic has brought commercial flight schedules to a virtual standstill, leaving airlines across the globe scrambling to survive.

Now, with the spread of the disease slowing in some countries, governments are looking ahead—tentatively—to the post-lockdown era and to how they can square the gradual resumption of aspects of daily life with the protection needed to avoid a damaging resurgence of the virus.

Airlines globally are also attempting to prepare for what comes next. But mapping out a recovery strategy amid uncertainty about how the disease will evolve once travel begins to ramp up again is no easy task.

Airlines will need to balance their urgent need to start generating revenues again after an unprecedented and damaging hiatus against the safety of their passengers and crew and the wider populations they connect.

As with previous crises that have touched the aviation industry, there may be no return to "normal" as such. New post-COVID-19 regulations will be incorporated into the rituals of air travel. Even so, carriers are cautious about how quickly they can expect to see a significant increase in activity.

With much of the world still in lockdown, it is difficult to predict how quickly the first stages of the return to a more normal level of air traffic will take place, but there will be some clues as to the pace of the recovery in the months ahead.

"If airlines continue to keep medium-term schedules—[in] July, August, September—largely intact, we would take this as a sign that airlines have confidence in attracting sufficient demand by that time again. If airlines start cutting flights further in advance, we would be worried that the recovery will be slower," Bernstein analyst Daniel Roeska wrote in an April 15 research note. "To judge the duration of the crisis, we would want to see the apex for new infections in EU countries to give us an indication when the sector can start to recover. In many cases this is flattening, but declines so far are slow," he added.

The International Air Transport Association (IATA) has revised its 2020 economic forecast for the global airline industry downward based on worsening economic forecasts and now predicts full-year demand in revenue passenger kilometers will drop 48%, creating a $314 billion revenue shortfall.

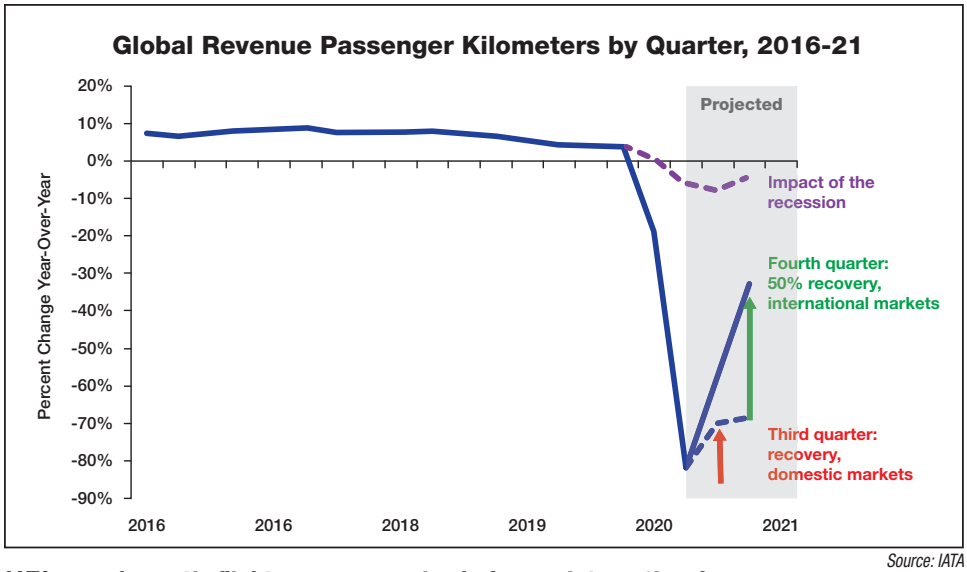
IATA says the effects of the recession alone will lead to an 8% drop in air travel in the third quarter.

Brian Pearce, the association's chief economist, anticipates that domestic air travel will begin to recover first, in the third quarter, followed by international flights in the fourth quarter. He believes there is "pent-up demand for air travel," but it is unclear whether it can be met if restrictions remain.

IATA is hosting a series of regional video conferences with governments and aviation authorities to discuss the restart, as it attempts to establish what rules and restrictions will remain in place even after flights are allowed to resume.

In Europe, Lufthansa Group believes it will take months for all international travel restrictions to be fully lifted and years for air traffic volumes to return to precrisis levels.

It is already planning for a future requiring a fleet around 20% smaller than before the coronavirus, with cuts across its airlines, including the perma-



Source: IATA

IATA sees domestic flight recovery coming before an international one.

KUDAK/WIKIMEDIA

nent retirement of six of its 14 Airbus A380s, seven of its 17 A340-600s, three A340-300s and five Boeing 747-400s, as well as cuts to short-haul fleets.

Air France-KLM CEO Ben Smith says it will be two years before the industry sees a return to 2019 traffic levels. With the airline group losing €25 million ($27 million) per day because of the crisis, he says it is aiming for a gradual ramp-up, with 40% of planned capacity on offer in July, 60% in August and 75% in the fourth quarter at the earliest.

"Forget 2020; yearn for 2021. 2020 by all accounts will be a trough year for EU airlines' profits," Roeska wrote. "Whoever makes it through the current crisis will benefit from a more consolidated market," he added, citing Ryanair and Wizz Air as the best placed, followed by International Airlines Group and EasyJet and then Air France-KLM and Lufthansa. He said the latter two groups are likely to need significant short-term funding, which they are already negotiating.

In the shorter term, those airlines that survive the immediate crisis, many of which will rely on sizable government support to do so, will probably need to impose now-familiar social-distancing restrictions and safety measures on their flights.

Passengers may be required to wear masks or airlines to leave empty seats in aircraft filled to only half or two-thirds capacity to maintain social distancing, as has been the case on some flights still operating in recent weeks.

Wizz Air is considering providing masks and leaving some seats empty, as well as other measures.

Low-cost carrier Wizz Air is looking into the possibility of mandatory masks and leaving a third of seats empty, a spokeswoman confirmed, adding that the airline was also considering further steps, with details to come.

"Health control is going to be a key element," IATA Director General/CEO Alexandre de Juniac said April 14. "We want to avoid a patchwork of measures in different countries." IATA is aiming instead for a consistent approach.

Airlines assume health checks will be required both at departure and arrival points, but they are still unsure as to what that will entail. The new rules also take in new aircraft-cleaning processes as well as changes to the way boarding and disembarkation will be carried out to avoid having too many people in a confined space.

Airports will also need to determine how they can ensure social distancing in departure lounges and as passengers go through checks.

But the crisis could be the catalyst for other changes, too. The International Civil Aviation Organization (ICAO) is consulting with global public health authorities on a "prototype" process that would validate that flight crews, and potentially passengers, screened for COVID-19 are safe to travel, instilling confidence as air transport demand resumes.

The process is in its early stages, Stephen Creamer, director of ICAO's Air Navigation Bureau, said on a Flight Safety Foundation webinar April 9. But the agency is pushing to get a framework in place and start soliciting industry feedback in the coming weeks.

ICAO's idea, dubbed the Public Health Corridors Concept (PHCC), would create a virtual "corridor, or bubble," for flight crews and other travelers. For airline personnel, globally agreed-upon tests would be administered premission at the home base and then again at the mission's completion. A certificate or other validation would be issued signifying no presence of the novel coronavirus.

Aircraft would go through globally accepted cleaning procedures that would be validated as a condition for return to service. The verified-bubble concept could extend to other airside and perhaps landside facilities, such as dedicated parking lots where access is controlled.

ICAO's plan is to develop the PHCC for cargo operations initially, then work on scaling it for passenger services. Even if the program never gets beyond the flight deck, it will serve a purpose.

Expanding the PHCC or a similar program to passengers would require significant coordination not just with industry stakeholders but also with local and state officials. Aviation executives are becoming convinced that such processes and the confidence-building they help create will be needed to nurse the industry's recovery.

"Airlines will need to focus on encouraging the flying public to resume flying," says Gilberto Lopez-Meyer, IATA senior vice president for safety and flight operations. "Airlines and governments will need to work with other affiliated sectors to ensure negative perceptions of travel are changing. This may imply a slow return to normal traffic."

As expected, given the unprecedented crisis airlines from which airlines are attempting to recover, industry and policymakers disagree on the details of safely relaunching international travel.

During a press call with U.S. aviation union leaders on April 6, Sara Nelson, president of the Association of Flight Attendants (AFA), rejected screening of passengers and airline employees before they enter an aircraft—such as by taking their temperatures—as a way to prevent the spread of the novel coronavirus.

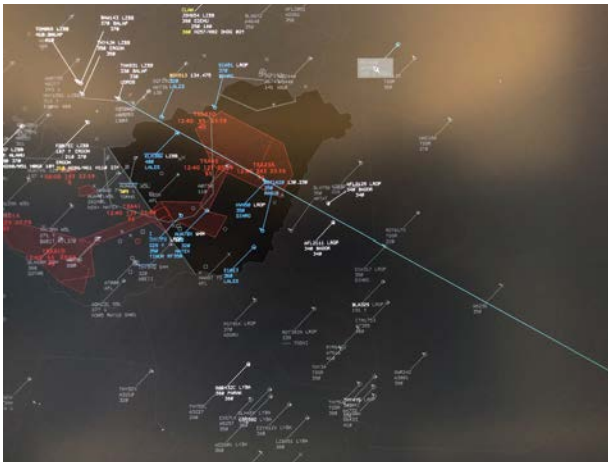
"A big reason that this virus is being spread across our country and around the world is because it can be spread when people are asymptomatic. We know for sure that this can be spread without any symptoms present," says Nelson. "It is important to be on the lookout for those symptoms because clearly that is an indication of possible spread. But the concern here is that screening will not mitigate spread because of the [traits] of this virus."

The AFA, which represents 50,000 flight attendants at 20 airlines, was calling for a suspension of leisure travel as the pandemic worsened in the U.S. "Even if you set up a screening procedure with tests, there is a time to get those test results back," says Nelson. "Screening passengers, while it may be a good step and is happening in some cases, is not going to help with stopping the spread of the coronavirus."

Free Route Airspace Gains Ground In Europe

- SOUTHEASTERN EUROPEAN NATIONS PIONEER CROSS-BORDER FREE ROUTES
- FRANCE, GERMANY PROCEED GRADUALLY

Thierry Dubois Lyon



HUNGAROCONTROL

Free route airspace enables more direct routings, which can generate fuel and time savings.

Implementation of free route airspace, a concept under which flight crews choose their preferred routes in a relaxed framework, is gradually becoming the norm in Europe. Carriers may begin to expect more direct routing, which can generate time and fuel savings—similar to what they experience when air traffic controllers allow shortcuts in Europe's upper airspace. As a result of the changing environment, controllers anticipate better trajectory predictability for aircraft.

Route extension—or the difference between a planned flight trajectory and the corresponding portion of the great-circle distance (the shortest distance between two points on a sphere)—is a key component of the rationale behind instituting free route airspace (FRA). Eurocontrol, the organization in charge of air traffic management (ATM) in Europe and Turkey, says route extension decreased to 2.77% in 2017. It credits FRA, among other initiatives, for that drop.

A goal of the Single European Sky ATM Research (SESAR) improvement program is the expansion of Eurocontrol's entire airspace by 2025. Under the plan, a few internal borders will still involve entry and exit points. Military areas will be the other exceptions.

Since November 2019, the South East Europe Free Route Airspace project has allowed operators to choose their routes as they see fit in a large, cross-border area, involving Bulgaria, Hungary, Romania and Slovakia. Calculated daily savings amount to up to 10,000 nm and approximately 70 metric tons of fuel.

The conventional way of allotting routes to flights is along a predefined, mandatory route structure, known as air traffic service (ATS) routes. A Eurocontrol working group determines ATS routes.

"In 2015, we asked ourselves: 'What if we eliminate all ATS routes and create a free airspace with entry and exit points?'" recalls Jozsef Bakos, head of ATS at Hungaro-Control, Hungary's air navigation service provider (ANSP). "From my standpoint, I cannot say which flightpath is the optimum, depending on high-altitude winds or anything else important for the airline."

That freedom of choice for the carrier was introduced in Hungary in February 2015. Romania and Bulgaria quickly followed. As a result, aircraft operators can now plan their flights freely across the airspace of the three countries 24/7 without the limitations of the geographical boundaries. Slovakia is still limiting itself to night hours.

"When we were using ATS routes, it was impossible to fly from Austria to Croatia via Hungary," Bakos says. "From the day after we dropped that system, Austrian Airlines flew such direct routes instead of circumnavigating the country."

Many controllers in Europe already permit direct routing for upper airspace; however, they give clearance tactically after takeoff depending on parameters such as traffic density and active military areas. Crews still have to plan for the fuel consumption that corresponds to the flight plan they have filed, rather than factoring in a controller's potential shortcut.

Structurally eliminating ATS routes takes ATM into another dimension. FRA instates routes that enable an aircraft to carry less fuel and thus save some.

From the controller's standpoint, adherence to the flight plan is improved. And traffic is streamlined, says DSNA, France's ANSP.

Nevertheless, "you need a very good medium-term conflict detection and warning system," Bakos emphasizes. In a conventional system, a controller knows which routes are busiest and is familiar with conflict locations. In FRA, conflicts are not more numerous, but they are spread all across the airspace.

France will begin to implement the concept in three of its five area control centers (ACC)—Brest, Athis-Mons (near Paris) and Bordeaux—for flights above flight level 195 (approximately 19,500 ft. in altitude). The change will be phased in over two years, starting in late 2021.

The other two ACCs, Aix-en-Provence and Reims, have yet to modernize. "The current system could be used for free routes but would require a lot of redefinition," says Michel Coz Elleouet, a DSNA controller and a member of the board at the SNCTA controllers union. As these two ACCs are upgrading to a new system that is fully compatible with FRA, DSNA has decided to wait for the upgrade to be complete before implementing FRA. Aix and Reims could implement FRA in 2023.

In Germany, ANSP Deutsche Flugsicherung (DFS) sees limited suitability of FRA.

In March 2018, DFS implemented the concept in the northeast, which is an area considered to be of medium complexity and moderate density. "However, in the so-called core area, along the London-Brussels-Amsterdam-Dusseldorf-Cologne-Frankfurt axis and then on to Basel and Munich, there is high complexity and a high demand for capacity," says Dirk Mahns, DFS' managing director of operations. "Offering too many routing options with interferences to this main flow would jeopardize capacity."

DFS will therefore soon proceed with 24-hour FRA (an extension from night hours) in the core area with unspecified "structural limitations," Mahns says.

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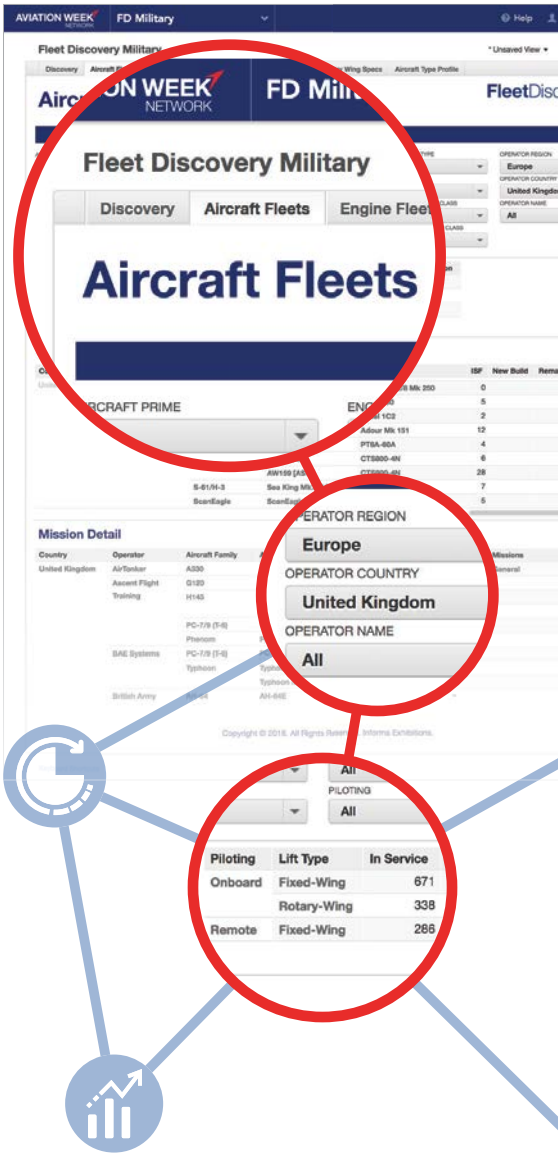

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AVIATION WEEK NETWORK

Europe's ATM Modernization Champions Strive To Keep Momentum

- DATA LINK ADOPTION ON FAST UPWARD CURVE
- SESAR PROMOTERS PREPARE ARGUMENTS FOR MORE INVESTMENT

Thierry Dubois Lyon

Europe's project for air traffic management (ATM) modernization is almost half implemented, and its promoters are looking to show the technology can deliver the promised benefits.

The Single European Sky ATM Research (SESAR) program's deployment alliance (SDA), the organization in charge of executing it, was emphasizing environmental progress when the COVID-19 pandemic hit. The SDA is now bracing for the full impact of the crisis, which may bring other considerations to the fore for its members—air navigation service providers (ANSP), airlines and airports—and partners.

SESAR DM

From the airlines' perspective, primary issues may change postcrisis, and SESAR's execution team is building a case for continuing ATM updates.

The European Commission tasked the SDA with fulfilling the role of deployment manager (DM). "The relationship with the public is important for us in these troubled times," says Nicolas Warinsko, the SESAR DM's general manager. His willingness to speak, in a period when not every organization is taking time for communications, signals the DM's concern that the current efforts might be wasted because of shifting priorities.

"We are devising a plan to boost ATM modernization in Europe, postcrisis," Warinsko says. Collaboration among carriers and the industry's investments are the two pillars supporting SESAR's advancement. "The crisis is harming these two pillars, due to survival reactions," he warns.

Some states may require air navigation infrastructure on their soil, citing sovereignty. This may undermine efficiency on the continental level.

Meanwhile, in a bid to cut costs, a carrier may question overflight fees that fund ground equipment for navigation, such as mode-S radars. "They might ask, 'Why shall I pay for these? My state-of-the-art aircraft uses satellites,'" Warinsko notes. Basing fees on utilization may jeopardize the funding of some systems needed for redundancy.

"We have yet to build resilience [in our infrastructure]," he says. "We will not discard ground-based technologies without thinking, but we have to reflect on keeping both [automatic dependent surveillance-broadcast (ADS-B)] and mode-S radars."

Expanding the use of ADS-B—a real-time tracking system where aircraft broadcast their position, altitude, speed, identity and other information—is believed to be a key example of SESAR's success thus far.

Adoption grew to 63% in December 2019 from 24% in August 2018 (measured over the fleet registered in the EU and four states associated in civil aviation). "We took over ADS-B in 2018, when the program was in a chicken-and-egg situation," Warinsko says. "It was missing a conductor. As every player was waiting for the others, the deadline was nearing and nothing was done."

Early this year, the take-up rate was projected to increase to 80% in June.

Another example can be found in data link, the widespread use of which is deemed the cornerstone of ATM digitalization in Europe. Data link services enable the digital exchange of information between aircraft and the ground. Progress has recently picked up.

"In 2014-15, a tentative entry into service actually turned the spotlight on some problems. In 2016, the European Commission asked [the] SESAR DM to handle technical corrections, as well as ANSP and operator equipage," Warinsko says. The adoption rate grew to 68% in January, up from 40% in 2018, according to the SESAR DM.

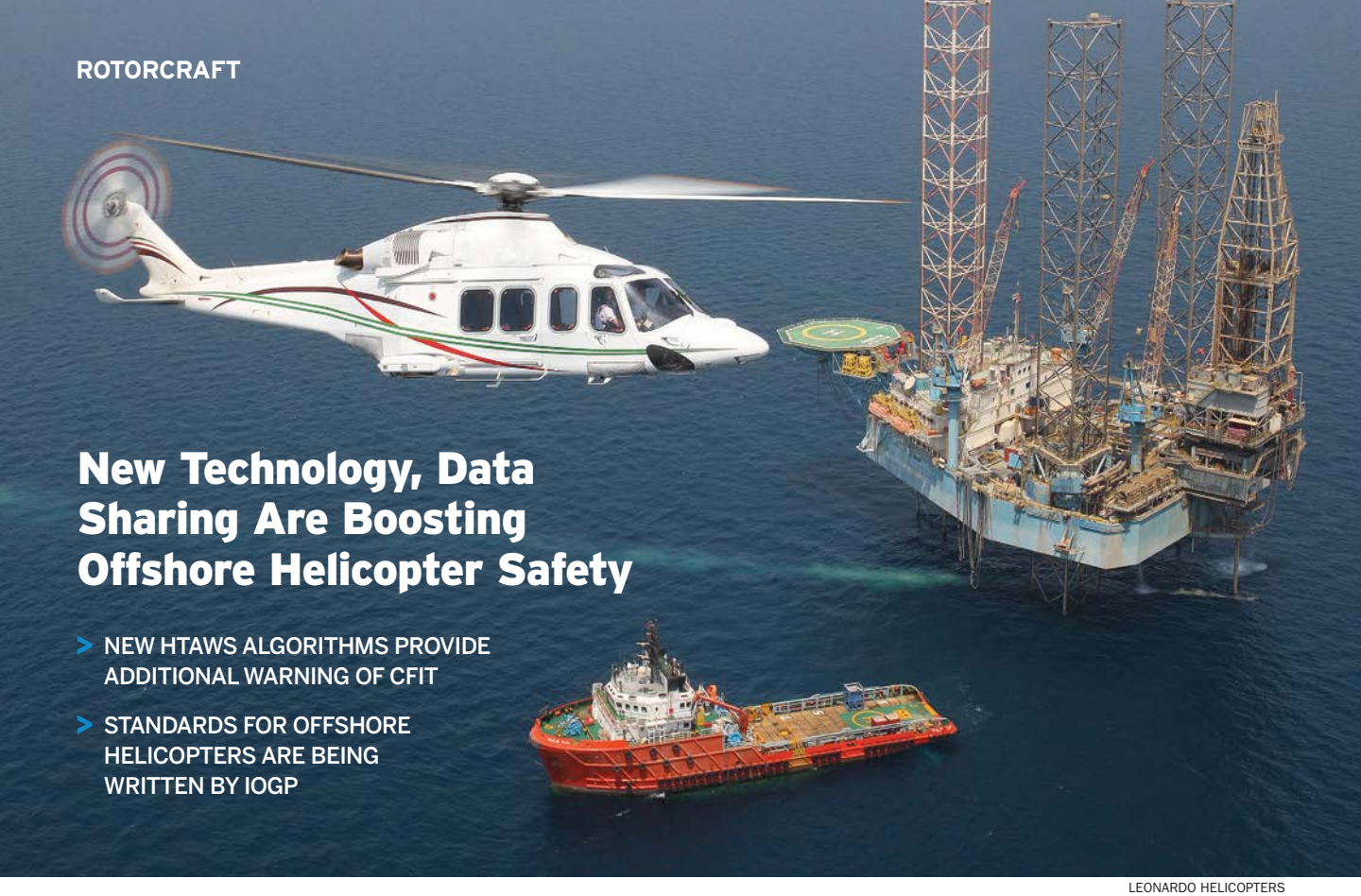
In 2014, both the ARINC and SITA ground networks were lacking capacity. Upgrading them to a multifrequency architecture from single-frequency solved the problem, according to Warinsko. "We managed the technological emergency, and we are now ahead of demand." Nevertheless, a complementary technology is thought necessary in the future. The SESAR DM's experts are considering curbing the load on ground networks by using a space-based infrastructure.

To make the case for further investment in the program, the SESAR DM is emphasizing how research and development has resulted in improved ATM in Europe. "SESAR delivers in the world of commercial operations," Warinsko says.

Since the program's launch in the mid-2000s, 142 of the 345 planned projects have been put into operation. Planned flight-time savings were to be 25,000 hr. in 2020, according to numbers released before the crisis and based on the assumption that 150 projects would be completed by June. The total was predicted to increase by a factor of 13 by 2030.

Fuel-burn savings were calculated at 25,000 metric tons for this year. This was planned to grow 14-fold by 2030. The European Green Deal, proposed by European Commission President Ursula von der Leyen, heralds the movement of environmental issues to the top of the EU's agenda, and the theme has grown in importance in SESAR's promotion.

For the 345 projects planned to be competed by 2030, a combined €2.9 billion ($3.2 billion) is calculated to be spent, including €1.3 billion in public funds. The projects will generate an estimated €16 billion in savings.



New Technology, Data Sharing Are Boosting Offshore Helicopter Safety

- NEW HTAWS ALGORITHMS PROVIDE ADDITIONAL WARNING OF CFIT
- STANDARDS FOR OFFSHORE HELICOPTERS ARE BEING WRITTEN BY IOGP

LEONARDO HELICOPTERS

Tony Osborne London

The novel coronavirus pandemic may have thrown another curveball at the long-suffering offshore helicopter industry, but in the meantime the sector is making transformative safety gains.

Concerns that low energy prices could drive operators to cut costs and so compromise safety have fortunately not materialized. Instead the industry is cooperating its safety body HeliOffshore to introduce new technology, industry data sharing and updated standards, with the aim of being as safe as its fixed-wing equivalents.

Since its launch in 2014, the London-based nonprofit's membership has grown to 50 offshore operators in addition to energy companies and the helicopter OEMs (*AW&ST* Oct. 6, 2014, p. 31). At its heart, HeliOffshore's approach takes advantage of data sharing to understand safety challenges affecting the sector.

"We can proactively target our resources onto the few things that are going to make a difference," says HeliOffshore CEO Gretchen Haskins, a human factors safety expert who was one of several authorities on a special committee to review the FAA's certification processes in light of the Boeing 737 MAX accidents.

An early success for the organization has been the development of Flight Crew Operations Manuals (FCOM) by the OEMs, now written for most helicopters serving offshore. Although FCOMs were already common in the fixed-wing world, the helicopter industry had left it up to operators to develop their own procedures for the technologies introduced in new platforms. Most OEMs now produce FCOMs for their platforms used offshore, allowing pilots to understand the design and automation concepts for each type; Bell is even working on an FCOM for its fly-by-wire Model 525. With the introduction of FCOMs, the "operators see the benefit of using everybody's knowledge and experience," Haskins says. Operators are increasingly adopting FCOM procedures, and the process is becoming smoother with the introduction of new types.

Another significant project for HeliOffshore has been the use of Human Hazard Analysis, an approach used in the nuclear industry to look for single points of failure that could lead to a catastrophic outcome. The review has resulted in "enhancements to procedures, changes in design and improvements in training," Haskins notes.

An example would be a component that could be inadvertently installed upside down. If it cannot be redesigned to prevent incorrect installation, then the risk of that possibility should be made clear and procedures put in place to prevent it. "It is a case of putting in layers of defense to prevent such events," Haskins says.

Leonardo's AW139 will be the first type to benefit from the new algorithms in HTAWS.

Airbus Helicopters has agreed to make Human Hazard Analysis a part of its design process going forward for all helicopters, Haskins says.

HeliOffshore has also been working with industry on adaptations to the Helicopter Terrain Awareness and Warning System (HTAWS) for use over water.

Although the technology has been around for years, HeliOffshore along with the UK Civil Aviation Authority, the International Association of Oil and Gas Producers (IOGP) and several operators have jointly funded new HTAWS capabilities, including seven new operational modes. HeliOffshore's examination of offshore accidents found that controlled flight into terrain (CFIT) is the largest single cause, claiming 41 lives in 10 accidents since 2013.

The new HTAWS modes significantly boost warning times, giving pilots more time to see, react and avoid a collision."This is going to be a lifesaving technology because it just helps the pilots to see and avoid obstacles," Haskins says.

The first OEM to implement the advanced systems will be Leonardo Helicopters with its AW139 twin-engine medium helicopter, through its Phase 8 upgrade to the aircraft's Honeywell Primus Epic avionics suite. Sikorsky and Airbus will follow suit, and Bell plans to integrate them onto the Model 525.

New technologies such as HTAWS are likely to feature in new offshore helicopter management guidelines being written by the IOGP. These standards will likely involve the latest technology and data techniques as they develop and could drive a new wave of offshore helicopter procurement. At Heli-Expo in January, Shell Aircraft, a company with a lengthy track record of driving offshore helicopter safety, called for adopting the Airbus H160 into offshore operations. And Norwegian energy company Wintershall Dea has called for introducing the Bell 525 into North Sea offshore operations.

The North Sea continues to be a testbed for safety technologies. Last year, HeliOffshore collaborated with UK air navigation service provider National Air Traffic Services (NATS) to trial automatic dependent surveillance-broadcast (ADS-B) technologies to support safe helicopter operations around the platforms. NATS began using ADS-B Out to provide surveillance in the area last March, and the helicopter operators have been looking at testing ADS-B In to deliver enhanced weather and rig-identifier information.

Haskins says the technology could warn pilots of conditions such as triggered lightning, a phenomenon caused by the interaction of the helicopter's rotor blades and positively charged cloud formations, which can be dangerous for aircraft operating offshore (*AW&ST* April 21, 2014, p. 49).

"Even in this time of crisis, offshore helicopters are a critical service," Haskins says. "This is an industry that's shown it can collaborate and cope during challenging times," he adds. "COVID-19 represents a new level of challenge, and we are going have to use the things that have worked well and foster innovation to find new ways of getting our mission done."

Speedy Adaptations Help Helicopters To Fight Pandemic

> LEONARDO HAS DEVELOPED BIOLOGICAL CONTAINMENT ADAPTATIONS

> BRISTOW AND CHC ARE EVACUATING OIL WORKERS FROM OFFSHORE PLATFORMS WITH MODIFIED AIRCRAFT

Tony Osborne London

The COVID-19 pandemic may have brought the airline industry to a halt, but for helicopter operators—both offshore and onshore—the routine of daily operations continues.

The rotary-wing industry has had to quickly adapt its aircraft and procedures for the need to carry patients with confirmed or suspected cases of COVID-19.

Nowhere has this need been more acute than in Italy, the epicenter of the outbreak in Europe.

Dozens of helicopters there, both civilian and state-operated, have been requisitioned for use by the Civil Protection agency to transfer patients from hospitals in the north overwhelmed by the illness to less affected facilities in the south.

LEONARDO HELICOPTERS

The biological containment capsules are bulky and leave little room, even in the cabin of a 4.8-metric-ton (10,600-lb.) Leonardo AW169.

Italy has the benefit of a large fleet of helicopters serving with various government agencies as well as commercially operated emergency medical helicopters. But few, if any, have ever had to be equipped to cope with such a highly contagious virus, and the equipment to carry patients has not been certified.

At Leonardo Helicopters, a "hot team" of engineers, usually devoted to resolving airworthiness or urgent requests from customers, has been working on developing installations and procedures for the use of stretchers fitted with biological containment capsules.

Such devices "are big, bulky plastic containers ventilated by forced air from an electrical motor with a battery that lasts 10 hr.," Leonardo Helicopters Chief Technical Officer Matteo Ragazzi tells Aviation Week. "There was no installation that was actually certified for aviation use, so we had to talk with EASA (European Union Aviation Safety Agency) and our national agency ENAC and work with them on developing a risk-based approach for the installation."

The configuration had to allow not only for the installation of the capsule but also room for medics to look after the patient in flight while also maintaining isolation between the cabin and the cockpit. The engineers developed installations, instructions and procedures for the company's AW169, AW139 and AW189 twin-engine helicopters.

"It is not a one-size-fits-all solution,"

Ragazzi adds. "We could not do this with a twin-engine light helicopter [because] you have to have a roomy cabin for the medical staff to be able to work on the patient."

Leonardo has passed details of the installations on to other airworthiness agencies with the expectation that similar configurations will need to be used elsewhere.

For patients with more complex needs, the company also developed modifications for the AW101 three-engine heavy helicopters being flown by the Italian Air Force.

These aircraft have been used for patients challenged with other underlying health complications that, along with the special biological protection stretcher, require additional medical equipment.

The Norwegian Air Ambulance service has begun using an Airbus AS332L1 Super Puma modified in nine days to carry a capsule stretcher and three medics.

Similar issues have challenged the critical energy industry, concerned that an outbreak offshore could have a serious impact on production.

Faced with potential outbreaks of COVID-19 on offshore oil and gas platforms, offshore helicopter operators have adapted parts of their fleets to be able to collect suspected COVID-19 cases from the rigs. In the North Sea, both Bristow Helicopters and CHC have modified several aircraft for COVID-19 cases. Bristow is using a trio of Sikorsky S-92s previously used in the search-and-rescue role. They are equipped with protective curtains to separate the cockpit from the passenger area, airflow systems and adjusted seating. Specific entrance and exit points are designated for each of the flight crew, paramedic and passengers to further ensure required distance is maintained. Each aircraft undergoes a full decontamination process after every flight.

Oil and Gas UK, a British trade body for the energy industry, has written guidelines for passengers heading to the rigs, categorizing passengers according to whether they have been in contact with the virus or are showing symptoms. Different categories of passengers cannot be mixed, the guidelines say.

A similar mission is being performed by Bristow in the Gulf of Mexico and in support of energy extraction operations in Trinidad and Tobago and in Guyana using a mix of AW139s, Sikorsky S-76s and S-92s.

Looking to the future, Leonardo is taking steps to develop a fully certified installation that would form part of the medical equipment for emergency medical service (EMS) helicopters.

Ragazzi notes that the bulky nature of the equipment, particularly the stretcher, could encourage EMS operators to look again at larger helicopter models, rather than the light single/twin-engine helicopters often used today. Larger cabins could allow medical crews to provide enhanced care or treatment during the flight to the hospital (*AW&ST* April 8-21, 2019, p. 55).

Big Questions

- SOFIA SET TO BE TERMINATED IN FISCAL 2021
- STUDY FINDS 767 AND POSSIBLY P-8 GOOD DC-8 SUCCESSOR OPTIONS

Guy Norris Los Angeles

Delivered to Pan Am in May 1977, the converted 747SP began space science observation missions in 2010.

NASA's two largest research aircraft, the Boeing 747SP airborne observatory and the McDonnell Douglas DC-8 flying laboratory, face an increasingly uncertain future amid budget reductions and growing problems of parts obsolescence.

Funding for the 747SP Stratospheric Observatory for Infrared Astronomy (SOFIA), which has been flying science missions since 2010, is now earmarked for termination in the agency's fiscal 2021 budget request. NASA has meanwhile begun studies of potential midterm successors to the DC-8-72, which it acquired in 1985 for airborne sciences research but is now becoming increasingly hard to support.

SOFIA, which was developed by NASA in partnership with DLR, the German Aerospace Center, was singled out for grounding because of its high operating costs and relatively low science productivity compared with other large science missions. The specially modified 1977-built aircraft incorporates an 8.2-ft.-effective-diameter reflecting telescope, the largest ever to be flown, and conducts observations in the stratosphere at 38,000-45,000 ft., putting it above 99% of the Earth's infrared-blocking atmosphere.

The observatory—which, along with the DC-8, is operated and maintained by NASA's Armstrong Flight Research Center—is managed for space science missions by the agency's Ames Research Center in cooperation with the Universities Space Research Association and the German SOFIA Institute at the University of Stuttgart. The 747SP, however, competes for astrophysics funding with the agency's Hubble Space Telescope, and from 2021, NASA will also be spending an estimated $172 million per year to operate the upcoming James Webb Space Telescope.

SOFIA received $85.2 million in the fiscal 2020 budget and will continue to operate for now, along with other funded agency aircraft and science systems, says David McBride, director of NASA's Armstrong Flight Research Center. He confirms, however: "The president's budget request for [fiscal 2021] does eliminate funding for SOFIA. The elimination of SOFIA has been proposed by the Office of Management and Budget in previous years. Congress determines the enacted budget for [fiscal 2021] and will determine the ultimate fate of SOFIA in [fiscal 2021] and beyond."

Even before the looming budget crunch, SOFIA observation flights had been suspended because of the COVID-19 pandemic. But NASA says the SOFIA science center continues other operations via teleconferencing.

Unlike SOFIA, which is scheduled to be put in long-term storage under current plans, the fate of the DC-8 is not expected to be decided for some time, says McBride, who acknowledges that long-term studies for its replacement are underway. "The DC-8 has long been a valuable asset for the agency," McBride says. "While it is a rugged airframe and works well in its current mission, Armstrong Flight Research Center is evaluating our options for replacing the aircraft in a manner that maintains our role in supporting NASA's airborne science mission. As an aging aircraft, it is more difficult to acquire spare parts, but we can continue to fly the aircraft for several more years."

The study of alternate aircraft options was "really a long-term, broad outlook that wasn't prescriptive but was more of a 'What sort of direction should we head in—something big or a fleet of smaller aircraft?'" says Thomas Ozoroski, a research engineer with Analytical Mechanics Associates, the Hampton, Virginia-based consulting group hired by NASA for the study.

Describing details of the concept study at the American Institute of Aeronautics and Astronautics SciTech Forum and Exposition conference in Orlando, Florida, earlier this year, Ozoroski says the evaluation "included discussions with scientists, and the key was to really listen to them and tie that together with the aeronautics requirements. They weren't always the same, but mostly they were."

Despite the vintage of the 1969-built DC-8, the airframe age itself "isn't much of a concern," Ozoroski says. "This aircraft flies only about 500-600 hr. per year, which in terms of airframe lifetime is considered relatively young. It has been modified a lot with cutouts for experiments and was converted into a -72 variant in the 1980s, when it was given new pylons and reengined with CFM56 turbofans [under the 'Super

70' retrofit program]. But there are growing concerns with operating an airplane that is this old," he adds.

Key supportability issues include access to the few remaining DC-8 flight deck simulators for training of the three-person flight crew and a shortage of spares for critical items such as tires. In the case of the latter, these are so rare that a spare tire, along with a DC-8-specific tow bar, are carried for science missions in the belly. "The spare tires are from a special manufacturing run of 50 produced by Goodyear. They don't make that tire anymore, and not being able to find more of them could be the thing that kills the ability to operate the DC-8," Ozoroski says.

The study modeled some of the DC-8 airborne science missions and evaluated the range and payload requirements against a range of alternative aircraft that included the Gulfstream G-V; Boeing P-8 (military derivative of the 737-900ER), 767-200ER and 777-200LR; and Airbus A330-200. "We didn't have the A321 in the list, but it is a possible as it's kind of a one-to-one trade," he adds. "But we also wanted to consider the possibility of a fleet of aircraft. There was some talk of using a fleet of G-Vs to do what the DC-8 does."

Three calibrated missions were used for the aircraft performance models, including a flight with maximum payload and fuel to bring the aircraft to maximum takeoff weight (MTOW), a flight with maximum fuel and sufficient payload to equal MTOW, and a ferry flight-type condition with maximum fuel and zero payload weight. The results helped to differentiate the capabilities of the candidate replacements, and the calibrated models were run to predict performance for selected airborne missions. These ranged from regular long-range transport flights and more demanding vertical-sampling science missions, including multiple climb-and-descent segments, to long-duration smoke-survey flights at low level.

The results indicated that of all the candidates, the 767 may be the best option. "The 767 is very similar to DC-8 in size and, being a semi-wide-body, fits the sweet spot in terms of being able to mount instruments along the sides without having wasted space in the middle," Ozoroski says. "The 767 is a nice blend of capabilities," including additional range, capacity and reduced operating costs compared with the older Douglas jet.

The P-8 emerged as a close runner-up while offering marginally less mission capability. The 737 derivative uses "substantially less fuel per mission," the study found, and could be useful for those cases that do not require the full capabilities of the current DC-8.

JIM ROSS/NASA

Although the DC-8, built in 1969, has airframe life remaining, spare parts such as tires are increasingly hard to source.

GUY NORRIS/AW&ST

Station Scramble

> BOEING TO REFLY UNCREWED STARLINER

> NASA PINS HOPES ON SPACEX

Irene Klotz Cape Canaveral

On Nov. 2, NASA will mark 20 years since the Expedition 1 crew reached the International Space Station, kicking off an unbroken succession of astronauts and cosmonauts living aboard the orbiting outpost.

But the chain is starting to thin. The Expedition 63 crew, which arrived at the station on April 9, will be short-staffed. NASA has yet to announce astronauts for follow-on missions, including who will be onboard when Expedition 63 Commander Chris Cassidy and his two crewmates return home in October.

ANDREY SHELEPIN/NASA/GCTC

NASA astronaut Chris Cassidy was accompanied to the launchpad at the Baikonur Cosmodrome in Kazakhstan on April 9 by mask-clad support personnel as the COVID-19 pandemic continued.

NASA had hoped to be flying astronauts onboard Boeing's CST-100 Starliner and SpaceX's Crew Dragon by now, but technical problems delayed both programs. SpaceX is in position to emerge from the quagmire first, though analysis of a Falcon 9 premature engine shutdown during a March 18 launch and a botched Dragon 2 parachute test on March 24 remain underway.

If those issues are resolved and remaining work completed, NASA astronauts Robert Behnken and Douglas Hurley could launch in late May or June for a flight test to the International Space Station (ISS). No launch dates have been scheduled, U.S. Air Force Brig. Gen. Douglas Schiess, the Eastern Range commander, told reporters April 9. Behnken and Hurley are training for a possible longer stay on the ISS to help bridge the staffing shortfall.

NASA last year began training the Boeing Starliner flight-test crew for a potential extended ISS stay of up to six months, but those astronauts are extremely unlikely to reach orbit this year. Boeing instead will repeat an uncrewed Starliner flight test following a troubled trial run on Dec. 20-22, 2019. The Orbital Flight Test 2 (OFT) is targeted for October.

"Flying another uncrewed flight will allow us to complete all flight-test objectives and evaluate the performance of the second Starliner vehicle at no cost to the taxpayer," Boeing said in an April 6 statement. "We will then proceed to the tremendous responsibility and privilege of flying astronauts to the International Space Station."

Boeing's investigation into software glitches that marred the orbital flight test of its CST-100 Starliner commercial space taxi is nearing completion, with no additional major errors discovered, spokesman Joshua Barrett said.

"To date, we have not found any additional errors with similar or anywhere near the same mission-impacting significance as the two declared issues," Barrett wrote in an email to Aviation Week. "There were a few cases where nonmission-impacting system adjustments will be made, but these are as expected during any first-time flight test."

OFT-1 failed to dock at the ISS as planned due to a software error that missynchronized the Starliner's mission-elapsed timer with the actual mission-elapsed time. The error cost the Starliner its first attempt to fire thrusters to reach the station's orbit. A communications problem then scotched a follow-on effort to position the Starliner for an ISS rendezvous.

Instead, Boeing conducted a two-day free-flying test, demonstrating the Starliner's systems and extending and retracting its docking ring. The capsule then successfully deorbited and parachuted to a touchdown in New Mexico.

During the abbreviated flight, Boeing engineers uncovered a second software issue that could have caused the Starliner's jettisoned service module to collide with the capsule after the deorbit burn. Those problems prompted NASA, on March 6, to declare the mission a "high-visibility close call," enabling it to broadly share lessons learned from the investigation.

Boeing and NASA decided to reverify the Starliner's entire flight software—1 million lines of code—prior to continuing with the flight-test program. The software verification process remains underway. "The work scope is well-understood and we are making good and steady progress," Barrett said.

The independent review team also is homing in on the likely root cause of the communications problem, which prevented OFT flight controllers from communicating with the Starliner via NASA's Tracking and Data Relay Satellites as planned. Recommended corrective actions are pending, Barrett said.

In January, Boeing reported a $410 million pretax charge in its 2019 fourth-quarter results to cover the cost of a possible OFT reflight, which would require the purchase of another Atlas V launch service from United Launch Alliance, among other expenses. Boeing is covering the costs associated with corrective actions needed after the OFT, Barrett said.

The delays with both Commercial Crew providers are hitting the ISS program just as U.S. paid rides on the Soyuz are coming to an end. Cassidy's April 9 launch was the last seat reserved under NASA's existing agreements with Russia's state space corporation Roscosmos. As Cassidy and his crewmates began their 196-day mission, negotiations for a ride for his backup, Stephen Bowen, were still underway.

LOGO ART: SHUTTERSTOCK

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COVER: THOMAS DE PIERRO

MAINTENANCE CHECK

The Origin of MRO

Twenty-five years ago, an event happened that would forever change the aviation aftermarket industry.

Three people saw a change coming in the airline industry and had a vision to harness the power of what they saw—and one made it happen. It was the birth of MRO—the acronym synonymous with today's aviation aftermarket, as well as the Aviation Week event series.

"The name and the first conference (MRO '96) in Dallas were hatched in a frenzy of meetings and brainstorming sessions headed by Ken Gazzola, Aviation Week's publisher; Don Fink, Aviation Week editor-in-chief; George Ebbs, president of the Canaan Group, a consulting firm that pioneered the expansion of MRO outsourcing and its modern supply chain; and Lydia Janow, who led the small Aviation Week conference unit at the time and provided the tradeshow executional expertise to produce the first MRO event . . . and every MRO thereafter, continuing to this day," says Greg Hamilton, Aviation Week Network president.

MRO '96 was held in Dallas on March 10-12 at the Fairmont Hotel's ballroom. Janow budgeted for 25 exhibitors and 350 conference attendees. "We ended up with 70 exhibitors (and a waiting list) and more than 500 conference attendees," she says. Although the curtain separating the conference and exhibition spaces did not drown out vacuuming underway during exhibitor setup, the conference was considered a big success. (We've improved details such as that since then.)

Gazzola had contacted Ross Perot, Jr., whose family led the establishment of Alliance Airport in Fort Worth, for his support. That entailed MRO '96 attendees touring the new airport, which was home to an American Airlines maintenance facility, and attending a spectacular Texas barbeque at Perot's Circle T Ranch.

At MRO '96, the theme of airlines needing to cut costs—by outsourcing maintenance and reducing inventories—was the hot topic. Airlines were being pressured to focus on their "core competencies" and shift other elements to suppliers. Stephan Regulinski, president of UAL Services for United Airlines, advocated outsourcing any maintenance that was not of a "value-added nature" for the carrier, but he cautioned, "United's employee ownership plan limits the airline from outsourcing more than 20% of maintenance work," according to an Aviation Week article about MRO '96.

Boeing President Philip Condit urged airlines and MROs to establish and sustain a "mutual dialog" with each to navigate this new world.

Engine OEM business fundamentals also were under pressure: Increased engine reliability decreased the number of powerplants needed, customers wanted cost guarantees and better service, and a Rolls-Royce speaker cited rising spares costs that were suppressing engine sales. This was prompting Rolls to "make it very difficult" for new entrants to get into its aftermarket.

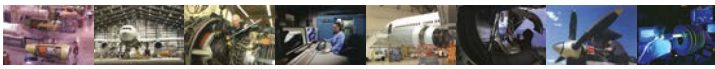
In 1996, *Overhaul & Maintenance*, the original name of this magazine that launched in 1995, pegged the MRO market to climb to $60 billion by the year 2000. Before the COVID-19 pandemic, Aviation Week was forecasting the 2020 commercial aviation MRO market dollar demand to be worth $91.2 billion, but now the forecast is 20-30% less.

Even with this drop, it's a big, dynamic market—and one that will continue to evolve and persevere. Happy 25th anniversary, and thank you for being part of it.

—Lee Ann Shay

AMERICAN AIRLINES

American Airlines CEO Doug Parker and I while touring the airline's Tulsa base before the big announcement (page MRO23).



Dear MRO Community Colleagues,

The global coronavirus pandemic is devastating in so many ways and of course has been debilitating across the air transportation community and its stakeholders.

Together, we face a situation with little to no route map. All of our families, businesses, communities and ways of life have been affected. It is difficult to focus on the future when we are consumed by the concerns of the present. With this in mind, we wanted to reach out and update you on how Aviation Week's MRO events team is navigating the situation.

MRO Americas has been rescheduled for Sept. 1-3, 2020, in Dallas at the Kay Bailey Hutchison Convention Center. The unprecedented postponement was necessary to protect our customers and employees. We also believe strongly that we should move forward with MRO Americas in 2020, as it plays an integral role in our customers' business operations. We worked to keep the event in Dallas, hold as much as possible to the original plans and expectations for this cornerstone of the MRO industry and harmonize with other industry events. We know there will be some scheduling hurdles, but we are confident this community will rally to overcome them.

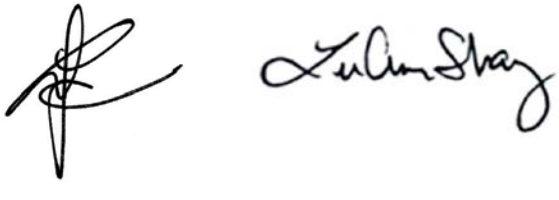
As we all deal with this crisis, our account and content teams remain focused on your success. All of our businesses are in uncharted territory, but the aviation industry has withstood many serious challenges, and Aviation Week's commitment to your success is unwavering. We are at the ready to support and provide flexible options for the best possible experience.

The conversations we've had with airline and MRO leaders and managers over the last few days have proven just how lucky we are to be part of this supportive, tight-knit industry. We are all being called upon to be our best selves and to exercise patience, understanding and compassion. This too shall pass, and we will rise, stronger and better than ever.

Stay resilient and safe during these coming weeks and months. We look forward to seeing you in September.

Lydia Janow
Managing Director
MRO & Air Transport Events

Lee Ann Shay
Chief Editor, MRO



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Highlights

Emergency Funding for U.S. MROs, Suppliers

The Coronavirus Aid, Relief, and Economic Security (CARES) Act sets up several new programs and adjusts some existing ones—each aimed at pumping much-needed cash into organizations or industry sectors. Large portions of the U.S. commercial aviation industry got specific carveouts in the $2 trillion economic relief package enacted March 27. While these loans and grants will help air carriers and other key industry players offset some financial losses and uncertainty caused by the COVID-19 outbreak, most suppliers will be looking elsewhere for money.

Thankfully, CARES act gives even the smallest companies options. Topping the list is the Paycheck Protection Program (PPP), a $349 billion pot of money designed to enable the U.S. Small Business Administration (SBA) to provide "expeditious" relief to eligible businesses, says an interim final rule published late April 2. The PPP provides SBA-guaranteed loans equal to up to 2.5 times monthly payroll costs, with a $10 million cap, that businesses can use to keep the lights on for two months. Eligible expenses include payroll, health care benefits, rent and utility payments as well as some interest expenses. The loans come with a 1% interest rate, maximum two-year terms, and require no collateral or personal guarantees. And they will be forgiven if 75% or more of the funds are used to cover payroll.

Businesses can only apply for one PPP loan, so the SBA advises applying for the maximum eligible amount.

Determining eligibility is straightforward: A business must find its North American Industry Classification System (NAICS) code, check the maximum employee size for its business category and compare that to its staff size. While the general small-business benchmark is 500 or fewer employees, aerospace has many exceptions. The threshold for aircraft engine and engine parts manufacturing/maintenance (NAICS Code 336412) is 1,500 employees. For aeronautical instruments manufacturing (334511), it is 1,250. If your business falls under multiple codes, the one that generates the most work determines the NAICS code. SBA has an online tool that walks you through the process at sba.gov/size-standards

Woodward and Hexcel Cancel Merger

Key aerospace and defense (A&D) suppliers Woodward and Hexcel have called off their planned merger due to the novel coronavirus outbreak, ending a three-month saga that baffled many industry insiders and has since been overtaken by survival necessities.

"The pandemic has resulted in a need for each company to focus on its respective businesses and has impacted the companies' ability to realize the benefits of the merger during these unprecedented times," they said in a joint statement. Neither company will pay a breakup fee to the other.

In the joint statement, the CEOs of both companies—who know each other well—upheld their reasons behind the erstwhile "merger of equals." The stock-swap deal, announced Jan. 12, was supposed to create a horizontally powerful entity—not vertically integrated—that could capitalize especially on reducing material weight and other sustainability technologies increasingly demanded as commercial aviation battles its poor climate-change image.

But financial analysts and aerospace advisors never bought the pitch and openly questioned the combination of such different companies—Hexcel is a leading provider of composites to A&D while Woodward excels in aircraft parts and fluid- and motion-control systems. At industry conferences in February and March, many commenters told audiences they did not understand the reasons. Also, the stock prices of both have dropped around 57% since the merger announcement.

Contracts

GA Telesis acquired five GE CF6-80C2B1Fs from **Atlas Air** for parting out.

Israel Aerospace Industries has gained FAA certification for its Boeing 737-800 freighter conversion program. It has delivered two to unnamed customers.

Kenya Airways secured $49 million in government loans to cover scheduled overhauls for 11 GE CF34-10s on its Embraer 190s.

Lufthansa Technik has landed long-term technical support contracts from two Russian carriers: **Red Wings Airlines** for engine (V2500/CFM56) and landing gear maintenance for eight Airbus A320s and four A321s, and **Smartavia** for Boeing 737NG spare parts.

Magnetic MRO won an **Airbus** contract to provide airframe maintenance for operators and owners in Europe, the Middle East and Asia.

RUAG MRO Switzerland was selected by the **Royal Netherlands Air Force** for PC-7 maintenance.

S7 Technics won a five-year consignment stock contract from **Satair** covering exclusive aftermarket distribution of at least 350 part numbers in Russia/the Commonwealth of Indepedent States.

United Arab Emirates-based **VD Gulf** secured a long-term maintenance/modification contract from **GECAS**; the first job is a Boeing 777-300ER cabin modification.

Contract Source: SpeedNews

Aviation and COVID-19

The aviation industry has faced its share of disruptive challenges, and each time it has emerged stronger. With that in mind, Aviation Week is expanding our COVID-19 coverage with content that not only helps in the short term with news and situational awareness but also skews to predictive and best-practices content that will help our industry make good decisions now—and for the better times ahead.

Updates *Access coronavirus coverage from across the Aviation Week Network—including current news, a new weekly webinar series and expert forecasts and analysis of what's next for our global industry:* **Aviationweek.com/coronavirus**

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EASA Revises Antiviral Cabin Air Recirculation Guidance

The novel coronavirus pandemic has forced the entire aviation industry to change at a moment's notice and rethink formerly benign issues such as how flight decks are wiped down and whether cabin air systems, as designed, are sufficient for protecting those onboard. The European Union Aviation Safety Agency (EASA) addressed both issues as part of a safety information bulletin (SIB) series aimed at limiting the spread of the COVID-19—but not without creating some uncertainty.

EASA's SIB urged operators to crack down on pilots and cabin crew members using their own cleaning products on aircraft. Using unapproved cleaning agents can damage surfaces or mix with other cleaning agents to create fumes that could endanger passengers and crew members, the agency says.

"Aircraft operators should, to the practicable extent, provide appropriate and sufficient disinfectants (e.g., disinfectant wipes) for all crew members, and establish appropriate procedures/guidance on their use, making sure that all possible touch points and transmission-capable surfaces are appropriately treated," EASA says. "This should occur before flight crew compartment and cabin preparation, with emphasis on ensuring all aircraft systems are correctly set before use."

Approved procedures and cleaning agents are discussed in more detail in other agency guidance and recommendations from the European Center for Disease Prevention and Control, EASA says.

EASA's call came on the heels of an Air Line Pilots Association (ALPA) plea to the FAA for mandates aimed at U.S. operators. The FAA in mid-March FAA issued advisory material on how operators can protect frontline employees and passengers during the pandemic, but ALPA says more is needed. In a March 31 letter to FAA Administrator Steve Dickson, ALPA President Joe DePete said that some airlines are using cleaning agents that do not meet U.S. Centers for Disease Control and Prevention guidance.

EASA is urging operators to limit cabin air recirculation.

AIRBUS

"We are aware of airlines claiming to have cleaned aircraft with alcohol-based disinfectants that fail to comply with the minimum 70% alcohol-based solution," DePete wrote. "The FAA should make airlines aware of their obligation to stringently adhere to these standards. We suggest including a list of specific products recognized to disinfect for the virus causing COVID-19." FAA has issued recommendations to operators, but as of April 8, had stopped short of mandating them.

ALPA leaders met with top FAA officials on April 8 and came away less than satisfied.

"Unfortunately, the FAA is refusing to act, putting flight crews and the flying public at great risk," DePete wrote in a letter to Transport Department Secretary Elaine Chao. "This bureaucratic inertia needs to stop—and action must be taken now to protect lives."

In the U.S., flight attendants were raising novel coronavirus-related cabin health concerns well before the World Health Organization declared the situation a pandemic on March 11. The Association of Flight Attendants urged hand sanitizer stations at airports and in aircraft and provision of kits for flight attendants with non-latex gloves and N95 masks, among other precautions.

EASA's operational guidance also tackled minimizing the virus's presence in cabins. Aircraft with High Efficiency Particulate Air (HEPA) filters in their cabin air system are well-equipped to minimize spread of the novel coronavirus, but those without should consider minimizing cabin air recirculation, the agency concludes. EASA's latest information on preventing the virus and the COVID-19 illness it triggers—updated April 7—revises previous guidance that recommended using air conditioning, which draws in fresh air, as much as possible.

"Whenever performing commercial air transport of passengers during the COVID-19 outbreak, aircraft operators employing recirculation of cabin air are recommended either to install and employ HEPA filters, according to the manufacturer specifications, or to avoid the use of cabin air recirculation completely," the agency says. EASA adds that safety-critical functions such as avionics cooling should be factored into any decision.

Recycling air lessens the load on air conditioning systems, which on most aircraft use air diverted from the engines. While this provides fresh air, it also reduces engine efficiency. Shut-

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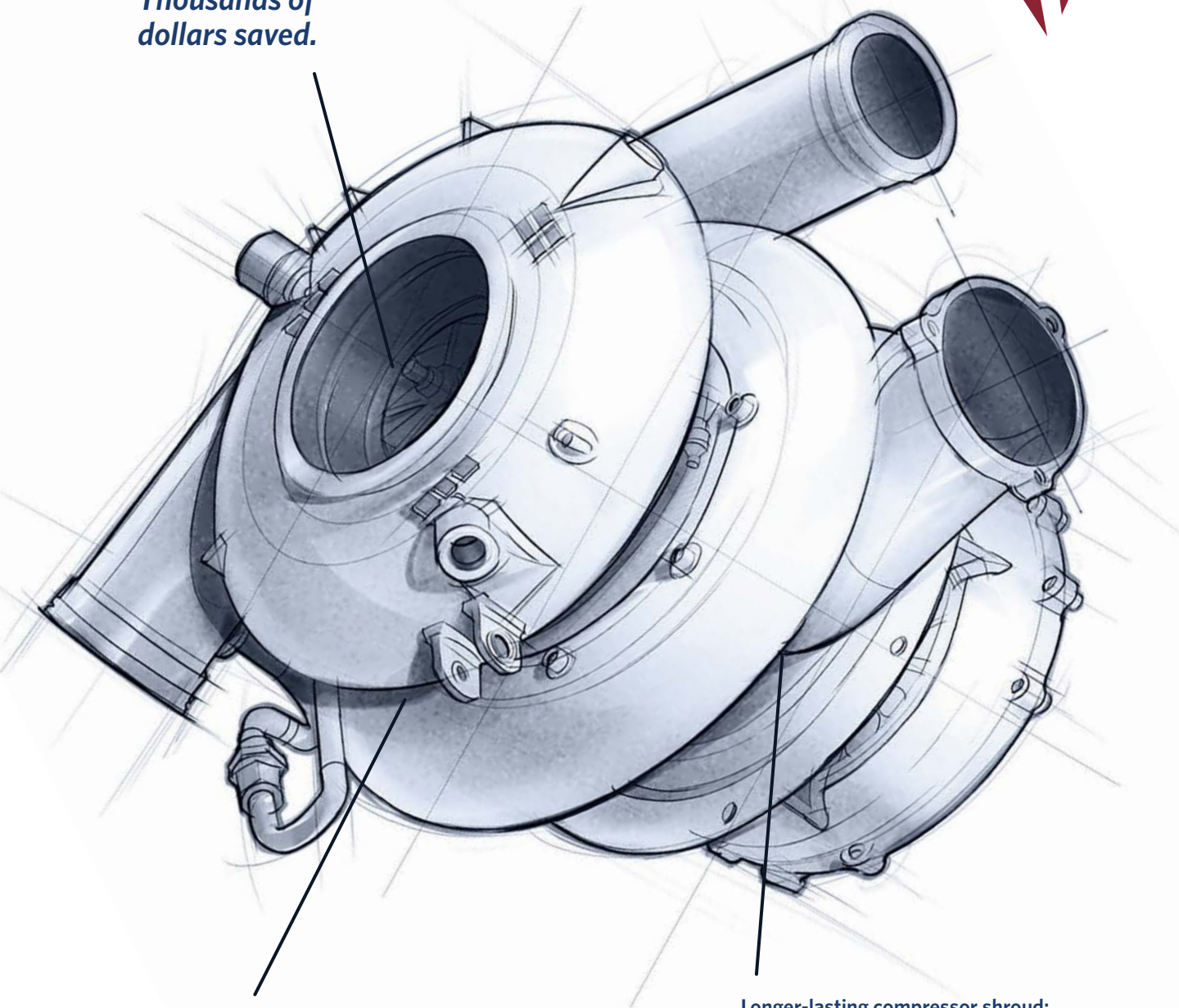

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ting off recirculation taps the air conditioning system, putting more fresh air through the cabin.

HEPA filters "have demonstrated good performance with particles of the SARS-Cov-2 virus size (approximately 70-120 [nanometers])," EASA explains. HEPA filters are standard on some aircraft—but not all. Suppliers including Donaldson and Pall Aerospace have developed retrofits for most transport category aircraft.

Even when using HEPA filters, EASA suggests operators boost fresh air intake by setting fan pack flow settings to "high" or the equivalent setting that increases fresh air flow.

"Operators should confirm with the aircraft manufacturers the practice of selecting the configuration high pack flow and follow their instructions for continuous use," the safety agency adds.

—Sean Broderick

FAA Adjusts Guidance and Policy Amid Pandemic

The FAA is adjusting on the fly to conduct as much of its oversight as possible while accommodating the new world order of social distancing: blending new processes, policies and deadline exemptions to keep operators compliant during the novel coronavirus pandemic.

As of April 8, the agency had issued 16 policy deviations and regulatory exemptions covering a wide range of issues. Many addressed training for pilots, cabin crew, dispatchers and others who are required to hold a license or to receive regular instruction. The general theme: Extend deadlines on recurrent training requirements to help avoid in-person instruction during the pandemic.

Pilots and flight engineers also will see upcoming medical certificate expirations extended through June 30. "Requiring pilots to undergo in-person medical examinations would further stress the health care system, and would increase the risk of transmitting the virus through personal contact between the doctor and the applicant," the FAA said.

In some cases, the agency is making small changes to allow surveillance to continue. For instance, airport inspections have not stopped, but inspectors and airport personnel are expected to practice social distancing.

In other cases, the agency developed procedures that will help industry stay compliant without requiring an FAA inspector's on-site presence. Foreign repair stations that already have approvals may not get annual inspections if travel restrictions prevent FAA personnel from getting to the shops, but they will not lose their approvals either. Other methods are being explored to safely bridge physical gaps with technology.

On March 31, the agency issued long-awaited policy on using real-time and recorded video "to perform prototype conformity inspections, engineering and ground tests, engineering compliance inspections, production conformity inspections, and inspections" for issuing 8130-3s, or airworthiness approval tags for parts and assemblies.

"Remote technology may have limitations that could render it unsuitable for some applications," the FAA said. "Accordingly, careful consideration and risk management should be applied when making a determination when to use it."

Video feeds were already permitted for observing certification-related tests, so long as the process is part of an FAA-approved plan. The new guidance, which has been in the works since 2018, broadens the use of remote feeds for use in training, inspections, and other procedures that manufacturers and maintenance providers need to comply with the agency's regulations.

"This is the new reality," says Sarah MacLeod, executive director of the Aeronautical Repair Station Association. "The agency has to be able to conduct normal activity and verify compliance as much as possible."

Another issue the agency has addressed: removing red tape so that Part 147 schools can shift to online classes for aviation maintenance technicians working toward their airframe and powerplant (A&P) certificates. Under current protocol, the FAA approves distance learning curriculum on a class-by-class basis—a process that the agency acknowledges can be "time-consuming." That is one reason only five of the 170 FAA-approved Part 147 schools had sought distance learning approval for their A&P candidates before the pandemic.

Updated guidance gives schools that comply with social distancing protocol the leeway to adopt temporary distance learning and testing programs for existing and newly enrolled students.

Agency approval is still required, but it is being fast-tracked. The FAA says about 40% of schools have asked for deviations, and 20% have suspended operations. The other 40% had yet to reach out to the agency.

—Sean Broderick

Temporary FAA policy will help repair stations and others maintain compliance during the pandemic.

SEAN BRODERICK/AW&ST

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ARSA UPDATE

Cooking Up Workforce Solutions

THE TITLE OF THIS PIECE WAS CONCOCTED ON THE spot by my colleague Christian Klein, ARSA's executive vice president, as he and I ran a workshop on aviation maintenance career development during ARSA's Annual Conference in March, before the coronavirus crisis hit the U.S.

As always, Christian provided an erudite "kicker" to set off the title: What do weekend cooking classes have to do with maintenance?

ANDERS RYMAN/GETTY IMAGES

Answering this question requires rewinding to a few minutes before Christian typed the words into his laptop. We were deep into the second hour of discussion on workforce and recruitment challenges, reviewing various government resources and programs available to businesses looking to stimulate technical talent. Wisely, he changed tack and asked the group for examples of useful retention activities.

One response stood out, if only because it was so unexpected: Cooking classes. Not just for employees, but for spouses and family members, together at special off-hours events hosted by the company.

The idea hasn't been implemented yet of course, due to the lockdown—you can stand ready for even more mouthwatering plays on words once it has been and we can report on it—but the underlying logic was quite interesting. Besides salaries, benefits and other "hard" payments to personnel, the company was considering what other "anchors" affect the decisions made by employees to change jobs.

The family experience, they determined, was key. Create a positive connection with the other people in your peoples' lives and make the company a part of that relationship.

We all know the stories of losing people. A technician can take another job for a marginal increase in pay, a slight change in commute or schedule, or in response to some other professional interest. Many do, and we hear routinely from larger employers (and some smaller ones) about the pains of investing in training and skill development for new people, only to lose them to others. We hear also about the cycle of technical personnel leaving for richer rewards elsewhere, only to turn around and seek even more from the company that had first hired them. In the worst cases, the story ends with those "boomerangs" actually getting what they ask for . . . when they weren't considered stellar performers the first time.

Surely, these discussions occurred during the workshop Christian and I were running, but let's stay with family engagement and what it means.

The basic idea is to create additional connection with wives, husbands, girlfriends, best friends, children and even, perhaps, pets. Doing so gives you allies, additional voices in the personal lives of your people who will advocate for your business should other options arise. A cooking class is a fun example, one that is meant to add a social element to the experience of your employees, but there are a number of other hard and soft benefits that play directly into the home lives of those who spend their working hours with you—family leave, educational opportunities, health resources and other activities can make a useful connection.

I've said before that one of the great blind spots in our industry-wide efforts to find new talent is that we overlook the challenge of keeping the talent we have. The working world has changed, and many employees don't intend or expect to spend full careers with the same company. Expecting to keep staff at all costs is foolhardy and probably against the larger interests of the maintenance community. Still, differentiating your company from other options is an important way to encourage people to stay and make your business more attractive than others.

This is where I ask for your input and feedback, so here it is: Help us learn more about how industry can inventively retain good people. Contact me at brett.levanto@arsa.org and share what you're cooking up.

Brett Levanto is vice president of operations at Obadal, Filler, MacLeod & Klein and an advisor to the Aeronautical Repair Station Association.

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Air Canada

Reliability is important to every airline, but it must be balanced against the cost of achieving it. At the recent International Airlines Technical Pool (IATP) conference, Henry Canaday spoke to Marc-Andre Huard, operations manager for components, about how Air Canada achieves this.


AIR CANADA

Is your basic objective to maximize technical dispatch reliability (TDR) while minimizing cost per flight hour or available seat-mile?

Yes, basically. But we also have an in-flight entertainment (IFE) metric—the percentage of seats that have IFE available for passenger convenience.

Are there TDR target metrics you can tell us?

It depends on the fleet. There is a range for each fleet. The older ones are lower, and the younger ones are higher. But there are also teething pains for younger jets. Also, we don't know initially which components on the new jets will fail the most often. OEMs tell us which ones are probable [to fail], but it usually takes two years to find out. Then we get into the golden age of low maintenance.

We publish these metrics internally in our control tower display. It shows the TDR for each fleet and IFE available, as well as causes and plans for action.

How much does a cancellation or delay cost you?

There are so many variables. We have a number for each fleet type. And for delays, it also depends on country. We must follow the rules for passenger protection that just went into effect in Canada. These went into effect last summer and increased on Jan. 15. Now the airline is trying to figure out the compensation.

What is your part strategy?

We use Servigistics to track failures. When a new aircraft is introduced, this tool is not as good. But once we are flying for a while, the tool gets smarter and makes recommendations. It tracks usage and how many flying hours we do. Then it tells us the likelihood of needing parts. It's not perfect. There is also the human [element], and you can always be misled. If we change parts sometimes, we adjust it. For engines, we have another group that looks at those.

Servigistics is also segmented. It's designed so we can specify 99% availability for no-go, low-cost parts. There are nine segments in all. We classify them as high-runners, medium-runners and low-runners—and low-price, medium-price and high-price. There are price limits for each segment. For low-cost, higher usage, no-go parts, we want [availability] there every time.

Servigistics takes information into account, calculates probabilities and makes recommendations on where we are short or where we have a surplus. Then we add in human factors.

Do you have flight-hour agreements?

Many. Half of our fleet components are on flight-hour agreements with OEMs Lufthansa Technik (LHT) and AAR.

Then why worry about part needs?

We still worry. We want to do a sanity check. Do we rent or own the right stuff? We get a home base kit and then we get two to three years of usage. So we want to do a sanity check and renegotiate so we can rebalance our home base kits as the platforms evolve.

Which other software do you use?

Our main [enterprise resource planning software (ERP)] for planning maintenance is Trax. Servigistics and Trax talk to each other. In 2013 we got Trax, and in 2015 we integrated them. Our old ERP, a DOS-based in-house system, only [transferred information] one way and [for] expendables, [not rotables], not [transferring information] in and out. We are happy with Servigistics and Trax now, but it was a difficult transition.

Why do you use IATP parts pools?

You can't have everything everywhere. It's easy if you go into some stations enough, like London eight times a day, where we put our own stocks. But if we fly seasonally into Athens a few times a week, we look for service providers. We ask other airlines because it costs less together. We don't have to buy parts, and we do not have to arrange logistics.

At the same time, I use the pool to offset spending on inventory at main bases. I carry inventory at Toronto, Vancouver and Montreal, and I can make revenue assisting an airline that only flies there once a week. It's a good way to generate revenue and help them out.

Is there a rule of thumb on how many times you must fly to a station to own your own inventory there?

No. Sometimes we cannot supply a wheel. Sometimes we

don't have the inventory to put there because the OEMs cannot supply the inventory fast enough. The minimum would probably be once a day, and we would try to put our own wheels there if we had the inventory.

Do you use any pools other than those from IATP?

Not really. We have access to the LHT pool under the flight-hour agreement, but that is a little different. We pay a flat rate for repairs and access to the pool.

For which parts do you use the IATP pool?

We use IATP for wheels and brakes and for no-go parts such as valves, engine components and wiper motors. [Wiper motors] are a simple but no-go item.

What are the advantages of IATP pools?

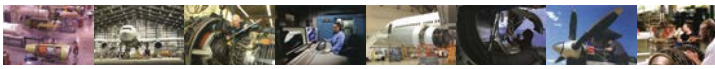
We can find other airlines that fly into our destinations. There is networking and getting to know people. The IATP conferences are a great venue for seeing new airlines that fly into a city we serve. Look at Starlux Airlines [which joined IATP in March]. They are just starting from nothing and in a few years will be flying 27 aircraft. They might fly into Canada, and I would not have known them except for IATP. If they called us and asked to borrow a part and I didn't know they were legitimate, I might fear losing thousands of dollars.

Aside from part pools, are you in other IATP pools?

We are in the aircraft recovery pool. It's very rare but very important if any of our aircraft ever went on an "excursion." You have got to be ready for that kind of event. And we are in line maintenance pools, but these are outside IATP. This IATP event is a good conduit to adjust those line pool agreements. We already know our line maintenance plan for this summer.

What do you hope to accomplish at this meeting?

For me, at every conference I find out the new operators that will fly into the places we fly to [in summer]. I want to make our parts available for other airlines to seek. Ethiopian Airlines just came to visit us. That can generate revenue. It's not huge, but we can make money from our inventory.



The MRO Generation

The maintenance sector has transformed itself in the past 25 years

Alex Derber London

Future histories of the aircraft MRO sector will probably cite as a pivotal moment the ongoing novel coronavirus crisis—and the changes its aftermath will force upon the industry. Yet writers of those histories would also do well to reflect on the factors that have shaped the aftermarket up to this point, some of which are now an entrenched part of its dynamics and some whose influence is only starting to play out.

From the 1990s and into the 2000s, the MRO sectors of successive regions had to adapt to the huge upheaval in the airline business caused by the rise of low-cost carriers (LCC). Lean, efficient and operating at aircraft utilization rates that had been unheard before that point, these new players were willing to outsource much or all of their maintenance. At the same time, they demanded stiff discounts and rapid turnarounds for fleet-wide support deals.

Pricing pressure was significant enough to cause a reconsideration of operations at SR Technics (which in the mid-1990s was the technical department of Swissair), recalls Jakob Straub, senior vice president of aircraft services, line maintenance and training services at SR Technics. "Some of our base maintenance activities were moved to Ireland, and we also had to offshore part of our services to low-cost countries, primarily to the [Asia-Pacific] region," he says.

Adapting to the new market demand also meant big changes to standard maintenance procedures.

"I remember when one of the new LCCs was entering the market and tendering their line and light maintenance services, they were asking for zero downtime in order to not cut out any operating hours," recalls Robert Gaag, Lufthansa Technik senior vice president of sales for Europe, the Middle East and Africa. "We thought, 'These guys are nuts!' But when you think about it, you can use all the time at night for maintenance, just not during the day. So you can design a maintenance program around it. Of course, today, that is standard practice in the industry."

ADDED FLEXIBILITY

Driven by the aircraft availability requirements of LCCs, aircraft maintenance programs drifted away from traditional letter-check intervals toward a more flexible approach endorsed by aircraft manufacturers. Thus, some elements of a traditional C check were incorporated into a work package equivalent to an overnight A check.

"We went away from letter checks and introduced a usage-parameter-based maintenance program, which allows a lot of flexibility in how you structure and schedule your

The advent and growth of low-cost carriers drove airlines to outsource more maintenance.

AAR

maintenance," says Bert Stegerer, head of maintenance and commonality marketing for Airbus. "You can optimize it for maintenance cost or for aircraft availability, so you can influence either the cost side or the revenue side."

At the same time, the OEMs sought to extend maintenance intervals and eliminate unnecessary tasks without compromising safety. These efforts have resulted in huge changes to maintenance scheduling over the past 25 years or so. For example, Airbus A320 A check intervals have gone from 350 hr. at entry into service to 1,000 hr. for the equivalent check today, while C check intervals have gone from 15 months to 36.

The effects upon MRO were not just felt from the LCCs themselves: Network carriers were forced to rethink their operations to compete, and often this meant a reduction of in-house maintenance capacity and the outsourcing of maintenance tasks such as engine overhauls and widebody heavy checks. Together with the rapid growth in the commercial aviation sector caused by LCCs, this resulted in a booming third-party MRO market.

"Growth of the global aircraft fleet and enlightenment among carriers to outsource their maintenance needs over the past two decades are [among] the key trends I have seen impacting the industry," says ST Engineering President Lim Serh Ghee.

Gaag notes that today's airlines have a mature, deep MRO market to which to outsource, but 25 years ago not all aftermarket incumbents had the scale to respond to the burgeoning opportunities for third-party work, paving the way for extensive consolidation over the following decades.

"Major airlines want to have major players behind them," notes Brian Loomer, vice president and general manager of aircraft services at AAR. "In the '90s, there were a lot of small private MROs providing services, and they have been bought up by large corporations delivering a much better service."

ENGINE MAINTENANCE

The last 25 years have also seen a thorough transformation of the engine maintenance business, as product design, materials, OEM strategy and data analysis have coalesced into a unique ecosystem that almost operates on a standalone basis within the aftermarket.

By and large, airlines have seen the reliability of engines shoot up. CFM says that time on wing for CFM56 engines has doubled since 2004, while unscheduled engine removals for the most popular -5B and -7B models have declined by 25%.

"The improvements in time on wing, coupled with thoughtfully designed and managed [life-limited part] lives, have enabled scheduled maintenance event timing to be pushed out, resulting in fewer shop visits over the life of the asset," says Aileen Barton, CFM marketing manager.

Widebody engine reliability has also improved, but unlike for narrowbody engines, this trend was accompanied by a reduction in maintenance provider choice as OEMs took over much of the aftermarket. This model, pursued most aggressively by Rolls-Royce, has driven further consolidation as MRO providers and airlines pursue OEM partnerships as the most economical method of adding new engine capabilities.

"For new-technology engines, you have to somehow cooperate with the OEM, or you are out," says Gaag.

CFM argues that this is not the case universally and that it remains committed to an open maintenance model that respects third-party providers.

"When there are competing MROs, such as in the CFM model, it drives not only lower maintenance cost but also improvements on intangibles, such as service quality, slot availability and ease of doing business or customer service," says Barton.

That said, it is undeniable that in recent decades, manufacturers of a range of aircraft components have emerged as significant competitors to MRO providers. "Competition was less [25 years ago], as nowadays the after-sales market has become attractive to the OEMs, which tend to regulate the spare-parts market with high parts prices and the proprietary rights with licence and royalty fees," says Straub.

"In 1995, the airframe manufacturers were clearly focusing on building airplanes," Gaag says. "Now they are getting in the turf of MROs. On the other hand, system OEMs are getting more independent from airframe OEMs. So there are more selected partnerships between MROs and system OEMs possible."

RISK TRANSFER

For engine and aircraft support, consolidation among MRO providers and more outsourcing by airlines were allied to the growth of full-service maintenance deals and a reduction of time-and-materials contracts in favor of support billed according to equipment use—on a dollar-per-flight-hour basis.

For airlines increasingly focused on their core operations of transporting passengers, simplicity was vital. As such, many preferred to outsource maintenance to a single company rather than manage numerous providers, a trend that has endured. "Many smaller MROs have been bought up, as you need to be able to offer a one-stop-shop solution for the current customers," says Loomer.

At the same time—starting in the mid-1990s—OEMs such as Rolls-Royce were pioneering full-service contracts billed on a per-flight-hour basis, the popularity of which boomed as they transferred the risk of unscheduled maintenance from operator to maintenance provider. And since the OEM was also the maintenance provider—at least in Rolls-Royce's case—such contracts also incentivized it to improve the reliability of its products.

Per-flight-hour support deals were quickly picked up by other component OEMs, while MRO providers, encouraged by the trend toward better reliability, also started offering them, particularly for component support.

"We tend to think that Lufthansa Technik invented the [cost-per-flight-hour] program for full component support of a commercial aircraft fleet in the second part of the 1990s," notes Gaag. "For the first time, a complete integration of all required spare and MRO services for all line replaceable units was established."

Besides transferring risk, another attraction of comprehensive deals was guaranteed availability of spare parts. This was enabled by another big MRO trend of the last 25 years: a shift away from individual operators holding large inventories and toward participation in pooling programs.

Parts pooling is now a common feature of the engine and landing gear aftermarkets and is also used for other compo-

nents, although its popularity varies, according to Gaag. "This was extremely successful in Europe but not so much in other parts of the world, for example in North America," he says.

Other strategies to mitigate the cost of spare parts, prices of which have risen above inflation for many years, have included parts manufacturer approval (PMA) parts, designated engineering representative (DER) repairs and used serviceable material (USM). Although these are all important elements of the MRO story, it is possible that OEM maintenance

LUFTHANSA TECHNIK

Predictive maintenance is part of a broader digitization trend that includes advances in manufacturing.

contracts and lessor contracts have prevented PMA parts from proliferating as much as expected. USM, in contrast, has gone from strength to strength, although it is another also vulnerable to the COVID-19 crisis, which could flood the market with parts stripped from aircraft of failed airlines.

TECHNOLOGY

Maintenance exists to support equipment, so changes in airframe, avionics and engine technologies will always require adaptation from MRO providers. Often this means new tooling and training, but sometimes technological change is so profound that it leads to new business models as well.

Although the basic form of passenger aircraft has not changed much in the past 50 years, the use of carbon fiber has increased over the last 25 years as manufacturers sought weight savings across more parts of the airframe. In turn, MRO providers had to expand their expertise from metal repairs to support of composite materials, adding a host of new inspection, testing and repair processes.

"If you want to get into deep repairs, you need an autoclave of a certain size," notes Gaag. "This is a very expensive investment that requires high utilization once you have it."

At the same time, the spread of composites across aircraft has meant certain inspection tasks are no longer necessary, notably fatigue- and corrosion-monitoring on parts previously made from aluminum. Another technology change that has lightened maintenance workload is the shift to fly-by-wire controls and flight control computers.

"If you have a mechanical flight control system, then you have to adjust cables and check for wear and tear, but all that is gone if you use just electrical signals," notes Stegerer.

Airlines also have benefited from better engine sensor data and vastly improved means to analyze it through machine learning and artificial intelligence, both of which have underpinned the rapidly growing field of predictive maintenance in the past 10 years. For airlines, this has meant fewer unscheduled maintenance events and less downtime, while MRO providers have been able to add new digital services to their product offerings.

"Analytics can be used to define the optimum inspection interval based on the duty cycle for each specific engine, with the goal of minimizing line maintenance and unnecessary inspections," notes CFM's Barton.

Predictive maintenance is part of a broader digitization trend that also encompasses a shift away from paper-based records; advances in 3D printing; automation of certain testing, inspections and repair procedures; and the first steps toward better parts and life-cycle tracking via experiments with distributed ledger technology. With the probable exception of predictive maintenance, few of these developments are mature enough to have significantly influenced MRO until now, but many are likely to do so in the coming decade, in some cases simply because the aircraft aftermarket lags so far behind other sectors.

"Why can an airline manager track the $10 book he ordered yesterday at any point in time, but not his $100,000 aircraft part to and from an MRO? We need to be better than that," states Gaag.

RECRUITMENT

While MRO providers look forward to efficiencies provided by new technology over the next decade, they also fear the growing shortage of technical staff. And since the maintenance business is likely to remain dependent on touch labor for the foreseeable future, the implications of this shortage are potentially far more significant than any gains realized from new technology.

"Recruitment really became an issue around 2015. Prior to that, it wasn't a major concern," says Loomer. "As the baby boomers started to retire and airlines at the same time started to hire more technical staff, it has had a major effect on the MROs. The industry has a major challenge looking forward, as we see a technician workforce shortage."

Gaag speculates that aircraft MRO providers' difficulties in attracting and retaining staff might have to do with a deromanticizing of the sector. "I have the feeling the profession of an aircraft mechanic does not have the same appreciation it had in Western societies 25 years ago. We are missing the aviation enthusiasts that we used to have," he says.

Here again the influence of LCCs is detectable, for they transformed air travel from a small luxury into a mundane part of modern lifestyles, at least in the West. OEMs and MRO providers have tried to rekindle interest with outreach programs, educational partnerships and even their own dedicated training colleges, but more may be required.

"We have to become better at selecting sites not necessarily at the lowest-cost location but close to young people who are interested in aviation," says Gaag. "And we have to do better to keep them."

Another—unwelcome—solution to the manpower shortage is possible. Maintenance demand could collapse following the COVID-19 crisis if it causes many airlines to fail and the survivors to reduce their fleets. For that reason, MRO managers must hope that recruitment remains a concern in a year's time.

The Executive Perspective

Aviation Week launched the first MRO event in 1996, which also launched the term "MRO." To celebrate 25 years of the industry, Inside MRO *reached out to some executives around the world to get their opinions on a few key questions about how the industry has evolved—and how it most likely will change in the decades to come.*

JOAN ROBINSON-BERRY

Vice president and chief engineer, Boeing Global Services

Over your career, what do you think had the biggest impact on MRO and why?

Looking back, I can't say there is a single "biggest impact" area but rather intertwined challenges, opportunities and observations that have shaped where MRO is today. And with thoughtful consideration, these learnings can help create an MRO evolution in the aerospace sector.

Boeing Global Services provides technical solutions for our commercial and government customers around the world. And we've been able to deliver on these by attracting and retaining a diverse, motivated workforce. But it hasn't always been easy, with MRO activities moving from paper records to digital solutions. It can be a challenge to find maintenance technicians with top-secret clearances and software engineers and aviation data scientists who have the critical thinking skills needed to perform with precision. This is why apprenticeship programs and internships that deliver hands-on career preparation are so important—they enable and help build a skilled workforce with top talent.

Another area that has impacted—and will continue to impact—the MRO services market is the ability to be more integrated and standardized, so that the value chain can deliver day in and day out for our customers. It's not an "us" or "them" mentality but a "we," and by having standards and common protocols in place, we have the opportunity to deliver improved operational efficiency for every single customer around the world. We can help connect the dots between OEMs, suppliers and MRO providers in such a way that the industry is better trained and aligned for improved quality and outcomes.

The manufacturing industry has also had an impact on MROs, particularly when needing access to a robust parts supply for older aircraft. Maintainers can't do their job if they don't have access to a seamless parts supply. It's about having the right part at the right time and in the right place. That's where advancements with additive manufacturing or innovative programs such as Boeing's used serviceable materials program can drive efficiencies and value for the aviation industry.

The MRO market has evolved and will continue to evolve as the industry accepts new innovations, advances technical solutions, partners for standardization and invests in training a skilled workforce.

ANNE BRACHET

Executive vice president, AFI KLM E&M

What is the biggest current challenge the MRO industry is facing?

The current circumstances are exceptional and have resulted in greater levels of unpredictability. Adaptiveness is part of our DNA. More than ever, during this coronavirus situation our teams are mobilized to support our customers as well as possible while following local government restrictions. They will be ready and engaged for a restart, whatever the time necessary for a new "takeoff" of the economy, but the situation is too fluid and uncertain to have a clear vision of the future.

The only certainty in a changing world, as we see it, is that innovation and adaptation will drive the business.

Environmental consideration issues will likely be one of the major challenges for players in the MRO market. Airlines around the world are challenged regarding the impact of their operations on the environment, and maintenance activities must play a role and take their full place in meeting this challenge. This is not a new issue for AFI KLM E&M, as we are already well-advanced in terms of circular economy or the reduction of polluting emissions, but this trend will accelerate over the next 10 years, and that will give us another opportunity to positively meet the times.

What do you see as the biggest opportunities and/or largest impediments in using data analytics to drive predictive maintenance?

In the digital field, Prognos is an important brick. Launched in 2016, it brings together different predictive maintenance solutions based on the exploitation of data from aircraft systems, in order to improve maintenance models and processes. We capitalize on the vast amount of data generated by the Air France and KLM fleets to develop these solutions and verify their relevance and operational performance before sharing these innovations with our customers.

For an airline, operational performance is a major challenge in terms of both economy and safety. Today, the use of data provided by the aircraft makes it possible to reduce the number of technical delays, reduce the number of technical tolerances and anticipate the interventions of maintenance personnel on the aircraft before equipment fails. We have several hundreds of aircraft that are tracked, and we reduce the technical effects felt by at least 50%. We are thus able to anticipate the arrival of a technical failure and reduce the volume of failures by 50-70%. Leveraging our in-

depth knowledge of aircraft systems, our ability to innovate and our big data skills, we are able to reduce operational impacts and the aircraft dispatch.

The main beneficiaries of this new branch of maintenance activities are passengers.

Predictive maintenance also has an impact on the supply chain and stock dimensioning. Because we can predict the needs of components, we can adjust the number of parts and where it is valuable to place them.

As another benefit, by reducing stock, repairing instead of replacing and reducing fuel consumption, big data technologies help reduce the environmental impact of the aeronautic industry. That's why, in 2019, Prognos was identified and certified as an environmentally efficient solution by the Solar Impulse Foundation.

JOHANNES BUSSMANN

CEO, Lufthansa Technik

What do you see as the biggest opportunities and/or largest impediments in using data analytics to drive predictive maintenance?

Ideally, predictive solutions will reduce the overall cost of operation, reduce operational interruptions and increase the reliability of the fleet. The number of airlines using the latest big data solutions is limited but growing quickly. Many airlines worldwide are looking at such solutions, but the products of real predictive maintenance are limited. Many products are just providing digital results without a direct connection to maintenance actions.

Therefore, Aviatar, our digital operations suite, can be directly and automatically linked to fulfillment actions. We are working closely with different maintenance and engineering system vendors such as AMOS or TRAX and other airline information technology providers such as NetLine to make our platform plug-and-play for operators. Aviatar's digital solutions can also be connected to any other data source, not just aircraft data.

However, big data is not an advantage by itself, and there are no "automatic" analytics. It is important to understand that "it is not the amount of data; it is the right amount of the right data" that makes the difference. It is about combining the data with the technical and operational experience of the engineering experts, both in the airline and the MRO organization, to deliver the best results. Prediction is nothing without fulfillment.

Data control is a key issue, because more and more OEMs restrict access to operational data for airlines that own the data. This reduces the choices for airlines to cooperate with MROs and other players in the market. I think we are not the only ones in this industry to say that this is not acceptable. Other impediments can be a lack of sensors or equipment on older aircraft. Also, on the newest aircraft, sensors on components sometimes cannot transmit in real time for reasons such as data links and/or other limitations, which do not allow it to be combined with other operational data.

The lack or the cost of connectivity, as well as limited data science experience/resources, or missing infrastructure and interfaces between the various data sources within an airline, limit the use of predictive technologies. Human factors, pilot unions and legal obstacles can also be impeding factors. In addition, internal stakeholders such as work councils may restrict the use of new digital technologies or the linking of certain data sources.

How do you think the MRO industry will evolve over the next 10 years?

Despite the current negative impact of the coronavirus on the global aviation business, I am sure that the aviation industry will remain on a solid growth path in the midterm and long term. Consequently, the MRO market will also continue to grow.

I am also sure that digitization and automation will become increasingly important for us and will lead to a significant change in how MRO services will be executed in the future.

Higher degrees of automation will have entered certain repair processes, from paperless maintenance and new diagnostic tools to robotics. All these aspects will not replace our highly qualified employees but will relieve them of the burden of many dull and repetitive tasks so that they can fully concentrate on the real value-adding jobs. Mobile applications will also play a major role in my vision of MRO 2030, but the information technology infrastructure will have to evolve for that to happen. For example, we are already pioneering in the field of 5G networks with two different use cases at our Hamburg base.

Moreover, I see our industry making significant progress in the next decade through the knowledge of collecting, analyzing and using large volumes of data. Building capacities in data sciences will help us leverage the full potential of predictive and proactive maintenance. Modern aircraft already produce this enormous amount of data, and by 2030 we will have greatly improved our knowledge on how to make use of it.

During your career, what do you think had the biggest impact on MRO and why?

I have been working in the MRO industry for more than 20 years now, but I think the event with the biggest impact took place not too long ago with the advent of digitization in our industry. Although we are only at the beginning of this process, it has already opened up so many new possibilities to rethink what we do and how we create value for our customers.

At Lufthansa Technik, this is happening in three dimensions: The first is the digitization of our core business, meaning that we will not change the existing work steps fundamentally but improve them step by step by implementing more digital aids.

The second dimension is the digital evolution of our existing products and services. In the future, we want to make digital solutions that were previously not possible, but we do not want to change the respective business model behind them. This is exactly the case in the field of predictive maintenance: The evaluation of aircraft, engine or component data will allow us to track and monitor their condition in real time. The fulfillment—for example, the rectification of any dam-

age—remains the same but will now take place exactly when it is necessary, not too early, not too late.

The third dimension—which, for me, will be the truly disruptive step—is the creation of a digital business model or a new digital ecosystem where our customers can display their entire fleet as a digital twin, providing an overview of the condition of each aircraft at all times. The impact of such developments will surpass anything previously seen.

LIM SERH GHEE

President of ST Engineering's aerospace sector

What is the biggest current challenge the MRO industry is facing?

The biggest challenge now may well be COVID-19, with impacts arising from customer demand reduction, the supply chain and workforce redistribution. However, the aviation industry has shown itself to be resilient—for instance, during the SARS outbreak in 2002—and should be able to rebound strongly.

The other challenge, which is becoming increasingly pressing, is the global shortage of aircraft technicians. The shortage will only be further compounded, even if just for a period, when manpower resources are pulled to return all the grounded Boeing 737 MAXs into service. The positive side to this is that it will serve to fuel the already accelerating adoption of technologies by the industry to optimize maintenance.

What do you see as your biggest opportunity in the next five years, and how do you plan to capitalize on it?

The OEM business is something we have been investing in and which we believe will allow us to capture significant synergies when integrated with our MRO business. In a market that is getting more fragmented, the breadth and depth in the value proposition we can offer as both an OEM and MRO service provider will help set us apart from our competitors.

What do you see as the biggest opportunities and/or largest impediments in using data analytics to drive predictive maintenance?

Manpower shortages, an increasing focus on sustainability and keen competition among airlines will be some of the key factors driving advances in predictive maintenance.

However, near-term implementation may not be as straightforward. Existing restrictions in access and rights to data controlled by various stakeholders mean that MRO service providers have to deal with imperfect and incomplete data most of the time. The aviation industry would benefit as a whole if we had an open-source environment akin to the software industry and in how applications are being developed.

How do you think the MRO industry will evolve over the next 10 years?

I believe sustainability will become one of the key focuses for the industry in the near-to-midterm. As it is, the global air transport industry has begun to take its environmental responsibility more seriously.

And as part of striving to become more sustainable in the business sense, I believe the industry will also step up its efforts in automating operations and using data analytics to reduce, reuse, recycle and recover.

Over your career, what do you think had the biggest impact on MRO and why?

The growth of the global aircraft fleet, which is especially strong in Asia-Pacific in recent years, and enlightenment among carriers to outsource their maintenance needs over the past two decades are some of the key trends I have seen affecting the industry. Such trends have a direct impact on the growth of the MRO industry and also on the level of competitiveness one now sees.

NORBERT MARX

CEO and general manager, Gameco

What is the biggest current challenge the MRO industry is facing?

Without a doubt the biggest and most urgent challenge we are fighting right now is how to deal with the COVID-19 situation. Gameco was hit hard already at the end of January, right during the peak travel season in China. Very quickly we established a program focusing on three main issues: how to keep our employees healthy, how to ensure aviation safety under these circumstances and how to keep the company stable, especially financially.

We have established a whole series of actions. Just to mention a few: This is a stressful and worrisome time, so to address human factors we established a hotline for psychological support and guidance for our mechanics or staff under quarantine. We split teams for social distancing or to prevent grounding of a whole team in case of an infection. Of course, special attention needs to be paid to the handover of work. Our line maintenance business is hit hardest, but we tried to rebalance the workload by pulling checks and modifications forward on grounded aircraft. We expect domestic flights in China will start to pick up again in April.

What do you see as your biggest opportunity in the next five years, and how do you plan to capitalize on it?

Gameco and China Telecom cooperated on the application of 5G technologies in 2019. Meanwhile, all our hangars and facilities are fully equipped with 5G infrastructure. Now our customers can perform remote quality inspections from their home office, or our engineering team can give onsite support to our mechanics with augmented reality equipment. We accelerated the use of this equipment due to the coronavirus pandemic, and it allows us to establish a 3D-cloud of virtual data points all over our facilities.

These 5G applications then can track, coordinate and address every aircraft, tool, working platform and piece of equipment within this cloud. Via face recognition, mechanics can be linked to tasks, performance of work can be coordinated and optimized, and material ordering and delivery can be handled with some clicks from a smartphone right at the point of

work. The potential is huge over the next couple of years, and our team is very excited about the opportunities.

JOSE LUIS QUIROS

Senior vice president of maintenance and engineering, Avianca

What is the biggest current challenge the MRO industry is facing?
There is definitely not one single challenge, and most of those that exist are not really new and will not disappear in the next few years: capacity, efficiency, flexibility, globalization and "customer satisfaction." But there is one affecting our whole society and MRO: the next steps in digital transformation.

After some years in which data acquisition, massive storage and accessibility have been problems, what we do with them and how we use them will become wide territory to be discovered, framed with the unsolved questions about who is really proprietor of the data and how the associated rights are protected.

Before, the important thing was to use data better to find solutions to problems already identified. Now, the issue is how we should change the way in which activity in MRO is executed based on a significantly different scenario, where data tends to no longer be a problem and the ability to draw information from it is extraordinarily higher than in previous decades.

Artificial intelligence (AI) is definitely shaping the business landscape, but it is not clear how. There has been a lot of hype about AI, and according to different market studies, demand for workers with AI skills has experienced steady growth over the past few years. When you add that there's currently a shortage of job seekers who can meet that need, it only makes the skills more valuable for those who do possess them or would like to learn. It will be necessary to carefully define the kind of jobs that are being created specifically. And now that AI is becoming a reality, there is an urgent need to understand how it is really affecting the learning and working environment.

What do you see as your biggest opportunity in the next five years, and how do you plan to capitalize on it?
MRO will develop in the Latin Ameri can region in the coming five years. Although it is exposed to a certain level of instability, like almost all other regions of the world, from the social, political and economic fronts, it will facilitate the required level of investment. The necessary workforce is available with the required technical skills and competitive costs, with excellent "soft skills" in terms of age, use of technologies, "digital mind setup," etc.

The combination of the aforementioned elements makes Latin America a fertile region, with a privileged geographical location, not only to satisfy its needs up to a much higher percentage, but also to attract business from nearby markets that started to have a hard time finding maintenance slots in the Asia-Pacific region.

What do you see as the biggest opportunities and/or largest impediments in using data analytics to drive predictive maintenance?
Predictive maintenance is obviously one of the low fruits of the digitization of our working environment, since the "intelligent" use of the large amount of data available, the relatively easy build-up of operational systems and failure mode patterns, and accessibility should allow this concept to become one of the most successful tools in our activity.

Nevertheless, there are some aspects around preventive maintenance that, in my opinion, are not helping to develop the concept to its optimal stage: It is not clear there is full alignment between service/platform providers and users in terms of what the final goals of predictive maintenance will be, and there is no proper balance between standardization and competition in terms of variety of available solutions.

With a much broader common ground among the industry players about what is really required and a clear set of minimum standards to be applied to the different solutions, we should be able to get better predictive maintenance tools.

How do you think the MRO industry will evolve over the next 10 years?
In the first place, evidently air transport growth and fleet evolution will set the frame for the MRO industry in terms of capacity and—such as whether MRO centers could do something additional to MRO—as an option for the coming 10 years, and therefore the drivers will be the same we have today.

On the other hand, the trend of consolidated OEMs getting a bigger portion of the MRO business (the OEMRO concept) will be even more deeply implemented, although I still see a question mark regarding whether or not airframe activity will be finally affected by this model, even with a limited scope (modifications, end-of-lease transitions, etc.)

I think we will see a significant change in the profiles of MRO technicians and engineers, not so much because of the changes in the professional skills (basically educational) but as a consequence of the faster evolution (revolution in some cases) of our society from many points of view and the impact on its members. This is not new, and it has been a constant for decades, but the depth and the speed of the changes are probably higher and will have a more visible effect on the MRO model.

It is important to confirm in the coming years whether diversity and inclusion will be competitive advantages or myths. The world is different from what it was 20 years ago and will change even faster in the coming years. The workplace, workforce and marketplace are changing in ways that require a different approach to management. Less than 5% of management roles are currently filled by women, and the inequality today is quite palpable.

And, finally, environmental care and sustainability will undoubtedly be considered a top priority when defining or reviewing repair and maintenance processes, and of course in designing and rebuilding facilities, not only to comply with regulations, but as a result of the companies' vision and social responsibility commitments.

Go Big

American Airlines is investing $550 million in its Tulsa base maintenance facility

The Tulsa facility has tail slots for Boeing 737NGs.

Lee Ann Shay Tulsa, Oklahoma

A few weeks before the COVID-19 pandemic began wreaking havoc with the U.S. economy and airline operations, American Airlines announced on Feb. 28 that its largest maintenance base will undergo a major transformation—to the tune of $550 million—over the next few years.

The investment at the base fulfills two of the carrier's needs for the next 20-30 years: a new hangar able to accommodate any aircraft that American Airlines flies—narrowbody or widebody—and upgrades to the rest of the hangars and infrastructure, says Craig Barton, American Airlines vice president of technical operations.

The base, erected during World War II to build bombers, was taken over by American in 1946 and reconfigured as a maintenance facility, as it moved its tech ops headquarters from New York LaGuardia Airport. Its original four hangars expanded to six, plus Hangar 80 across the field, where the team performs overnight line maintenance work.

While the hangars could easily house MD-80s, the last of which American retired in September 2019 as it inducts newer and bigger aircraft such as the Boeing 787, the hangars are not large enough. American has added tail slots for Hangars 1 and 2 to accommodate larger aircraft such as the Boeing 737, but having a tail stick out of the hangar is not a practical, long-term solution—especially in inclement weather.

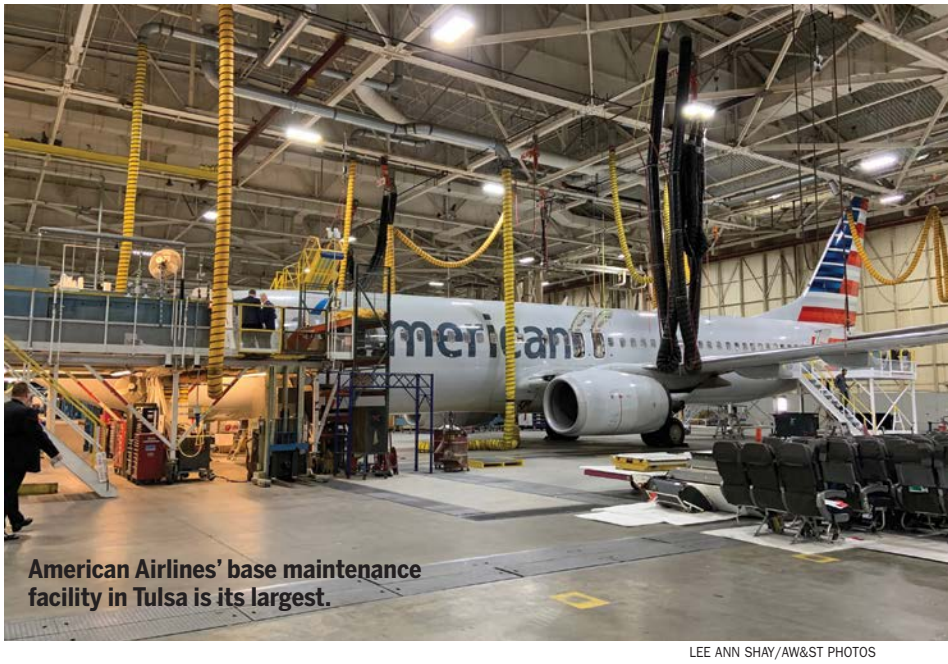
One of the facility infrastructure upgrades is to the fire suppression system, which needs to be manually monitored and is beyond its useful life, says Erik Olund, American Airlines' managing director of base maintenance. Other infrastructure projects include new roofs, sewer water lines, utilities and information technology upgrades—including adding Wi-Fi to the hangars so American can deploy tablets and real-time work packages.

Updating the central utility plant, built in the 1940s and '50s, with sustainable systems also has a green benefit.

American Airlines CEO Doug Parker says the Tulsa maintenance base is a "critical part" of the airline and that the investment reflects that. He points out that American has invested $20 billion in fleet renewal the last 5-6 years, and upgrading this facility is necessary to keep up with the fleet.

Barton says the Tulsa base changes will give the airline flexibility to "manage the mix" of narrowbody and widebody aircraft and the maintenance that is input. "It's key to keeping a good balance of what we do," he says, adding that American completes more maintenance in-house than other U.S. carriers. The base maintains about 900 aircraft annually.

The new 193,000-ft.^{2} hangar will accommodate two widebody aircraft or six narrowbodies—adding widebody maintenance capacity to the airline's system. The design will enable technicians to bring aircraft in tail- or nose-first, compared to the current nose-in-only option, and allow for a cleaner workspace around the aircraft. Instead of aircraft surrounded by the old, traditional docking, workspaces will include lots of natural light, clean power for the aircraft and modernized systems to make work processes more efficient.



American Airlines' base maintenance facility in Tulsa is its largest.

LEE ANN SHAY/AW&ST PHOTOS

Tulsa's Hangar 6 already has switched to some docking that could become the model for the others, says Olund.

The base already has extensive backshops in which component and engine maintenance are performed. So the basic capabilities list will not change during the renovation. But the current administrative building that houses engineering, records, human resources and other services that support the base will move to the new hangar, says Barton.

American also operates base maintenance facilities at its Dallas headquarters as well as in Charlotte, North Carolina, and Pittsburgh.

The Tulsa facility, the largest in American's network, has not received a major investment in 20 years and needs it to make it sustainable for the long term, says Kevin Brickner, senior vice president of technical operations.

American performs line maintenance in 30 U.S. cities and wants to make sure it has the right facilities, and that line and base maintenance needs are balanced. "In Miami, we just picked up a hangar on the north side of the airport that adds about 50-75% more [line maintenance] capacity," says Barton. The new hangar will allow American to perform more work that naturally should be done there, instead of forcing it elsewhere in its network.

LEE ANN SHAY/AW&ST

American Airlines executives Barton, (left), Olund, Parker and Brickner.

That was one of the drivers of the new $215 million, 191,000-ft.^{2} line maintenance hangar at Chicago O'Hare International Airport, which officially opened in January 2019. That hangar can simultaneously house six narrowbodies or two narrowbodies and two widebodies, including the 787.

While the plans included in that Feb. 28 announcement have not changed—as of early April, American plans to continue moving forward with the hangar—like all U.S. carriers that have grounded a significant portion or their fleets, it is evaluating how it will ramp up operations after the virus is contained.

The tech ops team is working on the master plan, which will outline everything from the green initiatives to how people, parts and aircraft flow into and out of the facility. "By the end of the year or early 2021, we expect the groundbreaking will start on the new facility," says Olund. Constructing the hangar should take about 18 months, but the whole project is scheduled to take place over seven years.

Structural Health M

Using sensors to monitor aircraft structural health could be an efficient way to accomplish this, so why isn't it being readily implemented?

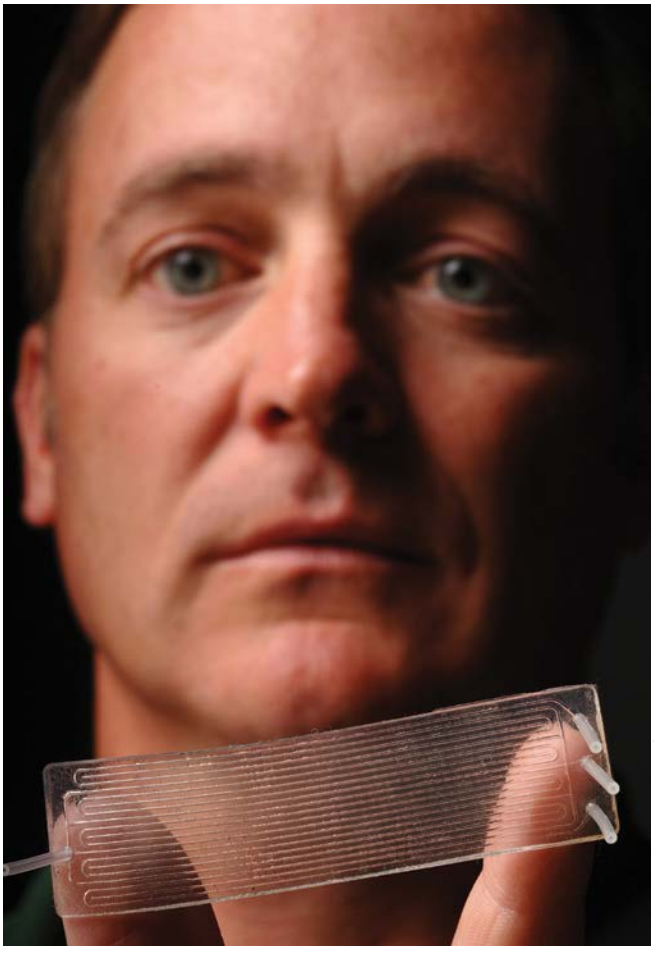
Paul Seidenman and
David J. Spanovich **San Francisco**

If an airframe structural inspection reveals a crack, the aircraft, by regulation, is grounded until repairs are made. By contrast, an engine turbine blade with a known hairline crack could remain on wing, as increased inspections determine when the blade must be replaced. To level the playing field, regulatory approval of structural health monitoring (SHM), employing high-tech sensors, is being sought.

Sandia National Laboratories in Albuquerque, New Mexico, a leading SHM research and development center, has primarily worked with five different sensor technologies—comparative vacuum monitoring (CVM), piezoelectric (PZT), fiber optics, carbon nanotubes and acousto-ultrasonics (AU). "Each has its own way of interrogating a structure to obtain signatures associated with specific types of damage," says Dennis Roach, a senior technical fellow there.

CVM and PZT are considered the maturing technologies. With CVM, a sensor in the form of a self-adhesive elastomeric patch—about the size of a credit card—is used. By applying vacuum pressure to the sensor's built-in rows of interconnected channels, any measurable change in the vacuum level will reveal a crack.

But PZT sensors have an advantage over CVM, says Amrita Kumar, executive vice president of Acellent Technologies in Sunnyvale, California. "CVM sensors are 'point sensors,' which means they need to be placed exactly at the location where damage such as cracks are anticipated," she says. "PZT sensors, such as Acellent's Smart Layer sensors, can be used in a network design to monitor an entire area for damage."



RANDY MONTOYA/SANDIA NATIONAL LABORATORIES

Dennis Roach of Sandia National Laboratories holds a self-adhering, comparative vacuum monitoring sensor used for aircraft health monitoring.

Kumar adds that another advantage of a PZT Smart Layer sensor network, compared to CVM, is that it can be used in both an ultrasonic and acoustic mode for crack detection. In an ultrasonic mode, the sensors can be used periodically to provide information on damage location and size. In an acoustic mode, the sensor network "listens" for external impacts and provides the location and magnitude of damage to the structure.

The Smart Layer sensors, says Kumar, have successfully undergone MIL-STD 810G and lightning-strike testing for use on any metal or composite structure. Also, the sensors have been proven for use in damage detection through extensive testing and validation at the coupon, component and flight-test levels.

"Boeing and Korea Aerospace Industries (KAI) have both adopted the technology and declared it 'tech-ready' and Airbus has flight-tested it on the A350," she says.

Monitoring

AIRLINE BENEFITS

"For airlines, SHM could be an airframe maintenance game changer, moving unscheduled actions to scheduled maintenance," says David Piotrowski, senior principal engineer for Delta Air Lines. "SHM will give us the data to safely manage our fleets more efficiently and in a more cost-effective manner. Rather than taking the aircraft out of service immediately for repair, the area could be monitored." This can help determine if a crack needs to be repaired right away, or if it can wait until the next scheduled maintenance event or another convenient opportunity.

Using SHM in this manner could enhance safety, as it allows for continuous, real-time monitoring versus today's periodic examinations, says Piotrowski. "While the technology is ready, there is more work to be done to persuade regulators of a data-driven, tail-specific maintenance program. Therefore, near-term applications of SHM will be limited to substituting for conventional inspections, which still provide substantial benefits to operators."

In fact, Piotrowski points out, Delta is currently performing a 1,200-cycle repetitive inspection of the rear pressure bulkhead fasteners on its Boeing 737NG fleet as mandated by an airworthiness directive (AD). The airline has requested an alternative method of compliance (AMOC) using SHM technology rather than eddy-current inspections, as required by the AD. Other applications on Boeing and Airbus fleets also are being prepared for AMOC requests.

"On the 737NG family, the eddy-current inspection requires removal of a galley. If sensors were located in that area, the technician would only need to remove the galley if a problem is detected," Piotrowski says. "Not having to remove the galley frequently would provide significant savings for the airline and allow the aircraft to be available for more revenue opportunities."

Delta Air Lines has been leading industry efforts with SHM since 2005, including work done by Northwest Airlines, which installed CVM sensors on two DC-9s in 2004-07. Delta, which merged with Northwest in 2009, flew sensors on Boeing 757s and 767s in 2005-12.

Most of the initial work, explains Piotrowski, focused on data collection and addressing the question of how well the sensors would work under real-world conditions. The next question, he says, was answered in 2014, when an FAA-funded program was established to determine what, if any, certification guidance would be needed to support SHM applications. Under the program, Delta—in partnership with Boeing, Sandia National Laboratories and Anodyne Electronics Manufacturing—installed 10 CVM sensors in the center wingbox of seven of its 737-700s. The center wingbox was selected because it is a high-stress area. The installations were approved by a service bulletin revision drafted by Boeing. Those seven aircraft are still flying with the sensors installed and to date have logged 110,000 flight hours and 56,000 cycles, says Piotrowski.

Other programs included sensor installations by Azul, in conjunction with Embraer, on the Brazilian airline's E190 jets, and an Air Canada Jazz CRJ that flew with sensors in 2009-10, he says. "Combining those with testing by Northwest and Delta, CVM sensors have flown some 1.5 million hr. to date," he points out. "We have proven that the sensors work under all operating conditions—flight cycles, pressurization, vibration, contaminants—anything that could impact them in flight," he adds.

Stephen Neidigk (left), Dennis Roach (center) and Tom Rice of Sandia National Laboratories set up a comparative vacuum monitoring SHM system to allow for remote visual inspection of aircraft structures.

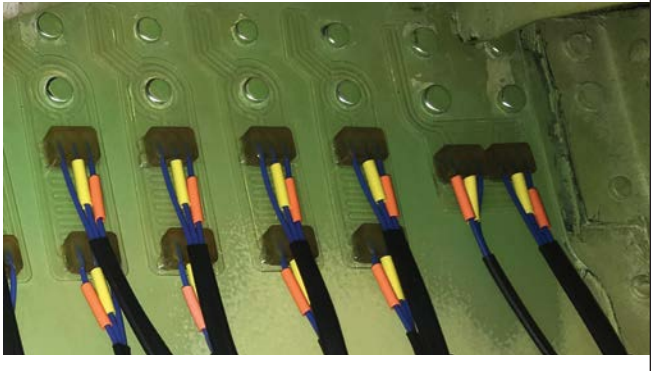
RANDY MONTOYA/SANDIA NATIONAL LABORATORIES

NDT SUBSTITUTE

Sandia National Laboratories' Roach reports that the current focus of study is the use of SHM as a substitute for nondestructive testing (NDT) tasks that often involve the application of human-deployed inspection methods to identify damage. These are labor-intensive processes that require inspectors to physically access the "structure of interest" to conduct manual inspections. The idea behind SHM, Roach says, is to place an array of embedded sensors throughout the aircraft to quickly alert the operator that some type of damage is taking place on a certain structure. To achieve this, the sensors are tailored not only to the parts of the aircraft being targeted but to the type of damage to be detected. As SHM evolves, the interrogation will move past "hot-spot" monitoring to include applications across a broad spectrum of aircraft components.

"Basically, each SHM application is reviewed for desired flaw detection such as cracks, corrosion or disbonds; location such as the surface or subsurface; sensitivity required; as well as structural material, and geometry," Roach explains. "Thn the sensor network approach is designed based on this information."

DELTA AIR LINES



CVM sensors supplied by Structural Monitoring Systems attached to the pressure bulkhead fasteners on a Delta Air Lines Boeing 737NG. Delta has requested authorization to use CVM technology as an alternative method of compliance for an AD pertaining to the fasteners, instead of the eddy-current inspections the AD mandates.

In some cases, there may be several types of damage to be detected in one area. "In the future, the desire is to move toward condition based maintenance (CBM), allowing airlines to automatically acquire information from the sensors and use that to make maintenance decisions," he says.

Roach adds that while there may be no need for more performance data in general, there will always be a need for testing the specific SHM application. In that respect, he says, additional flight history and successful operation from a series of applications will help move SHM into new areas faster. "We are acquiring that data now, but the newness of SHM technology—or any new aircraft technology—requires that the performance data be very comprehensive for each new application," he says. "Once we get downstream, we will be much smarter on the performance of SHM for each variance in application. This will streamline the process from initial identification of an SHM application to final installation and routine use of SHM solutions on commercial aircraft."

Rich Poutier, executive vice president, business development for Perth, Australia-based Structural Monitoring Systems (SMS)—the supplier of CVM sensors being used by Delta Air Lines for the 737 wingbox service bulletin inspections—reports that the next step for SMS is to obtain regulatory approval for application of the sensors to mandatory inspections. The FAA received an approval request from SMS in January 2019, he says.

Because the FAA considers the application of sensors to SHM a "new and novel technology," the agency is finalizing what is referred to as a policy issue paper, says Poutier. That paper will provide the regulatory inspectors with guidance material to use as reference for approving future applications of the technology—which will initially take place on a targeted case-by-case basis.

"Once a sensor application is identified, we then design a sensor configuration [to] target that area to monitor for a surface crack," he says. "The sensor can detect a crack as small as 0.1 in. [depending on the materials being monitored] and it can monitor crack growth until it reaches a size where the OEM would require a repair, based on the OEM's damage tolerance model."

According to Poutier, SMS is the only company certified by an OEM—Boeing—offering CVM technology for aircraft SHM through its patented and trademarked CVM product. SHM holds more than 30 patents globally for CVM technology, with 14 more pending. Those patents include surface crack detection along with detection of internal delamination within composites and composite bonds.

SMS selects targeted applications for its sensors, based on labor hours and aircraft downtime required for current inspection processes. Right now, the two with the highest priority are the 737NG aft pressure bulkhead, and the Wi-Fi antenna mount structure for all narrowbody aircraft.

"The aft pressure bulkhead AD calls for inspection of stringers 5-7L on the left side and 5-9R on the right side of the bulkhead," Poutier notes. "It was selected because there can be a high amount of false positive readings when using conventional low-frequency eddy-current probe inspections, which sensors could reduce." The false positive rate for many low-frequency eddy-current inspections averages 3-5%, he says. The result is unnecessary grounding of aircraft and galley removals to confirm if a crack exists on the forward side of the bulkhead.

For the Wi-Fi antennas, Delta Engineering (no affiliation with Delta Air Lines) holds the supplemental type certificate—licensed to Gogo—and has applied to the FAA for a revision to the instructions for continued airworthiness to include the use of CVM sensors as an option to visual and eddy-current inspections of the structure, Poutier adds.

While the FAA ignored a request for comment, the European Union Aviation Safety Agency (EASA) gave a cautionary response. "EASA does not believe that SHM will change existing strategies regarding damage tolerance philosophies," says Janet Northcote, its head of communications. "A conservative 'step-by-step' approach will be taken when considering potential adoption of SHM, as has been openly discussed in public forums with OEMs. It cannot be predetermined that use of SHM will allow flight with known cracks."

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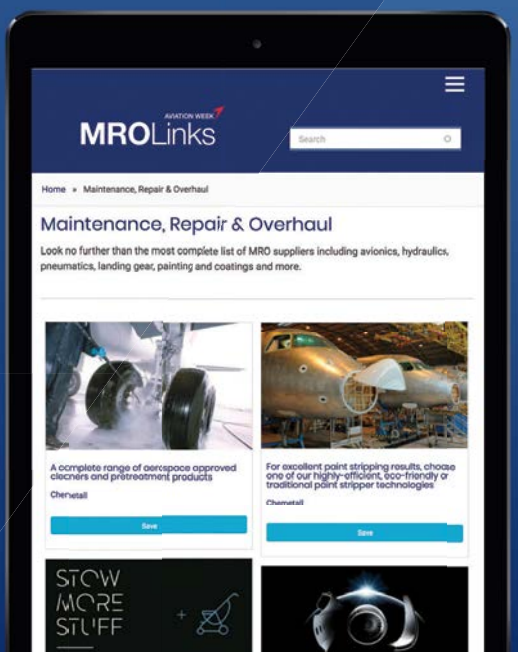


AVIATION WEEK NETWORK

Redesigning an MRO

STS takes faster, leaner approach in resurrected Monarch hangar

James Pozzi Birmingham, England

The start of 2019 saw the collapse of Monarch Aircraft Engineering (MAEL), the British MRO that had been operating for more than 50 years. A little more than 12 months after the demise of its Monarch Airlines affiliate, the MRO business still struggled despite private equity owner Greybull Capital's attempts to restructure the business. MAEL had inherited the airline's historic debts, estimated at more than £100 million ($125 million), and lost around 50% of its maintenance work as a result of the carrier's collapse.

The STS Birmingham facility, pictured on March 11, 2020.

JAMES POZZI/AW&ST

From a manpower perspective, an estimated 450 jobs evaporated immediately—depriving the domestic and continental segments of valuable technical expertise. The demise of MAEL also had ramifications for the UK's overall MRO capacity, with base maintenance capacity at Luton and Birmingham cut. Its line stations across the UK were sold off to several MRO specialists by administrator KPMG, which was appointed to oversee the offloading of assets, which included a continuing airworthiness management organization business and a Luton-based training academy. Surplus plant and machinery equipment at both facilities was auctioned off by Hilco Global.

British real estate specialist Avison Young acted as selling agent of the leaseholds for its two main hangars, at Luton and Birmingham. The latter, a more modern hangar than the former, having been built only in 2013, garnered significant interest. In October 2019, U.S.-based STS Aviation Group was confirmed as the buyer of the 200,000 ft.^{2} hangar, just one month after acquiring UK-based MRO Apple Aviation—signaling its intention to expand in Europe. Mick Adams, managing director of MAEL in 2009-14, was installed as CEO and senior vice president of STS' Europe operation and tasked with establishing new operation at the existing facility.

One month later, in November, on a brisk Thursday morning in England's second city, Adams sat ready to talk to Aviation Week in a near-empty hangar where he has been working with a small team of people to kick-start the new venture. The group includes former MAEL man Alan Brooks, who recently returned as base maintenance manager of the Birmingham facility, and Colby Payne, a former MAEL employee who was retained by the administrator at the hangar before being appointed commercial manager at STS.

Adams, who most recently worked at DHL Supply Chain following a four-year stint as vice president of MRO services at Etihad Airways Engineering in Abu Dhabi, jumped at the opportunity to oversee a fresh challenge at a facility he knows so well. "The demise of Monarch Aircraft Engineering undoubtedly left a huge gap in the UK and Europe's MRO industry," he says. "Couple that with STS' success story and appetite to grow the business within and around Europe—this was a marriage made in heaven. Doing a project of this nature was something I always aspired to do, but for one reason or another, I never got an opportunity to see it through."

On arrival at the Birmingham hangar, the specter of MAEL is still evident: Its logo adorns the hangar's exterior, while its purple and yellow colors linger in the carpets. Yet no doubt is left about the absence of a functioning maintenance operation—tooling stalls lie empty, once-vibrant meeting areas are empty, and the hangar floor is mostly bare save for stored equipment and several warehouse forklifts.

But Adams is not focusing on the past. He describes the task ahead as akin to "redesigning an MRO" rather than trying to re-create what came before. He says that although MAEL generally had a long-standing industry reputation for good-quality work, from a culture perspective, he's looking to run an altogether leaner operation in Birmingham underpinned by a flatter, nonhierarchical type of management structure aimed at quick decision-making. At this juncture in November, January 2020 is the target month to get the operation up and running, but a long list of priorities looms with the anticipation that the team could have to spend Christmas Day working in the hangar.

First, a leadership team needs to be built, with "the right caliber and mindset" to fit the culture, Adams says. Second, preparation for the UK Civil Aviation Authority (CAA) Part-145 audit is

also in the works, a process Adams predicts will be extensive. "This facility was operational just less than one year ago, so you can understand why some people might think a team of engineers can turn up and put on a light switch to make it all work again," he says. "But this is more equivalent to a startup, and in many ways, even more complex than that, as you have to deal with remnants of the old operation and any associated legacy issues before refreshing them."

Adams foresees that the company will adopt a "build slowly, grow quickly" mentality. "It's unlikely we'll be doing very heavy maintenance checks from Day One, and that's because we'll focus on higher volume fast turn, reasonable margin activities drawing on STS' capabilities around design and modifications," he says. This contrasts with previous MAEL work at the hangar, which undertook heavy D checks with a workforce of several hundred technicians. "It comes back to having the discipline to undertake the right type of work in the facility," Adams continues. "I can't imagine a day when we'd have multiple lines of D checks in the hangar for six to seven weeks at a time with all the complex logistics and infrastructure that has to sit around that."

While the collapse of MAEL along with UK airline Thomas Cook had an impact on the regional MRO segment, Adams feels that the timing of STS to expand in Europe could not be better. But this landscape necessitates being ready to adapt to the changing market. "The market has changed, and next-generation aircraft are the future. We have to manage the transition from legacy aircraft and supporting customers on those fleets while also building the skills [and] capabilities [to] transition into the next-generation of maintenance, adding capabilities for Part-21, design, training and everything else required."

Fast-forward four months, to early March 2020, and an uptick in activity is evident at the hangar following the winter months. From a visual perspective, some of the purple and yellow of MAEL has been changed to STS red, white and black. Teams of people are beginning to fill previously empty office space. Tool stores have also been restocked, following the undertaking of a time-consuming process in which STS individually identified more than 5,000 tools. This involved a total inventory check whereby teams maintained, calibrated and repaired the tools. In total, around $2 million was invested in new tooling in Birmingham, including some items from the hangar acquisition.

Perhaps the most visually striking image is the sight of aircraft returning to the shop floor. Just one week prior, Birmingham had been home to two Boeing 787s operated by Italian carrier Neos—representing STS' first third-party airline customer since taking ownership of the facility. The audit for UK CAA Part-145 approval had recently been concluded to acquire the base maintenance certificate. Still short of its base maintenance approval at that time, STS provided touch labor to work with the airline's own engineers on performing double engine changes.

Approval for the UK CAA certification came three weeks later, on April 1. As Adams envisaged, services will include aircraft modifications, structural repairs, engine changes, A checks, C checks, lease transition and bridging checks. Initially, these services will be offered for the Airbus A320 family and A330, as well as Boeing 737NG and 757 aircraft. Further aircraft types, such as the Embraer 190, are expected to follow in the same month, and the Boeing 787 base maintenance certificate should be achieved by May 2020. Once ramped up, the hangar will operate across five to six maintenance lines.

On the manpower side, several technicians have joined the operation. As of mid-April, 10 technicians and 14 mechanics were at work, and the number was expected to rise further in April for the summer months, before building up to 60 mechanics and 20 technicians later in the year. Adams says interest in roles remains strong, and several former MAEL employees expressed interest in returning. This was reflected at management level, with former MAEL staff Ian Bartholomew, Malcolm Welsby and Mike Ainsworth joining the team. Engagement with new talent has been encouraging thus far—a recruitment fair held in the same month over a two-day period also garnered strong interest, with between 90-100 potential employees attending.

However, although STS has overcome challenges and hurdles to establish a new MRO presence in Birmingham, another one looms in the form of the COVID-19 pandemic, which has led to a slowdown of the global aftermarket. Since the outbreak, many aircraft have been grounded, and a wave of maintenance cancellations is anticipated throughout this year. While STS continues to run its operations, with heightened staff safety procedures, it has not escaped the impact of the novel coronavirus.

Despite being wary of the long-term impact of COVID-19, Adams remains bullish about the industry's prospects. "Maintenance never goes away—if the coronavirus is brought into check, the grounded aircraft will come back into service. There will be some necessary maintenance during that period, before a backlog of maintenance and perhaps modifications and airworthiness-directive work to ensure those aircraft are brought back into service. This will likely all happen much later in the year, so capacity and resources will need to be managed very carefully."

Monarch to STS in Birmingham: A Timeline

2017 October Monarch Airlines collapses, leading to more than 1,800 jobs lost. The affiliated Monarch Aircraft Engineering business carries on as a standalone entity.

2018 December Monarch Aircraft Engineering is put up for sale by private equity owner Greybull Capital.

2019 January Monarch Aircraft Engineering collapses, resulting in the loss of around 450 jobs. The Birmingham Airport hangar is among the sites closed.

March Monarch Aircraft Engineering assets–including hangars, tooling and equipment–are put on the market by KPMG.

October STS Aviation Group announces its acquisition of Monarch's former Birmingham Airport hangar.

2020 January STS begins operating in Birmingham.

April STS is granted UK Civil Aviation Authority certification for base maintenance in Birmingham.

Digial Extra *Take a look at the current global MRO trends by world region:* **AviationWeek.com/MROTrends**

BLUE ORIGIN

Price of Reusability

Reflying rockets is cool, but does it make financial sense?

Irene Klotz Cape Canaveral

The first Falcon 9 rocket to land successfully after dispatching a payload into orbit stands on permanent display outside SpaceX headquarters in Hawthorne, California, a testament to the perseverance of founder, CEO and chief engineer Elon Musk, who wants a fleet of fully reusable spaceships to reduce the cost of colonizing Mars.

The vision is shared by fellow tech entrepreneur Jeff Bezos, whose Kent, Washington-based Blue Origin space company is developing a series of reusable vehicles, beginning with the New Shepard suborbital passenger transport system. The New Shepard made 12 uncrewed flight tests over the last five years, with more to come before commercial flights begin.

Bezos also has pumped $2.5 billion into developing the

Blue Origin is developing the BE-4 engine, which it will install on its reusable New Glenn rockets and sell to United Launch Alliance (ULA) for its onetime-use Vulcan booster. ULA plans to eventually reuse just the engines.

New Glenn, a reusable system powered by seven BE-4 methane-fueled engines designed to carry nearly 50 tons to low Earth orbit. "That is the smallest orbital vehicle we are planning to build and launch," says Clay Mowry, Blue Origin vice president of sales, marketing and customer experience.

But the first BE-4s to power a rocket to orbit may not be aboard the New Glenn. United Launch Alliance (ULA) is buying the engines to power the first stage of its Vulcan rocket, an expendable booster—at least for now—which, like the New Glenn, is slated to debut next year.

At some point, ULA may decide to recover and reuse just

A SpaceX Falcon 9, which landed on a drone ship positioned in the Atlantic Ocean, returned to Port Canaveral, Florida, on Dec. 7, 2019, after delivering a Dragon Cargo ship into orbit for NASA.

the BE-4 engines, a pair of which will fly on each Vulcan. The idea is for the engine compartment to disengage after launch and fall back through the atmosphere protected by an inflatable hypersonic shield. A helicopter would be positioned to snag the engine section midair as it makes a parachute descent. ULA calls the approach its Sensible Modular Autonomous Return Technology, or SMART.

"It does not impact, in any significant way, the overall performance of the launch vehicle because you don't have to save fuel to fly home with," ULA CEO Tory Bruno tells Aviation Week. "You still get to burn up all your fuel, separate your engine, which is the most expensive piece, and recover it."

"We have not really changed our assessment over the last couple of years because we have yet to see the other forms of reusability—flyback or propulsive return to Earth—demonstrate economic sustainability on a recurring basis," Bruno says. "It's pretty darn hard to make that actually save money. . . . We've seen nothing yet that changes our analysis on that."

SpaceX currently is the only launch company reflying orbital rockets. SpaceX launched its final version of the workhorse Falcon 9 booster, called the Block 5, in May 2018. Within two months, the company was flying Block 5s exclusively. The upgrade includes higher-thrust Merlin engines, stronger landing legs and dozens of upgrades to streamline recovery and reuse.

Block 5s were designed to fly 10 times with minimal maintenance between flights, and up to 100 times with refurbishment. SpaceX President and Chief Operating Officer Gwynne Shotwell says the company no longer expects to need to fly a Falcon 9 more than 10 times.

"We don't have to ramp up our production, at least for boost phases, like we thought we were going to," Shotwell said on March 10 at the Satellite 2020 conference in Washington.

"From a reliability perspective, we want to know the limits of Falcon 9, so we'll push them, but . . . some government customers want new vehicles—I think over time, they will come to flight-proven vehicles as well," she added. "But if I have to build a couple of new ones every year, or 10 new ones a year, that adds to the fleet, and I don't know that I'll have to push a rocket more than 10 [flights.]"

With regard to how much the company has been able to cut costs by reflying rockets, Shotwell would only say, "We save a lot of money."

As a privately held company, those operating expenses are not publicly available, but the Block 5 flight record is. So far, SpaceX has flown 14 Block 5 core boosters over 31 missions, including two Falcon Heavy flights, which use three cores apiece.

Of those 14 boosters with flight history, five remain part of the operational fleet. The rest were expended—several after multiple missions—due to payload performance requirements or unsuccessful landings. One booster was intentionally destroyed as part of a Crew Dragon capsule launch abort flight test.

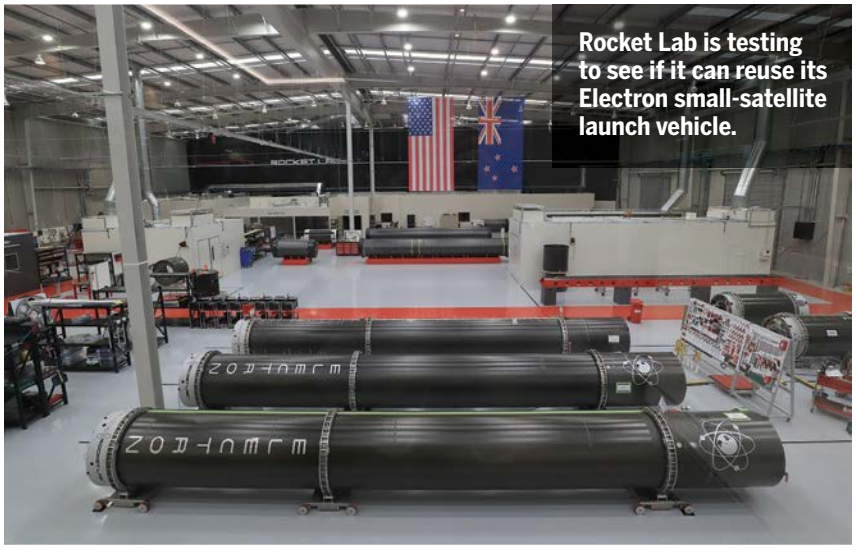
SpaceX's fleet leader flew five times before failing to land on a drone ship stationed off the Florida coast on March 18. SpaceX has not said if the botched landing was related to a premature engine shutdown during the final phases of ascent. The rocket's remaining eight Merlin engines compensated for the shutdown, and the payload—a batch of 60 SpaceX Starlink broadband satellites—reached its intended orbit.

While it continues to fly the Falcon 9 and Falcon Heavy for NASA, national security and commercial missions, SpaceX is developing a fully reusable, human-class deep-space transportation system called Starship at its own expense.

Another company testing the waters of reusability is Rocket Lab, which builds and flies the Electron small-satellite launcher.

"For a long time, I said we weren't going to do reusability," Rocket Lab CEO Peter Beck said in August 2019, when he announced the new initiative. "This is one of those occasions where I have to eat my hat."

Electrons do not have the performance for a propulsive return like SpaceX's Falcons do, so Rocket Lab is pursuing a midair, helicopter recovery system to snare the booster's first stage. The intent is not to reduce costs per se but to increase flight rates without having to boost production. The company currently is producing one Electron rocket about every 30 days. "We need to get that down to one a week," Beck says.



Rocket Lab is testing to see if it can reuse its Electron small-satellite launch vehicle.

ROCKET LAB

"We view [rocket reuse] as sort of a journey," ULA's Bruno adds. "We're going to start with the engines because we're pretty sure we can save money with that and pass those savings on right away. As we learn more by doing, we'll continue to assess other valuable parts of the rocket, and we may discover that we can do that there as well."

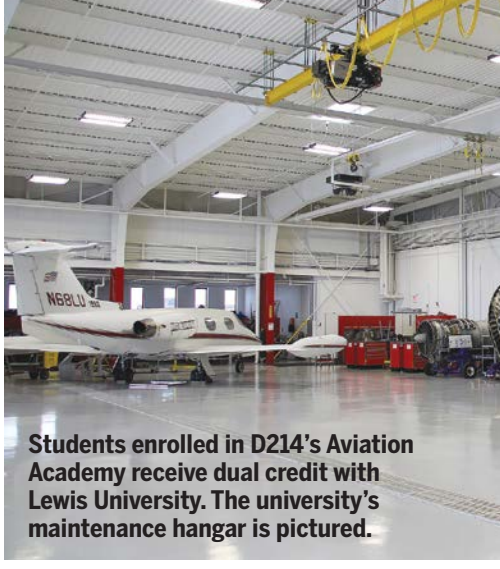
"There is one funny thing about reusability," he adds. "As you make your rocket less expensive, and you make parts of your rocket less expensive, it's harder to close a business case on reuse because the thing you're recovering isn't as valuable. There's a balance there."

SPACEX

Workforce Wins in Chicago

A grassroots aviation workforce program is thriving in the 'Windy City'

Lindsay Bjerregaard Chicago



Students enrolled in D214's Aviation Academy receive dual credit with Lewis University. The university's maintenance hangar is pictured.

Interest in aviation careers is booming in the Chicago area, thanks to a new partnership between a local high school district, an airframe and powerplant (A&P) school and American Airlines' Tech Ops team at O'Hare International Airport (ORD). Informally launched less than two years ago by two of American's crew chiefs at ORD, the Educational Outreach Program has "mushroomed almost instantaneously," says Gary Percy, crew chief of aircraft maintenance at the airline

The program's roots began with the simple desire to spark a passion for aviation careers in younger generations. A contact of Percy's from Township High School District 214 (D214), located near ORD, reached out to him for input on an aviation academy the district was trying to set up.

According to Megan Knight, D214 director of programs and pathways, the aviation academy developed as a result of strong demand for qualified aviation professionals in the area. "What we saw, looking at the job outlook, was there was so much opportunity in this space that was untapped; so we wanted to create a talent pipeline into the field of aviation with our kids," she explains. "We've always had a really strong transportation program—we have a lot of students in our autos program—and so we felt like we had the target audience in terms of our students, and that allowed us to move forward."

The academy, now in its second year, is run out of Chicago Executive Airport (PWK) in partnership with American Airlines and Lewis University. Students in the program take two dual-credit, introductory courses—Aviation Fundamentals and Aviation Physics—that count toward transcripted college credit and are taught by instructors from Lewis. Knight says the coursework caters to students regardless of which area of interest they are pursuing, so they are not pigeonholed into one field.

Classes take place in a recently renovated portion of a T-hangar at PWK, which features a classroom and lab

Wheeling High School students toured American Airlines' ORD hangar.

AMERICAN AIRLINES

LINDSAY BJERREGAARD/AW&ST

space. According to Knight, hands-on learning experiences at the airport are a major element in generating interest among high school students. "We want the kids to be there and feel the energy of that. To be able to go to school and to have aircraft taxiing right in front of you is really unlike anything that our kids have ever seen. Most people don't have a high school experience that looks like that," she says.

In addition to helping D214 develop curriculum based around certifications that are critical in the field of aircraft maintenance, Percy and his colleague Jack O'Callaghan, technical crew chief at ORD, began arranging hangar tours for students at ORD. A centerpiece of these tours is walking students through the Boeing 787, "a flying computer," Percy says.

"The younger generation, that's what they do—whether it's gaming, programming or anything like that. The airplanes are so computerized, and I think that's what draws them to it," he says.

American's ORD Tech Ops staff lets students look inside the electronics compartment of the aircraft to see "the brains of what makes the airplane operate," O'Callaghan adds, which also presents photo opportunities inside the aircraft.

Knight says several Aviation Academy classes have visited American's ORD hangar, and the airline has been working with D214 and Lewis University on how to best develop a career pathway for students.

"They have been really interested in how to grow their talent pipeline, so they have a vested interest in helping us grow this pathway and the interest [of] students," she says. "They've been very involved and are helping us explore opportunities and opening up their facilities to our students to inspire them to think about going into this field—whether on the aviation mechanic side or even on the pilot side."

According to O'Callaghan, word about the program has spread quickly in the area, and ORD Tech Ops has seen a high level of interest from other local high schools.

"We're trying, with the help of our station director, to figure out the best way to put it out there that there are technical opportunities for A&P mechanics and within American Airlines," he says. "But the bigger picture is getting kids involved in aviation, because there are lots of companies and opportunities out there."

O'Callaghan points out that an A&P license can also open up career opportunities outside of aviation. "That A&P ticket is a valued commodity in other industries because [other companies] know what kind of training you received in school. Disneyland hires A&P mechanics, because [they've] got a background in pneumatics, hydraulics and electrics," he says.

Percy and O'Callaghan are now working with American's other departments to grow the Educational Outreach Program system-wide, especially since some of the airline's other maintenance stations have expressed interest, and "corporate is trying to catch up," Percy says.

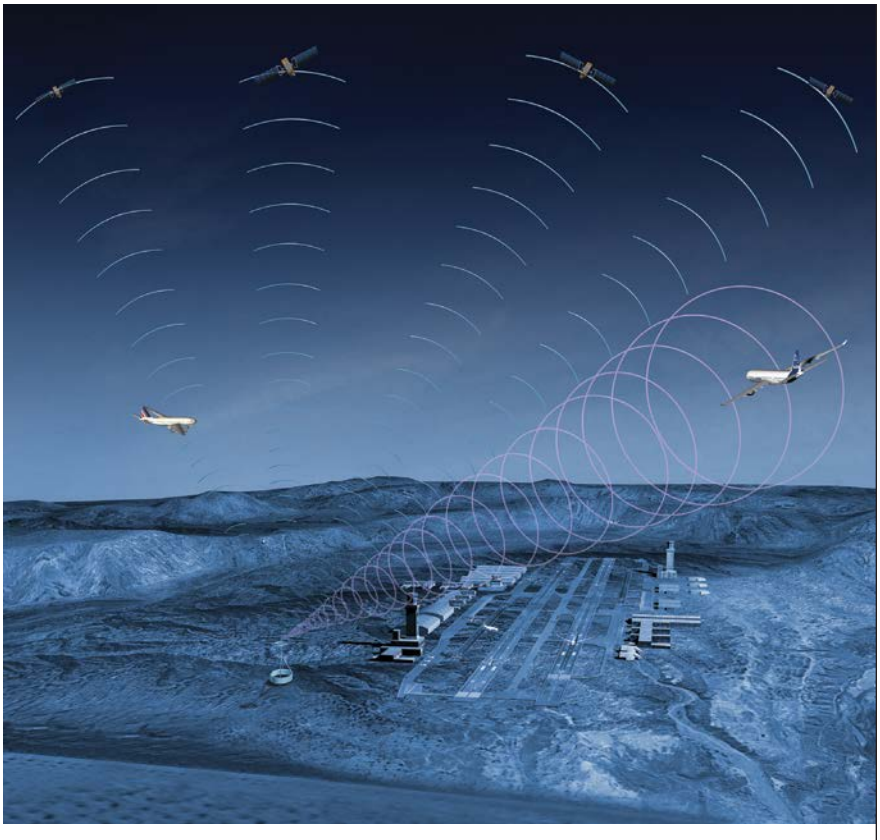
Within the next year, D214 hopes to implement some work-based learning opportunities for Aviation Academy students and strategically increase access to the program for all six of its area schools.

"What's exciting about this is that it's developing and it's growing, so our partnership with American is only going to become stronger," says Kathy Wicks, partnership manager for D214's Center for Career Discovery.

"We're really at the infancy stages of that right now," Wicks says. "So we're very excited and have talks planned for the future to map out where we think this can go, which students we can teach and also the parent component as well, to really help everyone understand the opportunity. So I think there's more to come—the sky's the limit."

Next-Gen Navigation

New systems are more dependent on satellites but also more accurate



COLLINS AEROSPACE

DFMC technology is considered key to the evolution of navigation because it increases the number of frequencies the receiver accepts from satellites, while also receiving data from more than one satellite constellation—all of which improves aircraft position accuracy and integrity.

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

The ongoing global implementation of automatic dependence surveillance-broadcast (ADS-B) "Out" has accelerated a further shift from ground-based infrastructure to satellites, as avionics OEMs roll out a new generation of onboard navigation products.

"The industry continues to evolve the airspace to take advantage of the increased accuracy and integrity benefits that satellite navigation provides," says Joe Gallo, global marketing director for commercial avionics at Collins Aerospace.

Gallo notes that three important features are on the near-term horizon for satellite navigation. One is dual-frequency (DF), which is the capability to receive data on two frequencies from each GNSS (Global Navigation Satellite System) satellite, enabling more precise measurements by eliminating ionospheric and multipath interference.

The second is multiconstellation (MC), in which GNSS satellite constellations such as China's BeiDou Navigation Satellite System and Galileo increase the total number of satellites available, significantly improving accuracy and integrity.

Then there is radio frequency interference (RFI), the focus of which is to detect and mitigate both intentional and unintentional RFI and increase the overall performance of GNSS receivers.

"Additionally, the industry is evaluating the vulnerability of satellite navigation and looking for alternative position, navigation and time (APNT) sources," Gallo notes. "Availability is a key issue that needs to be addressed."

Gallo calls the U.S. ADS-B Out mandate a "key example" of where the airline industry is relying on the accuracy and integrity of satellite navigation. He adds that beyond ADS-B Out and ADS-B In, dual-frequency multiconstellation (DFMC) and RFI are key to the evolution of navigation.

For instance, he says, DFMC "could likely support the implementation of LPV" (localizer performance with vertical guidance) in regions that do not benefit from satellite-based augmentation systems (SBAS) such as Wide Area Augmentation System (WAAS) in the U.S., Russia's Global Navigation Satellite System (Glonass) in Europe, and GPS-aided GEO-augmented navigation (GAGAN) in India, he says. LPV provides a precision approach capability, which does not require ground infrastructure but is currently SBAS dependent.

"The implementation of SBAS is new to the commercial aircraft market, and LPV implementation on these aircraft is coming in the near future," says Gallo. "The next generation of navigation systems will incorporate DFMC, RFI and LPV—both with SBAS and potentially MF/MC. They are on the horizon for most commercial aircraft." As an example, he cites the GLU-2100, which is Collins' latest multimode receiver.

"The GLU-2100 has a modern, robust hardware design and will support all navigation features now and for the foreseeable future including LPV, GBAS Categories 2/3, DFMC and RFI," he notes. "All of these future capabilities can be added with on-wing software-only upgrades."

Gallo adds that the GLU-2100 is certified on most Boeing airliners, with installation under OEM service bulletins (SB) and supplemental type certificates (STC). Certification is slat-

ed for Airbus platforms later this year, with availability in 2021 under Airbus SBs and STCs.

TECH FOCUS

Today's navigation system technology enhancements are focused on GNSS multiconstellation systems, dual-frequency development and adoption, and integration with ground-based augmentation systems for GPS precision landing, as well as the implementation of upgrades for ADS-B mandate compliance, says John-Paul Gorsky, lead sales manager at Honeywell Aerospace for air transport and regional. "With SBAS in full operation and thousands of LPV approach procedures available today, we are working with the aircraft manufacturers to introduce LPV approach on a larger portion of the air transport and regional airliner fleet," he explains.

Honeywell has been "instrumental in the introduction of LPV" on the Airbus A350 and Embraer E-Jet fleet, says Gorsky. "And now, the integrated multimode receiver (IMMR) work is progressing to make LPV available on the [Airbus] A320, A330 and [Boeing] 737 series through IMMR development programs and Airbus flight management systems (FMS)," he notes. Gorsky says Honeywell expects to add satellite landing system (SLS) approach capability to the A320 and A330 FMS this year.

"In conjunction with the IMMR certification already achieved, the certification of the SLS feature of the FMS later this year will make the SLS approach option available in both forward fit and retrofit on these fleets," he adds.

Another area of focus at Honeywell, notes Gorsky, is the development of communications management unit (CMU) and FMS capability to support operation of the Future Air Navigation System (FANS) 1/A for controller pilot data link communication (CPDLC) in the U.S. airspace. FANS—originally certified in conjunction with Boeing in the mid-1990s for transoceanic operations, delivery of route clearance information from air traffic control (ATC) and directly loaded into FMS via data link—is considered key to airspace modernization in the U.S.

"The tower phase, in which predeparture clearance delivery is provided over data link, is now fully operational at 63 airports including all 36 of the major hubs. The en route [in-flight] clearance delivery via CPDLC phase is currently in [initial operational capability] and will result in additional efficiency gains for equipped operators when it becomes operational next year," notes Gorsky.

Citing other developments, Gorsky says that for inertial navigation systems (INS), sensor technologies based on micro electromechanical systems continue to be pursued for commercial aircraft applications, especially for attitude and heading reference systems, flight control and secondary systems.

"Tightly integrated GPS/INS systems provide more robustness and high availability as a navigation source. They ensure maximum availability of the more efficient [required navigation performance (RNP)] procedures in areas where there is significant terrain masking preventing continuous GPS coverage, or during times of unreliable GPS reception in general," notes Gorsky. "[Micro electromechanical systems] inertial sensor technologies can also offer greater reliability and mean times between failures."

FUEL SAVINGS, NOISE

For the past decade, GE Aviation Systems has been working with the FAA on the agency's Continuous Lower Energy, Emissions and Noise (CLEEN) program. GE's approach has concentrated on the FMS, rather than structural changes to the aircraft or engine, says Gary Goz, product director for navigation airborne systems at GE Aviation Avionics.

"The FMS only requires a change to the flight management computer for older systems. And on newer ones, just an aircraft interface device to connect to a pilot's secure device to access these new calculations—both on and off aircraft," says Goz. "While the fuel savings would be small compared to the larger structural changes, they would be more readily available to an existing fleet."

Noise abatement, he points out, has several unique challenges that the industry must face as well. "We are working collaboratively with the FAA on approaches there," he says.

Further developments with FMS at GE, says Goz, include a new application that has been redesigned to

L3HARRIS TECHNOLOGIES

L3Harris Technologies includes an in-trail procedures (ITP) application as part of its SafeRoute+ ADS-B In retrofit solution, as pictured. ITP is typically used on over-ocean flights, providing the flight crew with a vertical profile of surrounding traffic more than 100 nm away. One result is significant fuel savings, which translates into CO_2 emissions reductions.

significantly reduce and/or eliminate inflight resets—a known nuisance with FMS in commercial aviation. In addition, he says, LPV will become available later this year as an upgrade to the Boeing 737 FMS, as part of the system's version U14. Required navigation performance, which GE identifies as RNP-0.1, is already incorporated in its current product line.

In the meantime, ongoing developments are taking place with ADS-B as airlines see the value of ADS-B In—the step beyond ADS-B Out. The most recent example is SafeRoute+, developed by Aviation Communication and Surveillance Systems (ACSS), an L3Harris Technologies and Thales joint venture. Certification was announced this March, as an ADS-B In retrofit solution, under a technical standard order for the software and new ADS-B guidance display. SafeRoute+ software and hardware installation on American Airlines' Airbus A321 fleet—its initial application—is being accomplished under a just-issued STC. It will also be available for retrofit on the A320, 737 and regional airliner platforms.

"ADS-B In relies on approaches such as RNP procedures, maximizing airport throughput by use of onboard distance-spacing tools," says Terry Flaishans, president of avionics at L3Harris Technologies. This includes crew-assisted visual separation, which means less time in the terminal area and fewer go-arounds.

"It also incorporates onboard time-based spacing tools such as interval management, providing less variability in aircraft delivery to the runway," Flaishans notes. "The air traffic management ground infrastructure is being upgraded to enable those operations such as the evolution toward time-based management."

Flaishans points out that ADS-B In technology leverages ADS-B Out transmissions. International Civil Aviation Organization performance-based navigation and U.S. trajectory-based operation in the national airspace system call for surveillance applications such as ADS-B In, he notes. "They provide greater situational awareness about other aircraft, sharing information similar to what ATC is using on the ground," he says. "With ADS-B In, you are safely reducing aircraft spacing on approach, reducing ground delays, and having the ability to increase runway capacity without expanding the airport."

Operators want to maximize the benefits of equipping their aircraft with ADS-B Out by being able to use that information for more direct routes and less flying time, says Flaishans. Along with that, ADS-B In applications enable greater airport efficiency by increasing block time predictability. Surface applications increase safety by reducing runway incursions.

"With the large number of existing aircraft, ADS-B In can be beneficial now, without waiting for the technology on new aircraft," he adds. "We are retrofitting aircraft and certifying these systems—today."

Is Pratt's Geared Turbofan Settling In?

The year ahead could see an end to nagging entry-into-service issues

AIRBUS

Sean Broderick Washington

This year is shaping up to be one of significant transition for Pratt & Whitney's geared turbofan (GTF) program, as nagging reliability issues that have plagued the fleet may finally be put to rest and the engine's lucrative aftermarket potential begins to move the company's bottom line.

Four years after delivery of the first GTF-powered aircraft, a Lufthansa Airbus A320neo with PW1100G-JMs, the engine family's level of regularly scheduled MRO demand remains low. But executives at Pratt parent UTC pointed to early GTF shop visits as a welcome tailwind in late 2019, helping offset expected declines in legacy Pratt models. Before the novel coronavirus-related decline in air transport flying rendered 2020 guidance meaningless, Pratt was projecting a mid-single-digit rise in commercial MRO work. IAE V2500 demand was expected to be the main growth driver, but the company highlighted the GTF and its initially light shop visits as a contributor during a late January earnings call.

The ramifications of the virus and the COVID-19 illness it causes will almost certainly include flipping the global air transport MRO business from a trend of growth to contraction—at least for this year. For Pratt, idled customer engines provide opportunity to roll upgrades into the fleet that will address remaining reliability issues that have plagued multiple members of the PW1000 family since their service entry.

Most pressing is a PW1100G-JM turbine blade upgrade to guard against blade fractures that have been linked to numerous in-service incidents and inflight engine shutdowns.

Operators reported 57 instances of low-pressure turbine (LPT) third-stage blade fractures from January 2017 to November 2019, with 28 linked to seals wearing, fracturing and releasing debris that struck and damaged the titanium-aluminum blades. Pratt developed a more durable blade using a nickel-based alloy and is both replacing in-service parts and installing them in new engines. The FAA mandated the blade upgrade in a November 2019 directive, giving operators one year to comply.

But at least a dozen more failures have occurred since last November, prompting Pratt to revise its inspection recommendations in a February 2020 service bulletin calling for borescope inspections of turbine piston seals on engines with the original blade configuration. The FAA's order, which the European Union Aviation Safety Agency (EASA) adopted, is based on the bulletin.

"Pratt & Whitney's service bulletin and the related FAA mandate require inspections as a mitigation measure while we upgrade the low-pressure turbine (LPT) in the PW1100G-JM fleet to the latest configuration," the company said. "The closing action for these inspections is the LPT upgrade, which is already certified and is incorporated in all new production engines and during planned maintenance visits."

The problems have hit Indian carriers particularly hard due to a combination of the operating environment and certain high-thrust flight profiles. Following four inflight shutdowns within a week in November 2019, India's Directorate General of Civil Aviation (DGCA) ordered IndiGo Airlines to ensure its

India is fast-tracking PW1100G-JM turbine blade upgrades.

entire fleet of PW1100G-JMs contain the new LPT by Jan. 31. The DGCA later revised the deadline to May 31.

Pratt, Airbus and Indigo proposed a revised deadline of July 1, 2020, but the DGCA pushed for a month earlier. The FAA has ordered all engines to have modified blades by mid-December 2020, while EASA has issued a de-pairing mandate.

"We're doing some accelerated inspections and accelerated retrofit to get the older design blade out of the fleet," UTC President Greg Hayes said. "That will happen mostly in India in the first half of the year, and we're monitoring it around the rest of the world. The [fleet-wide] retrofit is going to take through the end of this year to complete."

Two other reliability-linked retrofit programs—the auxiliary gearbox and combustor liner—are also progressing. An upgraded, fourth-generation combustor liner is due out around midyear, Pratt says.

Meanwhile, production is rising. Pratt boosted year-over-year GTF production 20% in 2019 and was projecting a similar jump in 2020 before the pandemic set in. The company does not break down its large commercial engine deliveries by model, but Aviation Week's Fleet Data Services showed 1,400 in service as of late March 2020 and 4,090 more on order. Aviation Week's forecast projects the in-service fleet will surpass 4,500 in 2025 and will top 5,800 in 2030.

A320neo-family aircraft are forecast to still be dominating the fleet in a decade, with about 70% of the installed base. PW1500G-powered A220s are expected to have about 20% of the market, followed by Embraer E190E2s with PW1900Gs at 11%. A remaining sliver is made up of PW1400Gs powering Irkut MC-21s and PW1200Gs installed on Mitsubishi SpaceJets.

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1. Green Maintenance Vehicles

Company: **Certified Aviation Services**
Specifications: Certified Aviation Services (CAS) has begun using electric-powered vehicles as part of its efforts to become more carbon-neutral. For use by interior crews at Los Angeles International and San Diego International airports, CAS has added four Global Electric Motorcars (GEM) that feature an attached hitch for secure transportation of equipment. The GEMs will be rolled out over the course of 2020, and CAS says it hopes to introduce more electric cars throughout its 19 U.S. line stations, including replacing its larger step vans with electric-powered step vans.
marketplace.aviationweek.com/company/certified-aviation-services

2. Eliminating Ozone Hazards

Company: **Lufthansa Technik**
Specifications: To reduce environmental risks from inspecting aircraft fire extinguishers, Lufthansa Technik (LHT) has started the Effect (Extreme Fast Fire Extinguisher Check and Test) project at its Hamburg component shop. Instead of temporarily purging, storing and processing ozone-depleting halon from the container for reuse, the Effect process entails placing the filled pressure tank in a special jig and heating it in a chamber, which triggers sound waves that can be used to determine whether there is damage to the tank. According to LHT, the process also cuts turnaround times to 90 min. or less.
marketplace.aviationweek.com/company/lufthansa-technik

3. Reducing Carbon Emissions

Company: **EcoServices**
Specifications: EcoServices provides a closed-loop engine wash system called EcoPower that it estimates has saved customers more than 10 million tons of carbon emissions and more than a billion gallons of jet fuel. EcoPower cleans engines in 1-1.5 hr. with highly purified water while collecting engine wash waste, so aircraft do not need to be moved to a wash bay. The company says EcoPower improves the operational flow of aircraft washing while meeting airport environmental regulations, providing fuel-burn savings and reducing carbon emissions and maintenance costs. Washes can be performed at EcoServices' global service centers or through an equipment lease program, and the service recently expanded to Madrid in February through EcoJet Aviation.
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4. Certifying Sustainability

Company: **Intertek**
Specifications: To help companies evaluate their environmental impact, Intertek launched its Total Sustainability Assurance (TSA) solution in 2019, which audits a variety of functions and provides independent certifications that enable companies to demonstrate their commitment to sustainability. According to Intertek, it has worked with MRO customers to implement changes that reduce carbon footprint, conserve and reuse raw materials, and reduce waste. Part of TSA includes Intertek's Inlight supply chain management solution, which helps businesses map their suppliers and identify possible environmental, human rights, and health and safety risks.
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5. Sustainable Airport Operations

Company: **Harris Miller Miller & Hanson**
Specifications: Consulting firm Harris Miller Miller & Hanson (HMMH) provides environmental planning services for airports to achieve regulatory compliance and more sustainable operations. HMMH conducts environmental studies for clients such as regulatory agencies and airframe and powerplant

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manufacturers to improve sustainability in the areas of renewable energy and reduction of noise, waste and emissions. The company has helped a variety of airports implement optimal positioning and noise-barrier systems for aircraft maintenance run-up facilities to reduce noise complaints. It also helped an airport reduce air pollution through use of electrically preconditioned air and electric ground power to reduce aircraft reliance on auxiliary power units and diesel ground power units.
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6. Reducing Fuel Burn and Emissions

Company: Avix Aero
Specifications: Avix Aero's Strut Data Collection System (SDCS) is a sensor-based kit used to calculate and optimize an aircraft's center of gravity, which improves aerodynamics and can help operators lower fuel burn and greenhouse gas emissions. The SDCS consists of pressure sensors installed in each landing gear, manifold, wiring harness and data-collection unit, which take rapid pressure readings that are converted within seconds to a center of gravity measurement using Avix Aero's proprietary algorithms. Avix Aero has obtained supplemental type certificates (STC) for the Boeing 737 NG family and is working to achieve STC for Boeing 777, 787 and Bombardier CRJ family aircraft by late summer.
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7. Safer Aircraft Degassing

Company: NanoVapor
Specifications: NanoVapor's patented degassing technologies are aimed at reducing downtime and creating a safer workplace. The NanoVapor system, composed of a delivery unit and chemical-based molecular suppressant, is an alternative to methods such as nitrogen tank inerting, water filling and air purging. NanoVapor says the nontoxic, eco-friendly system reduces aircraft degassing time to less than 1 hr. while minimizing the release of harmful volatile organic compounds and lowering maintenance costs.
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By DAVID MARCONTELL

David Marcontell, Oliver Wyman partner and general manager of its Cavok division, has aftermarket experience with leading OEMs, airlines, MROs and financial services.

MRO After the Crisis

The cyclical business will renew itself, but what will that entail, and how long will it take?

To say that COVID-19 is having a devastating effect on aviation is an understatement. With hundreds of millions of people living under stay-at-home orders and unemployment rates in the U.S. and Europe rising faster than they ever have, global airline capacity in available seat-miles is down 59% compared to what it was at this time last year. The International Air Transport Association is forecasting airline losses of $252 billion—a tally that has been revised upward twice in the last six weeks.

At my own firm, we cut our 2020 forecast for demand in the MRO market by $17-35 billion to reflect the nearly 11,000 aircraft that have been taken out of service and the 50% drop in daily utilization for those that are still flying. Oliver Wyman also lowered its projection for new aircraft deliveries by 50-60% versus 2019 after a comprehensive review of original equipment manufacturer (OEM) build projections versus airline demand. Deliveries for most current-production models are expected to drop 50% or more in 2021 and 2022. As a result, we project that it will be well into 2022 before the global MRO market might return to the size it was before COVID-19.

The post-COVID-19 MRO industry is likely to be smaller and further consolidated.

This crisis has gone well past the point of a V-shaped recovery. Lasting damage has been done, and not unlike the Sept. 11, 2001, terrorist attacks or the 2008 global financial crisis, the behavior of governments, businesses and the public is likely to have been changed forever.

Following 9/11, it took nearly 18 months for passenger traffic to return to its previous level, and when it finally did, travel looked very different than it had before the attacks. Passenger anxiety and the "hassle" factor associated with heightened airport security caused people to stay at home or drive. It took nearly a decade for the public to adjust to the new normal of commercial air travel.

In a post-COVID-19 environment, it is not unrealistic to expect new screening protocols to be put in place to help manage the risk of reinfection or an emergence of new hot spots. Already, international public health officials are considering such tools as immunization passports and body temperature scanning (already in use by some airports) that would be applicable to everyone on every flight, much like our security screening is today.

In addition, virtual meeting technology—adoption of which is expanding quickly out of necessity—is now becoming business as usual for work and socializing, and it's unlikely we will turn away from it entirely even when the disease is a memory. These combined influences will undoubtedly slow passenger traffic growth.

COVID-19 also will change the industry's labor landscape. For the past several years, the aviation industry has been concerned with a looming labor shortage. Before the coronavirus crisis, regional airlines were already being forced to shut down because they couldn't find enough pilots; others were trimming flight schedules. A stunning 90% of the Aeronautical Repair Station Association's 2019 survey reported difficulty finding enough technicians—a situation that cost ARSA members more than $100 million per month in unrealized revenue.

COVID-19 will change all that. With the global fleet expected to have 1,200 fewer airplanes flying in 2021 than 2019, the industry will need roughly 18,000 fewer pilots and 8,400 fewer aviation maintenance technicians in 2021. The depth of the cutbacks is the equivalent of grounding 1-2 years' worth of graduates from training and certification programs around the world. How many would-be pilots and mechanics may now be dissuaded from pursuing a career in aviation with those statistics? If people turn away now, when aviation comes back it may be a few years before that candidate pipeline is restored.

Another example of permanent change from aviation's last cataclysmic event was the consolidation of the OEM supply chain after the Great Recession. Tier 1 and Tier 2 suppliers went on a buying spree, gobbling up smaller companies. While the post-COVID-19 business environment will undoubtedly be hazardous for these same suppliers, the consolidation of the past decade has put them in a better position to survive this upheaval.

Can the same be said for the MRO community, which comprises many smaller, privately held and family-owned companies? I suspect not. While governments are scrambling to provide financial relief for small businesses hurt by the global economic shutdown, these efforts will likely fall short. The result might well be a further consolidated MRO community dominated by the OEMs plus a handful of fully integrated firms that provide support to both OEMs and airlines.

COVID-19 is a painful reminder that aviation always will be a cyclical business. With each cycle, the industry renews itself, performing better than before. One should expect this cycle to be no different. The biggest question is: How long will this cycle last?

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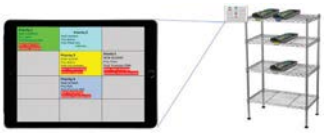

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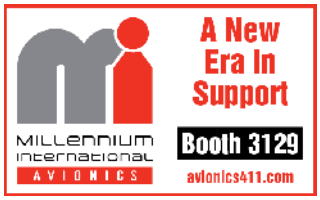

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FAST 5

Former Astronaut Norm Thagard

As the first American to live on the Russian Mir space station, **Norm Thagard** knows a thing or two about being cooped up. He spent four months isolated with two cosmonauts who had been told not to let him help with their experiments and chores. With the arrival of the Spektr science lab delayed, time passed slowly. His advice for the quarantined: Have a project. Thagard spoke to Aviation Week Space Editor **Irene Klotz** from his home in northern Florida, where he is sheltering, along with his wife, during the COVID-19 pandemic.

NASA

Thagard spent four long months with not much to do as the first NASA astronaut to live on the Russian Mir space station in 1995.

When you look back on your days on Mir, what stands out as most important? The thing that impressed me the most was that I was underworked. A lot of the equipment I was going to use was coming up on the Spektr, but the module didn't come up until a month or so before the end of the flight. So a lot of the time I just was sitting around twiddling my thumbs, and when you're in a spacecraft with not much to do and only two companions, that's not what you want. It bothered me a lot.

When I came back, I told NASA that for flights above six months, people had to be kept pretty busy with meaningful work, otherwise psychological things would start to get to you.

Is there anything else besides keeping busy that would be helpful for people who are isolating in their homes because of the coronavirus? As long as you're busy and you really believe in what you are doing, that's probably sufficient. As my wife would readily admit, I'm an obsessive-compulsive person. I like to keep busy and make things just so.

One thing I remember from your Mir flight is when your commander's mother passed away unexpectedly, and how you dealt with that. The problem for me was I knew my crewmates well and I thought we were friends, but culturally I wasn't sure about how one would approach a friend whose mother had just died. I could never know whether or not something I might think [to say], which would be standard for an American to say to such a friend, might be culturally offensive to a Russian, so I held back.

In hindsight, what do you think were the most important results of the shuttle-Mir program? We learned we could work together, although there were obviously differences. In my case, I thought it worked rather well. I know the Russians were having terrible economic problems at the time, but they still somehow seemed to do what they needed to do. And in spite of those problems, I thought that they did pretty well by way of their treatment of me and my wife and youngest son, who were over there with me.

What has been your coronavirus quarantine project? I had been kind of dawdling around trying to write an autobiographical book . . . but progress was really slow. Now I'm only a few pages from the end of the entire air-to-ground transcription from my first mission, STS-7 in June 1983. Then I'll do something about the post-flight activities, and that'll be the end of the book.

DARPA Automates Dogfighting To Develop Pilot Trust in AI in Combat

> ACE PROGRAM FOCUSES ON HUMAN-MACHINE TEAMING IN AIR COM-

> ALPHADOGFIGHT TRIALS WILL PIT AI ALGORITHM AGAINST EXPERT FIGHTER PILOTS

U.S. AIR FORCE

The Lockheed Martin F-16 will represent aircraft with digital flight controls in DARPA's AI-automated dogfighting demo.

Graham Warwick Washington

A pair of machine-controlled aircraft dogfighting against a pair of human-piloted fighters in the skies over Nevada—that science fiction scenario is one potential culmination of a new DARPA program to automate air combat maneuvering using artificial intelligence.

The Pentagon advanced research agency's Air Combat Evolution (ACE) program aims to use dogfighting as a crucible within which to develop and test pilot trust in artificial intelligence (AI). Officially, the project is planned to culminate in combat between two teams, each comprising one human-piloted fighter teamed with an AI-controlled aircraft—a stress test of the pilot's trust in the machine.

The possibility of two AI "agents" teaming up to dogfight two human pilots is something ACE program manager Lt. Col. Dan Javorsek is "deliberately holding off" until it is clear how well AI can perform in the context of highly dynamic aerial combat.

"If it turns out there is a limit to how well the computer science community is able to generate performance in this context, we may only let them be in a human-machine pair," he says. "But if it turns out that they do very, very well . . . then we should also see how well the machines team with each other, independent of the human."

Part of DARPA's wider push to advance AI, ACE is also part of its "mosaic warfare" concept for changing how individual platforms are brought together to form force packages. Mosaic warfare puts a premium on machine-to-machine communication and human-machine teaming for adaptability and flexibility.

As a precursor to ACE, the research agency is running the AlphaDogfight Trials (ADT), a competition designed both to prove the concept of using AI to automate aerial combat and to energize the algorithm-development community it plans to tap into under the formal program.

Two trials have been conducted under ADT, and the final flyoff event was planned for April 7-9 at the U.S. Air Force's AFWerx innovation hub in Las Vegas, adjacent to Nellis AFB in Nevada. This has now been postponed to Aug. 17-20 in response to the coronavirus COVID-19 pandemic.

"One of the fortunate aspects of the AlphaDogfight Trials piece is that because it's unclassified we can do a lot of it via telework," Javorsek says. "The algorithm-development pieces are continuing to march ahead."

Eight teams from academia and industry were selected for ADT in October 2019. In the final event at AFWerx, the teams will compete against each other for the first time. The algorithm developer that wins the tournament will then go up against one of the Air Force's top fighter pilots, mirroring chess champion Garry Kasparov's match against IBM's Deep Blue supercomputer.

"The reason we targeted the AFWerx location in Las Vegas is that Nellis is where the Weapons School is," Javorsek says. "If we want to see if these algorithms are making the grade, we need to put them up against someone who is considered to be at the top of that pecking order—a graduate of the Weapons School."

There is a deeper reason for choosing Las Vegas. "We wanted to draw these pilots in at the core of the program, because it's about aviator trust in this kind of autonomy. How far we are able to move the needle on whether fighter pilots trust the system is largely a function of how much they interact with it," he says."If I have the pilots at the leading edge of their field be the ones that are humbled by the technology, I am probably a lot more likely to get the broader [fighter pilot] community to recognize the value of what is coming out of the computer science community," Javorsek says.

ACE will develop AI algorithms to automate within-visual-range combat and test them first in a modeling and simulation environment, then in subscale unmanned aircraft and finally in live 1v1, 2v1 and 2v2 combat between full-size aircraft.

As a precursor to ACE, ADT is limited to demonstrating algorithms for

1v1 dogfighting in a simulation environment. The algorithm developed by each team fights against a series of increasingly capable AI agents developed for DARPA by Johns Hopkins University's Applied Physics Laboratory.

The first ADT trial in November was "a marble roll," Javorsek admits, a relatively simple exercise to ensure the interfaces allowed algorithm developers to show up with the equivalent of a thumb drive, plug it in and play the game. Their opponent was a low-performance, basic fighter maneuver agent.

"In Trial 1, everybody got to go up against that low-performing agent, which kind of just drives around," he says. Each AI agent has a different behavior. "We have an agent called Zombie that just flies in a straight line. He's representative of a cruise missile that doesn't react when another aircraft gets close."

Even a behavior that simple has value, he says, because pilots do not have to dogfight every target. "Sometimes you have to shoot down something that doesn't know you are there, or doesn't care because it doesn't think," Javorsek says.

"So we deliberately give them a handful of these agents because we are trying to show that if you are just going against a cruise missile, this kind of autonomy might be awesome because it saves you having to maneuver the aircraft into position to take a shot. You can continue to be the battle manager and let the autonomy do that," he says.

The ACE program is about developing "properly calibrated" trust in autonomy, which Javorsek defines as: "Can I turn this level of aircraft control over to the autonomy, and in what situations? If I want to be an effective battle manager, the intent is to only take over myself when it's absolutely necessary, and in order to do that, I have to be properly calibrated to the level of autonomy in my system."

Today, he says, pilots only trust autonomous systems to do basic things such as take off and land. "What we are trying to do is expand that discussion into more dynamic and complicated environments that are fraught with a lot of decisions—challenges that tended to be off-limits for AI researchers until now."

Although ADT Trial 1 was a relatively benign test of the AI algorithms, and it was "almost comical to see some of the things they were doing," Javorsek says those same mistakes are things pilots do early in air combat training when they are learning what works and what does not.

In Trial 2, held in January, algorithm developers faced off against more capable AI agents. "We allowed the dogfight agent to be more creative, with more performance capability," he says, noting again the parallel with how pilots are trained, where they face an adversary whose performance has been artificially limited so they have an advantage.

"In training a new pilot, I give them what is called a limited adversary," Javorsek says. The limited adversary has reduced thrust and performance, but the pilot being trained gets to use all of their thrust and maneuverability "and it gives them the opportunity to learn some of those lessons without constantly being foiled," he says.

In Trial 2, algorithm developers faced an adversary agent that could not use afterburner or maneuver more than 45 deg. away from the horizon. "If in Trial 1, you were going against cruise missiles, then in Trial 2 you got something that could react to you. But it's limited, so a bomber-type airplane that might not climb as well or turn as tight."

In the third and final ADT event, "they will go against the fully maneuvering agent, which will take all those restrictions off," Javorsek says. "And we will also have them compete against each other, because by that point they should be capable of handling a fully dynamic maneuvering environment. If they do well, they get to go against the human."

With ADT acting as a proof of concept, DARPA has released its solicitation for the air-combat autonomy algorithms to be used in ACE. "What we really care about is the human-machine teaming element, and before we went into the larger ACE program, we wanted to make sure the algorithms were ready. And what ADT is showing is that they are in fact ready," he says.

Development of algorithms for local combat autonomy is Technical Area (TA) 1 of ACE. DARPA is now awarding contracts for the other three areas. TA2 involves developing methods to measure pilot trust in the autonomy. TA3 will scale the algorithms from local combat autonomy to larger air campaigns. TA4 involves integrating those algorithms into full-scale aircraft and conducting live flight experiments.

Under TA4, a single contractor will modify two aircraft types for the live demo: the Aero L-39 jet trainer and Lockheed Martin F-16 fighter. The L-39 represents aircraft without digital flight controls and will be fitted with an advanced tactical autopilot to host the algorithms, while the F-16, with its digital fly-by-wire system, is a surrogate for the Lockheed F-22 and F-35.

"If we can show extensibility by applying these algorithms successfully and safely to these two different platforms, it helps us with our transition to the services, which operate those kinds of airplanes," Javorsek says. "And it allows us to talk directly to the fighter-pilot community, which ultimately has to trust these systems. If we only did it on the F-22, it would not be doing it in quite the same room."

Under TA1, contractors will develop AI algorithms not just for 1v1 combat, as in ADT, but 2v1 and the capstone 2v2 demonstration. This is "a significant increase in the level of difficulty because you can't be selfish anymore," he says. "When you are 1v1 you make selfish types of decisions. When you are 2v1 or 2v2, it's much more nuanced, and I'm curious to see how these AI algorithms handle those nuances."

Under TA2, a single performer will develop a biometric system that will instrument pilots and measure their physiological reactions, "so that when the pilots do these live dogfights, we can capture whether they are trusting the system and properly calibrate the level of trust with real data as opposed to a paper survey," he says. One key metric for the program is the cross-check ratio—essentially how often the pilot grabs the stick to counteract the automation.

The live dogfighting demos are planned for fiscal 2023, increasing in complexity from 1v1 to 2v2. Two AI developers are planned to make it all the way through to the capstone event, the dogfight between two human-machine teams. "The goal is to have an AI performer and a human go up against another AI performer and their human." And if the AI does well enough, science fiction could become reality.

ROTARY REFRE

U.S. DEFENSE DEPARTMENT

The U.S. Army continues flight-testing CH-47 Block II upgrades to support the special operations community.

Lee Hudson Washington

Though the U.S. Army is pursuing a set of new vertical lift programs to arrive in the 2030s, it is still pouring billions of dollars into a near-term effort to ensure its fleets of AH-64 Apache, CH-47 Chinook and UH-60 Black Hawk helicopters can compete in a future war.

In March, the Army selected companies to refine designs and develop prototypes for two future aviation platforms. The service selected Bell and Sikorsky to compete for a new armed scout helicopter envisioned to replace Apaches used in the armed reconnaissance role. In addition, the Army chose Bell and Sikorsky-Boeing to continue risk-reduction work to ultimately replace the Black Hawk.

While those platforms mature, the Army must add new technologies to its Apache, Chinook and Black Hawk fleets, which will remain in the service's inventory for many years to come. The goal: to keep the aging platforms relevant in a future fight.

By the mid-2020s, the service plans to reconfigure the aging Boeing Apache to compete in a multidomain operations environment. The Version 6 (V6) kit is the first in a suite of upgrades necessary to support the Pentagon's vision. The kit includes a new fire control radar, radio-frequency interferometer and an expanded manned/unmanned teaming capability.

In the fall, the service will introduce another element into the AH-64E Apache V6 kit, the Gen III Day Side Assembly, formerly known as the Modernized Day Sensor Assembly (M-DSA). During operational testing, users were impressed with the clear picture for target acquisition and the ease of locating a designation site made possible by electro-optical/infrared fusion.

"The good thing about the way we've architected this program is that the production line will be switched to V6, and we'll have the ability to upgrade any of the V4s into the V6 configuration," Patrick Mason, the U.S. Army's program executive officer for aviation, tells Aviation Week.

The service expects industry to integrate a similar multispectral targeting capability into Future Vertical Lift (FVL) platforms that resides in the V6 kit, Mason says.

The Army's FVL cross-functional team is leading demonstrations, and the unmanned aerial system program office is conducting a technology assessment. Mason anticipates that by 2021 the service will have a better idea of which kinetic or nonkinetic

PAUL STEVENSON

The UH-60V Black Hawk updates the aircraft with a digital infrastructure compared to the analog architecture in the UH-60L.

technologies will be implemented in the initial increment for air-launched effects (ALE)—the ability to deploy unmanned systems from a helicopter at tactical altitudes.

The Army plans to outfit both the Apache and General Atomics MQ-1C Gray Eagle with ALE in the mid-2020s, but it has not selected specific technologies. The service is subsidizing two simultaneous efforts that are slated to wrap up at year-end by using funding secured from other transaction authority agreements through the Aviation & Missile Technology Consortium.

General Electric to ensure the critical design review is executed in a "rigorous manner" and is completed by the end of the year. Mason still anticipates the first unit will test the engine in 2021. The service is slated to integrate the engine into the Apache in 2021 and into the Black Hawk in 2022.

The next upgrades on tap for the Boeing CH-47 Chinook are additional software loads for the digital flight control system and the common avionics architecture system. These upgrades are planned for June but may be delayed because of the COVID-19 crisis.

cause of travel restrictions imposed on government workers in response to COVID-19. The crews are composed of both government and industry personnel, he says.

The Army's other significant upgrade program is the conversion of 760 UH-60Ls to the V configuration. The UH-60V features a glass cockpit with electronic displays instead of analog dials and gauges. Additionally, the new variant includes a centralized processor that allows for software updates.

The Army is reaping substantial cost savings by upgrading the L models in-

U.S. ARMY

The AH-64E Apache will receive a suite of upgrades to compete in a multidomain operations environment.

In the interim, the Army selected the Spike Non-Line-of-Sight missile for the Apache. It has greater range than the AGM-114 Hellfire missile and guided rockets the Apache currently carries.

Once the Army selects the initial ALE, the service must determine if the Apache will need additional capacity or greater range for its sensors.

The service must also upgrade the engine for the Apache and Black Hawk, but the novel coronavirus pandemic has delayed the critical design review of the Improved Turbine Engine program. Mason's team is working on the design review virtually.

"Obviously, this is an incredibly unique and unprecedented time that we're dealing with right now," Mason says.

The Army is working closely with

"We're trying to monitor and understand exactly what we're going to be able to do as we get into June," Mason says.

The Army will not speculate on a timetable for software upgrades, which depend on a multitude of factors including unit availability.

Nonetheless, the service is still pushing ahead with Block II flight testing in Mesa, Arizona, to support the special operations community.

"We have some disruption obviously due to the COVID pandemic," Mason says.

The limited user test is scheduled to kick off in March 2021 at Fort Bliss in Texas, although it may be pushed back if not enough progress is made in flight testing. Flight testing in Mesa is not paused, but the team is not generating sorties at a sufficient rate be-

stead of purchasing new aircraft. The service estimates the upgrade costs at $12 million per unit in fiscal 2020 dollars, instead of buying a new UH-60V for approximately $21 million.

Due to COVID-19-related travel restrictions, the Army is unable to conduct user assessments, which delays the full-rate production decision. The service anticipates the effort will enter full-rate production in the fourth quarter of fiscal 2020, two quarters behind the previous schedule.

Mason's team partnered with the Corpus Christi Army Depot on the Texas Gulf Coast to convert the aircraft. The depot anticipates completing the initial tranche to field the first unit next year, he says.

"It's a very unique and cost-effective way to increase the capability of the L models," Mason says.

COVID-19 Complicates T901 Milestone as FARA Awaits New Engine Design

> DESIGN FREEZE FOR T901 COULD SLIP SLIGHTLY

> FARA PROTOTYPE SCHEDULE LEAVES LITTLE ROOM FOR DELAY

Steve Trimble and **Lee Hudson** Washington

The Bell 360 Invictus and Sikorsky Raider X helicopters are the stars of the Future Attack Reconnaissance Aircraft (FARA) Competitive Prototype program, but both designs need the GE Aviation T901 turboshaft engine to fulfill performance promises.

In fact, three pillars of the Army's aviation modernization program—the winner of the FARA competition, along with the enduring Boeing AH-64 and Sikorsky UH-60 fleets—are depending on GE's 3,000-shp successor to the T700 to stay on schedule.

U.S. ARMY

The Army verified that a preliminary design of the GE T901 engine fits into the engine nacelle of the AH-64 Apache, despite generating 50% more power than the T700 it will replace.

A first attempt at a quick start after the contracts were awarded last year already faced one setback, with a protest from the losing bidder that put the program on hold for three months. Now, program officials are scrambling to keep the program on track despite administrative disruptions caused by moves to limit the impact of the novel coronavirus and COVID-19 pandemic.

A critical design review (CDR), which, if passed, allows GE's supply chain to start building the first components, is set for this summer, but the pressure is growing.

"That is one of the things that we're continuing to monitor because we're not able to get together for the critical design review for the engine," says Patrick Mason, the U.S. Army's program executive officer for aviation. "So we're executing that in a virtual environment right now."

For the moment, the Army aviation acquisition staff is sticking to the schedule: A first engine is to be delivered to testing in June 2021, followed by a preliminary flight rating at the end of 2022.

"But obviously, the critical aspect is doing the engine critical design review this year, and how we do that in a rigorous and appropriate manner given the restrictions that we have in dealing with the pandemic," Mason says.

But Mason acknowledges the CDR milestone could slip by 3-6 months.

"It's going to be done this fiscal year," Mason says. "I would [expect it] in the third- or fourth-quarter time frame that we're looking at right now."

The Army's plans to reengine the AH-64 and UH-60 with the T901 could be the first to be directly affected by any delay. Within six months of the first T901 entering testing, the Army plans to complete the CDR for the reengined AH-64. A preliminary design of the T901 passed a "fit check" event in January, with a 3D-printed version of the turboshaft loaded neatly into an AH-64 nacelle. A CDR of a T901-powered UH-60 is scheduled for late 2022.

But the schedule perhaps most at risk is the flight demonstration phase of the FARA Competitive Prototype program. The Army has committed to launching production for the winner of the FARA competition by 2028. Eight years may seem like plenty of time, but in that window the competitive prototypes must be designed, flown and evaluated. The Army then has to select a winner, which must be converted to an operational design, built and delivered to flight testing.

The first critical date in the FARA schedule is 2023, the year that the flight evaluation between the T901-powered prototypes begins.

The Army now plans to award a preliminary flight rating for the T901 at the end of 2022, leaving only months to deliver compliant engines to the manufacturers of the competing FARA prototypes. The backup plan if the T901 is not available: Switch to the 2,638-shp YT700-GE-706. But that would deprive both FARA contenders of a chance to prove their performance capabilities with a representative powerplant.

The Army has waited a long time for a new engine. GE started producing the 1,622-shp T700-GE-700 in 1978 for the original AH-64A. The latest version, the T700-GE-701D, offers a maximum power rating of 1,994 shp. Fifteen years ago, the Army started to work on the replacement by launching requirements studies for the Improved Turbine Engine Program (ITEP). The goal remains to deliver an engine that can produce 50% more power than the -701D, with a 25% improvement in fuel efficiency.

GE's design sought to avoid the risk of attempting a new configuration. The T901's single-spool core with a free-power turbine relies on the same design approach as the T700 and leverages GE's investments in 3D aero and advanced materials for commercial turbofans to achieve performance increases.

SpeedNews

Status of the Industry
A Two-Part Series

APRIL 28, 2020 & MAY 12, 2020

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Dr. Kevin Michaels
Managing Director
AeroDynamic Advisory

U.S. Army Independently Testing High-Speed Rotorcraft Configurations

> CHITA TRIALS PRE-DATE ARMY'S FARA REQUIREMENTS

> "ADVERSE INTERACTIONS" WILL LIMIT FUTURE ROTORCRAFT SPEEDS

Tony Osborne London

With an eye on its rotorcraft future, the U.S. Army has been quietly performing independent experiments with advanced high-speed rotorcraft configurations.

A modular wind tunnel model, the Compound Helicopter Interactional Aerodynamics (CHITA), was developed by the Army's Combat Capabilities Development Command Aviation and Missile Center Technology Development Directorate (CCDC AvMC TDD) in conjunction with NASA to help de-risk future rotorcraft such as the Army's Future Attack Reconnaissance Aircraft (FARA) and the Future Long-Range Assault Aircraft (FLRAA) and even platforms beyond.

Initial CHITA tests at Langley used a conventional helicopter configuration with a slowed rotor.

The model, tested in NASA Langley's 14 X 22-ft. wind tunnel, uses a robotic traverse system to allow the position of wings, horizontal and vertical stabilizers, and propellers to be shifted into different configurations, and then tested at speeds of up to 230 kt., significantly faster than the FARA and FLRAA requirements.

With work on CHITA dating as far back as 2017, the model predates the FARA program and was initially developed as a follow-up to the Army's Joint Multi-Role efforts, providing, as CCDC officials say, an "unbiased answer" to how the Army's in-house experts would have attacked the problem of high-speed, long-range flight.

The aim of CHITA, first revealed by CCDC officials during presentations in London in February, was to provide a "benchmark quality set of data" for high-performance computing tools, CCDC officials say, validating the computational fluid dynamics tools for aerodynamic performance and unsteady flow interactions.

The data will allow engineers to better understand strong interactional aerodynamic a phenomena such as rotor-wake interactions.

"Accurately predicting these interactions can help future configurations avoid aeromechanics problems that tend to occur late in programs and can lead to limitations on the upper end of the speed range," CCDC officials said in response to emailed questions.

CHITA also features power management for simultaneous operation of Mach-scaled rotor and propeller blades, and the coordination of rotating and nonrotating data systems. The fuselage is mechanically separated from the wings, allowing engineers to get data on individual loads and moments on each of the aerodynamic bodies flying in close proximity; for example, the influence of dynamic systems such as the main rotor can be measured on both the left- and right-hand wings.

Since work began in 2017, engineers have been testing the configuration of a conventional helicopter concept equipped with a high-advance-ratio rotor or slowed rotor system.

Using the traverse system, this configuration has been tested with and without wings and with a pusher propeller. The wing position was also varied as part of the trials.

Engineers have found that "adverse interactions" will be the "most likely limiter of ultimate speed," but they note that the interactions are difficult to predict. So the CHITA capability, they say, will "assist avoidance strategies" for those interactions.

CHITA is expected to reenter the wind tunnel in 2021 with a focus on "other in-house concepts" and measuring "how far out the speed boundary can be pushed with a high-efficiency configuration," CCDC officials say. The engineers note that they are being careful not to overlap industry efforts; the CHITA work, they say, is "complementary" and will help to validate tools, answer fundamental questions and enhance the testing capability for the next generation of high-speed rotorcraft.

The CHITA work is one of a number of science and technology programs underway within the CCDC looking at future rotorcraft systems. Studies are examining structures technology in terms of their crashworthiness, survivability and weight, while studies on engines and drive systems are aligned so that new dynamic systems are ready to support new engine concepts.

One of the studies, the Alternative Concept Engine, is examining technologies for a variable-speed power turbine capable of supporting a slowed rotor and enabling the aircraft to increase its speed by reducing rotor drag. The Army is looking to insert the turbine technology into an existing engine or have it form part of a future engine. Work dating back to fiscal 2014-15 in conjunction with NASA had already proved some of the technologies to a Technology Readiness Level (TRL) 5, but continuing work will take that through to a demonstration at TRL 6, officials say. The aim is to conduct a demonstration in fiscal 2023.

BACKGROUND: MARIA DEMCHENKO/GETTY IMAGES

The CMV-22 is scheduled to begin flying missions to Navy carriers in 2021.

U.S. NAVY

TILTROTOR TAKEOVER

> U.S. NAVY BEGINS TESTING ITS FIRST CMV-22 OSPREY

> THE CMV-22 IS MORE THAN A ONE-FOR-ONE C-2 REPLACEMENT

Lee Hudson Washington

The U.S. Navy is preparing for the introduction of a new aircraft to its carrier air wing, the Bell Boeing CMV-22 Osprey, which will assume the carrier onboard delivery role at a time when demand for the mission is greater.

In the last 10 years, the requirement for logistics supply to the carrier battle group has increased dramatically. The need for resilient and agile logistics was reinforced in the National Defense Strategy. The service also needs an aircraft capable of flying in engines for the Lockheed Martin F-35 aircraft that will equip its carrier decks beginning in 2021.

Increased demand prompted the Navy to ask for more aircraft to conduct the carrier onboard delivery (COD) mission. The Navy purchased a fleet of 39 Grumman C-2 Greyhounds, which started service in 1964. The Navy began purchasing CMV-22s in 2018.

"This is mainly driven by the requirement for more logistical support based on new threats and the new operational employment strategies of the carrier strike group," Col. Matthew Kelly, V-22 joint program manager, tells Aviation Week.

Central to the Navy's decision to retire the high-wing C-2 has been its transition from the Boeing F/A-18E/F Super Hornet to the F-35C Lightning II fighter. The CMV-22 tiltrotor is equipped to support the future carrier air wing by internally carrying the F135 engine power module, which will not fit inside a C-2 and must be replaceable at sea.

"This capability will be a game changer for the air wing of the future and drove the need to match up the F-35C and CMV-22 operational deployments," Capt. Dewon "Chainsaw" Chaney, Fleet Logistics Multi-Mission Wing commodore, tells Aviation Week. The first CMV-22 deployment may coincide with the first F-35C deployment aboard the USS Carl Vinson (CVN-70).

The Osprey will require more crew, however: A traditional C-2 detachment deploys with two aircrew, while a CMV-22 detachment deploys with three, Chaney says. But the CMV-22 has much greater range than the C-2. The Osprey can fly 1,150 nm, hundreds of miles farther than the Greyhound. Two potential drawbacks of the CMV-22, though, are carrying capacity and altitude. "The C-2 can fly higher than the V-22 due to its cabin pressurization, and [it] also has more internal

volume than the Osprey," he says.

To provide oversight of the new community and conduct staff, train and equip functions, the Fleet Logistics Multi-Mission Wing was established in October 2019. The Navy's fleet replacement squadron will stand up this fall to support future training for Navy pilots, aircrew and maintainers.

"Right now, sailors are training to fly and maintain the MV-22 with Marines in New River, [North Carolina], San Diego, Hawaii and [are] even deployed overseas," Chaney says. "This training will enable our teams not to skip a beat with CMV-22 operations."

The C-2A Greyhound has been in service since 1964.

U.S. NAVY

After receiving the first CMV-22 Osprey in January, the Navy immediately entered developmental testing at NAS Patuxent River in Maryland by testing one of the new variant's key differences—its larger fuel system.

The CMV-22 is outfitted with bigger sponsons and greater fuel capacity and has an extra fuel tank in each wing compared with the Marine Corps MV-22, Kelly says. The Navy is the third service to adopt the V-22: The Marine Corps pioneered the MV-22 tiltrotor, and Air Force Special Operations Command adopted the CV-22.

"After it came here, we did some initial flying-qualities testing just to make sure it was ready to go," Kelly says. The squadron anticipates receiving the second CMV-22 in late spring, followed by the first CMV-22 operational squadron, Fleet Logistics Multi-Mission Sqdn. 30 (VRM-30), at NAS North Island in California this summer.

The first test aircraft is outfitted with "basic instrumentation," and the second will have a "more extensive instrumentation package," Kelly says. "That [second] aircraft will really do the heavy-duty envelope expansion and loads testing."

Following the initial flight tests, Air Test and Evaluation Sqdn. 21 (HX-21) conducted performance and electromagnetic-effects testing. "Before we're able to take it back to a ship, there are some systems on the aircraft that make it electrically a little different" from the MV-22, Kelly says.

For example, the CMV-22 features a public address system, high-frequency radio and different cargo lighting system. One of the key requirements for the COD role is the ability to load and unload aircraft at night. The program must ensure the lighting system is adequate for sailors to perform safe, effective and rapid cargo transfer, he says.

Since only a few major differences exist between the V-22 variants, the program is tackling an accelerated timeline from first aircraft delivery to first deployment. The test program will last roughly two years.

"It's unique because we generally don't introduce a new aircraft or a new mission, but we've already done all of the background work," Kelly says. "We know how it flies around the ship, and we've already done some risk reduction where we could with the MV-22."

For three weeks in 2016, the MV-22 performed the COD mission to develop a concept of operations to use the Osprey in that role. High-gross-weight testing was conducted because the CMV-22 has a larger fuel load.

"We tested an MV-22 at those higher gross weights around the ship to ensure that flying quality and handling quality wouldn't be degraded at those higher gross weights," Kelly says.

Additionally, the testing included the launch-and-recovery window, assessing flight deck cycle times and how the remainder of the air wing responds, he says.

"Going forward, I'm sure there will probably be some adjustments based on new things they've learned," Kelly says.

Once developmental testing is completed at Patuxent River, operational testing will begin with the aircraft integrated into the carrier air wing. The pilots and aircrew will practice cycle times, loading and unloading, and the operational test squadron will embed with VRM-30 to assist in prepping for first deployment.

In 2018, the Navy started putting pilots and maintainers through the V-22 training squadron at MCAS New River in Jacksonville, North Carolina, after which they were assigned to VRM-30. "It was great teamwork between the Navy and Marine Corps to ensure a very smooth transition of the CMV-22 into the fleet," Kelly says. "We've even had some pilots and maintainers go on deployment with Marine Corps squadrons to get shipboard experience."

The Navy selected C-2 and H-60 pilots and maintainers to cross-train in the V-22. Kelly says this provided a "good blend of understanding" because in some respects the tiltrotor Osprey acts like a fixed-wing aircraft, while in other scenarios it has more characteristics of a vertical-lift aircraft.

"We truly believe that the tiltrotor will bring a very unique capability to the carrier air wing," Kelly says. "And we're looking forward to seeing the unique ways the Navy will employ it."

U.S. NAVY

Tilting Into the 2020s

The first, and so far only, operational tiltrotor, the Bell Boeing V-22 Osprey first flew more than 30 years ago, in March 1989. In service with the U.S. Marine Corps and U.S. Air Force and to be deployed by the U.S. Navy and Japan Ground Self-Defense Force, the tiltrotor is entering a new phase of life with a series of significant upgrades, either already underway or planned over this decade.

U.S. Marine Corps MV-22B

Common Configuration—Readiness and Modernization Brings the entire fleet to late-model Block C configuration to increase capability and reliability and provide an open-architecture foundation for future upgrades. Subsequent technology insertions will occur in 4-6-year cycles.

Nacelle Improvement Increases mission readiness rates 10-12% by removing eight of 10 wiring interface boxes, changing wiring types and upgrading nacelle structures.

Degraded Visual Environment Includes flight control logic to improve aircraft handling qualities, enhanced visualization and sensors, as well as improved pilot cueing.

Aircraft Survivability Equipment Includes AAQ-24(V) directed infrared countermeasures, new missile warning system, upgraded countermeasures dispenser and threat displays.

Digital Interoperability Adds the MAGTF Agile Network Gateway Link (MANGL) to bring on Link 16, CDL, ANW2 and TTNT data links. Adds Iridium beyond-line-of-sight satcom.

U.S. AIR FORCE

U.S. Air Force Special Operations Command CV-22B

Common Configuration Block C/20 modification program improves reliability and maintainability.

Nacelle Improvements Adds wiring and structure upgrades plus improvements to engine inlet separator and infrared suppressor.

APQ-187 Silent King Includes low-probability-of-detection/interception K-band radar for terrain-following/terrain avoidance, ground-mapping, weather information and aircraft/ship detection.

Enhanced Self-Deployment Adds improvements to ice protection, worldwide airspace access, engine performance, weight reduction, defensive avionics and weapon systems.

U.S. NAVY

U.S. Navy CMV-22B

Increased Range Adds ability to transport up to 6,000 lb. of cargo or personnel to 1,150-nm range for carrier onboard delivery mission.

Fuel Capacity The MV-22B Block C airframe has two new tanks in the wing plus forward sponson tanks for additional capacity. Gross weight increased to 52,600 lb. (vertical takeoff and landing) and 57,000 lb. (short takeoff and landing).

Systems Includes improved fuel-dump capability, beyond-line-of-sight high-frequency radio, public address system for passengers and improved lighting system for cargo loading and unloading.

Sprawling Alaska Complex Becomes Newest Home for F-35A

> ALASKAN U.S. AIR FORCE BASE OWNS FIRST F-35

> INITIAL F-35 DELIVERIES SET TO BEGIN IN APRIL

Lockheed Martin handed over the first Eielson AFB-bound F-35A in early April.

LOCKHEED MARTIN

Steve Trimble Washington

Tucked deep within Alaska's rugged interior, next to a town named "North Pole," Eielson AFB may seem an unlikely station for 54 Lockheed Martin F-35As. But the commander of the 354th Fighter Wing asserts the location is more central than it looks.

Indeed, the logic of Euclidean geometry places Eielson within a daylong flight, assisted by aerial refueling, of the biggest hot spots for the Indo-Pacific Command and European Command. On a great circle route, the Alaskan base is closer to Taiwan than Oahu by more than 300 nm. To reach Estonia across the Arctic Circle, Eileson's future F-35As would have roughly the same ferry flight as Air National Guard F-35As flying from Burlington, Vermont, the next-closest U.S. F-35 base.

"A lot of people think Alaska is kind of stuck in the corner of the map. But as an airman lives, we're actually in the middle of everything," says Col. Benjamin Bishop, the 354th Wing's commander.

Another advantage of Eielson's location is its neighbors. Although a remote location, the base is less than 230 nm north of a Lockheed Martin F-22 squadron stationed at Joint Base Elmendorf-Richardson and adjacent to the home of the F-16-equipped 18th Aggressor Sqdn. and, not least, the Joint Pacific Alaska Range Complex, which is the largest U.S. instrumented training range for air combat. The U.S. Air Force declared the F-35A operational in 2016, but service officials are still learning how to optimize the aircraft's capabilities, especially in joint operations with F-22s.

"I see the F-35 really maturing in the skies of Alaska," Bishop says.

That maturation process is about to get started. In early April, Lockheed transferred ownership to the Air Force of the first F-35A bound for the newly reactivated 356th Fighter Sqdn. at Eielson. Despite administrative disruptions caused by the response to the novel coronavirus and resulting COVID-19 pandemic, Bishop still expects to complete the first F-35A delivery to Eielson on schedule in April. The 356th should receive ownership of its first three F-35As by the end of April.

The 356th was reactivated seven months ago with only two employees—the squadron commander and the deputy. Since then, the squadron has added eight trained pilots and a full complement of trainers and maintainers, Bishop says. About 1,200 active duty personnel will be added to the base when the 356th and a still-unnamed second squadron are at full strength, doubling the size of the Alaskan base's current workforce.

The Air Force has been preparing for Eielson's dramatic growth since the F-35A basing announcement in 2016. The $500 million expansion project is made more challenging by the base's location, which is 1.42 deg. of latitude, or about 85 nm, further north of Norway's Orland Main Air Station, another F-35A base.

Norway qualified a drag parachute to slow the F-35A on icy arctic runways in winter. The Polish Air Force adopted the same modification with its announced F-35A selection in January, but the U.S. Air Force decided the added weight of the drag parachute is unnecessary. The U.S. Air Force decision is helped by the fact that Eielson boasts the world's second-longest runway, at 14,507 ft., which the base's busy snowplows work to keep clear through the long Alaskan winter, Bishop says. The F-35A is rated to land and take off from surfaces with a Runway Condition Rating (RCR) of 7, only two steps up from a completely iced-over RCR-5 surface.

"We have a whole team of airmen that are really focused on that [snow-removal] mission alone, and it's not just the runways. It's the taxiways, too," Bishop says.

The Air Force also had to make other adjustments to the F-35A's standard survival gear. The 18th Aggressor Sqdn., for example, includes a sleeping bag rated for -40F in the survival seat pack of the F-16, designed to keep pilots warm overnight after an ejection until they can be reached by a rescue team. But the same sleeping bag does not fit inside the F-35A seat pack, so the base's support staff has stuffed the pack instead with supplemental heating equipment.

For maintainers, the Arctic weather presents another challenge. The Army Corps of Engineers is constructing a 16-bay shelter for the F-35A on Eielson's permafrost terrain, the first of several such structures to support the aircraft during the Alaskan winter.

The shelter "is not really for the aircraft," Bishop says. "It is more for the maintainers. When it's -40F, it's really difficult to work outside for an extended period."

Leonardo Hopes the Falco Xplorer Can Plant a Flag in the MALE Market

- FALCO XPLORER FIRST FLEW IN JANUARY
- LEONARDO HOPES TO CERTIFY THE UAS TO NATO STANDARDS

Tony Osborne London

Europe is still some way from developing a medium-altitude, long-endurance (MALE) unmanned aircraft system of its own.

European industry continues to eagerly await a green light for the development of the so-called EuroMALE, the twin-engine, 11-ton platform proposed by Airbus, Dassault and Leonardo. Meanwhile, Piaggio's dreams of transforming its P.180 Avanti executive turboprop into a UAV left the company insolvent and looking for a buyer after Emirati investors withdrew their money in late 2018.

LEONARDO

Falco Xplorer flight trials are being conducted from Trapani, Sicily.

Instead, Europe's needs for a MALE design are being met by a mix of Israeli- and U.S.-built platforms. In addition, Turkey has made inroads in Ukraine, and Serbia is purchasing Chinese UAVs.

Undeterred by Piaggio's travails, Italy's Leonardo has pressed ahead with the development of a niche MALE platform of its own—the Falco Xplorer—an aircraft the company describes as a "light MALE" with a maximum takeoff weight of 1.35 metric tons.

After unveiling the aircraft at last year's Paris Air Show, Leonardo is now pressing ahead with flight testing: It completed a first flight in January, a second flight in March and is planning a third for later in April. Flight testing is taking place in Sicily.

"We are confident of success in the market," says Fabrizio Boggiani, senior vice president for airborne systems at Leonardo's Electronics business.

"The key is the payload capability, and 350 kg [770 lb.] is a large mass we can use for sensors and fuel," Boggiani says. "Compared to other platforms, this ratio of useful payload to maximum takeoff weight is quite impressive."

In comparison, Turkish Aerospace's Anka platform has a maximum takeoff weight of around 1.6 metric tons and a useful load of around 200-250 kg. The Chinese-made Chengdu Aircraft Industry Group Wing Loong has a payload capacity of around 100 kg and a 1.1-metric-ton maximum takeoff weight, a study by the Royal United Services Institute suggests.

Leonardo is hoping the Xplorer can build on the success of its smaller, tactical Falco-family brethren, with which it shares commonality through onboard systems and ground control stations.

At double the weight and size of the earlier Falco Evo, the Xplorer model is being targeted for the intelligence, surveillance and reconnaissance mission. With the platform's payload capability, Boggiani notes that it should be able to take several different payloads aloft at any one time.

Likely payloads will include the company's LEOSS electro-optical camera and its Gabbiano Ultra-Light search radar—the latter has ground-moving-targeting-indicator and synthetic-aperture-imaging modes. Leonardo also plans to fit its SAGE electronic intelligence system and an automatic identification system for maritime use.

"We expect we can fly multimission profiles and provide data to many different users at the same time," Boggiani says.

Leonardo hopes to complete development and achieve certification with Armaereo, Italy's military airworthiness authority, toward the end of the year, although this timeline could be challenged by the novel coronavirus and COVID-19 pandemic. The company hopes to secure certification under NATO's Stanag (Standardization Agreement) 4671 certification requirements for UAV systems. Achieving this level of certification would open up the platform to operate in 80% of Italy's airspace, compared with just 20% that the older Falco EVO can operate in now, Boggiani says.

A second prototype Xplorer is expected to fly later this year to support the certification and testing of payloads.

"Once we have got this NATO standard, we expect we can easily move to a civil certification," Boggiani suggests.

Certification is seen as one of the platform's key selling points. But the manufacturer also notes that the platform is free of the U.S. International Traffic in Arms Regulations (ITAR), making it more easily exportable than ITAR-restricted platforms. It also falls into Category II of the Missile Technology Control Regime.

Since the aircraft was unveiled in Paris, Leonardo has been in discussions with potential customers. But the manufacturer has a keen eye on its home market.

"The Italian market is one of the main goals," Boggiani explains. "We know there is an interest because the Italian end user wants to expand the basket of UAV solutions to which they have access." A potential role could be the replacement of the Italian Air Force's General Atomics MQ-1 Predators.

"We know that the Xplorer can serve more than one requirement in the Italian military domain," Boggiani adds.

Leonardo plans to package the Xplorer as a system of two air vehicles and a ground control station, but the company wants to remain in line with its push to develop services. It is also proposing an intelligence-by-the-hour service, with Leonardo crews operating the aircraft on behalf of individual customers. The company is already flying the Falco EVO on such a contract with the United Nations in the Democratic Republic of Congo.

HYPER PLAN

> TALON-A AND -Z SUCCEED EARLIER HYPER DESIGNS, NOW FEATURE SINGLE FIN

> REUSABLE BLACK ICE SPACEPLANE REMAINS ON ROAD MAP

Guy Norris Los Angeles

Multiple Talon-As (inset) could be carried by Stratolaunch, pictured with future concepts Talon-Z (left) and Black Ice (right).

Reborn Stratolaunch—the Mojave, California-based developer of the giant carrier aircraft originally designed for air-launching medium-class rockets—has released new details of the revised hypersonic flying testbed designs it aims to develop as a key element of its plan to turn the unique vehicle into a platform for supporting high-speed testing.

Having first emerged in late 2018 under the leadership of Stratolaunch founder the late Paul Allen, the repurposing strategy toward hypersonic test continues as the central pillar of the company's business plan under its new owner, Cerberus Capital, which acquired the project in 2019. The launch aircraft, which made its first, and so far only, flight in April 2019 is being prepared for the resumption of flight tests later this fall.

Stratolaunch believes the 500,000-lb. lifting capacity of the carrier aircraft makes it ideally suited to support the growing needs of the U.S. defense industry for reliable access to Mach 5-plus test conditions. Although other development payloads such as air-launched hypersonic weapons could conceivably be dropped from the Stratolaunch, the company's main focus is the provision of dedicated test vehicles that could support a wide range of high-speed research and technology experiments.

The initial flying testbed, Talon-A, is a fully reusable, autonomous, liquid rocket-powered vehicle targeted at flight speeds up to Mach 6. Derived directly from the Hyper-A concept unveiled two years ago, the sharply swept delta-wing aircraft shares the same 28-ft. length and 11.3-ft. wingspan but is now configured with a single vertical tailfin in place of the wingtip-mounted canted fins on the original design. Launch weight similarly remains at around 6,000 lb., and as before, the vehicle will be capable of recovering for an autonomous horizontal landing as well as taking off horizontally under its own power.

Updated renditions indicate up to three Talon-A vehicles could be carried aloft beneath the Stratolaunch carrier aircraft, using a version of the pylon-adapter configuration originally developed for launching smaller rockets. These include the Northrop Grumman Pegasus XL, which was intended to prove the platform's initial air launch capability. Stratolaunch says missions with single-aircraft drops are due to start in 2023 and adds that follow-on near-simultaneous, multiple-launch capability "may support specific operational scenarios."

Stratolaunch will also offer another vehicle, the Talon-Z. Like the original Hyper-Z, this will be a basic, scaled-up version of the Talon-A. Although no details of the updated vehicle have been provided, a new rendition also indicates a single fuselage-mounted vertical fin in place of the Hyper-Z's wingtip-mounted fins. Under Stratolaunch's original plan, the follow-on derivative was to be significantly larger, with an overall length of 80 ft. and a 36-ft. wingspan.

The more capable Z version is expected to target test conditions up to Mach 10 and, with an all-up weight of 65,000 lb., will offer longer-duration flights that could potentially see the vehicle boost to 500,000 ft. altitude and cover ranges up to about 800 nm. Stratolaunch is not discussing a timeline for the second vehicle, but under its original plan, estimated tests of the follow-on derivative could come within five years of the A model. Under the latest schedule, this could mean Talon-Z will make its test debut by around 2028.

The two vehicles will be able to carry both internal and external payloads, the latter including bolt-on propulsion or flow-path experiments as well as finlike structures for boundary-layer transition and other investigations. The company's new Talon-A graphic shows a variety of internal and external locations for experiments, including self-contained volumes in the nose and midfuselage with standardized interfaces for power for smaller tests. Additional experimentation zones will be sited on the wing leading edge as well as the belly area, where inlets and flow-path tests will take place.

Initial design of the Talon appears to be relatively well-advanced based on preliminary work already conduct-

STRATOLAUNCH CONCEPTS

ed by the Paul Allen-owned company. A 3.5-ft.-long model of the original concept was tested in 2018 in the 4 X 4-ft. subsonic wind tunnel at the U.S. Naval Academy in Annapolis, Maryland, which provided initial data on characteristics for approach and landing. It is unknown whether a series of follow-on high-speed tests scheduled to take place at NASA Marshall Space Flight Center's trisonic facility in late 2018 and early 2019 were conducted as planned.

Stratolaunch is also officially resurrecting the longer-term Black Ice spaceplane project, which will build on the Talon design to offer an air-launched space-shuttle-like capability to orbit. The concept, which also emerged in 2018, would be a "fully reusable spaceplane that enables advanced on-orbit capabilities and cargo return," the company says.

In terms of powering the Talon and follow-on vehicles, Stratolaunch "is working with engine providers to procure the rocket engine," the company says. "We will disclose our engine provider when we have more news to share." Longer term, the company also appears to be holding the door open to resurrecting the development of the PGA liquid rocket engine to power the new vehicle family.

In January 2019, Stratolaunch announced it was abandoning development of a proposed space launch vehicle that would also have been powered by the PGA engine. At the time, preliminary development of the engine was progressing at NASA's Stennis Space Center in Mississippi. Commenting on the possibility of restarting the PGA program, Stratolaunch says only that "long-term development plans will be disclosed at a later date."

SUPERSONIC

> DELTA WING REPLACES LAMINAR FLOW DESIGN FOR BETTER ALL-AROUND PERFORMANCE

> EMPENNAGE AND WING CHANGES ENABLE SHORTER, LIGHTER DESIGN

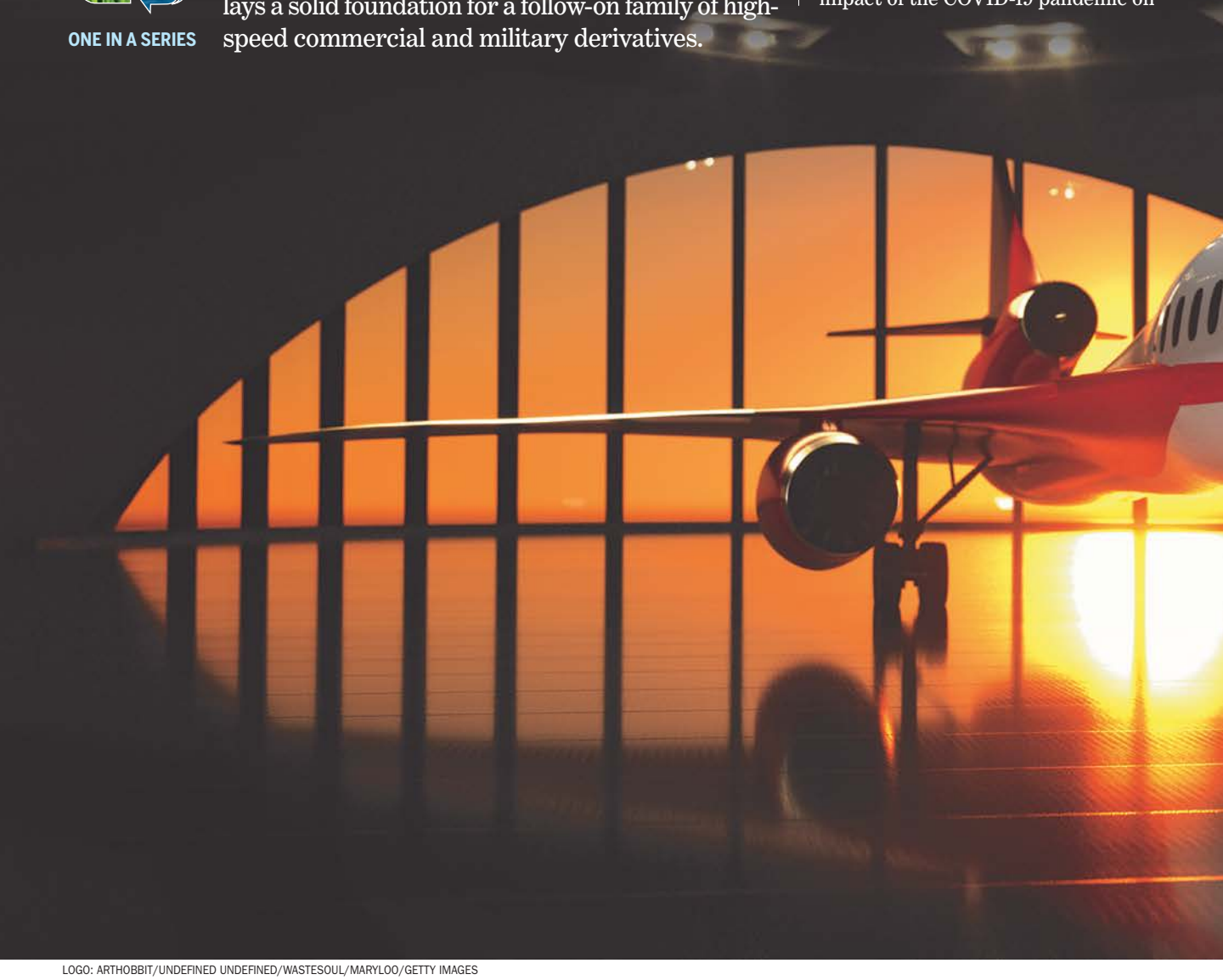
Guy Norris Los Angeles

ONE IN A SERIES

As its team of aerospace heavyweights continues to grow, aircraft developer Aerion Supersonic has unveiled a finalized design for the AS2 business jet, which it believes is not only sustainable but also lays a solid foundation for a follow-on family of high-speed commercial and military derivatives.

With a radically new swept delta wing, revised underslung engines and a sleeker empennage, the configuration differs fundamentally from previous AS2 iterations and is emblematic of a greater level of maturity both for the aircraft design and the company itself, says Aerion CEO Tom Vice. "It's representative of the amount of innovation we've been putting into the airplane," he says. "But we've been putting an equal amount of thought into our long-term strategic plan and the way we look at the marketplace."

Notwithstanding the devastating impact of the COVID-19 pandemic on



LOGO: ARTHOBBIT/UNDEFINED UNDEFINED/WASTESOUL/MARYLOO/GETTY IMAGES

EVOLUTION

air travel in 2020, Aerion believes the appetite for reduced journey times and enhanced global mobility will inevitably return in a post-pandemic world. Regardless of whether this happens sooner or later, the company acknowledges that long-term market acceptance of the AS2 still hinges on achieving environmental sustainability, both in terms of noise and emissions.

Combining low noise and carbon-neutral performance while meeting the AS2's original ambitious performance goals "is really, really hard," says Vice. Designed to supercruise with nonafterburning engines over ranges around 5,000 nm at up to Mach 1.4, with a cabin large enough for 12 passengers, the AS2 design was already challenging without the sustainability factor. "[The prerequisites] pulled us in a lot of different directions," he says. "Our task was to optimize around those competing requirements and come up with an aircraft that could meet them all simultaneously."

The configuration is led by Aerion's aerodynamic design team in the company's Reno, Nevada, headquarters and a Palo Alto, California-based group that developed a proprietary multidisciplinary design optimization tool for the supersonic aircraft project. "Those two teams have been working together nonstop over many years, especially the last two, and that's why this airplane looks the way it does," says Vice.

First unveiled by founder Robert Bass in 2004, the year after the retirement of the Anglo-French Concorde, the initial Aerion configuration was designed to operate in a new market niche below that Mach 2.2 airliner. Targeted at supersonic speeds over water, it was also tailored for efficient high subsonic, or transonic, flight

Aerion believes the AS2's new delta wing and revised empennage will boost aerodynamic efficiency and maintain its push toward fully sustainable supersonic operation.

AERION SUPERSONIC

around Mach 0.96 over land where, in most countries, no sonic boom is allowed.

To fill this hitherto untapped market, the configuration employed a novel wing design shaped for passive supersonic natural laminar flow (SNLF)—a condition in which the boundary layer flow remains stable for longer before becoming turbulent and causing friction drag. The technology was championed by aerodynamicist Richard Tracy—Aerion's co-founder and chief technology officer—who believed the low-drag, low-aspect-ratio shape would permit the aircraft to fly with limited transonic drag penalty at high subsonic speed over land and, where permitted, supersonically up to Mach 1.6.

Initial development focused on thin wing profiles in which shaping, rather than active control systems such as suction, could stabilize the boundary layer through pressure distribution. Encouraged by flight-test results of a scaled wing section with NASA in 2010, Aerion estimated the SNLF wing would have 20% less drag than a conventional delta wing and contended that increasing laminar flow fraction could lead to significant weight savings.

Although the overall design morphed from a twinjet to a trijet in 2014 as takeoff and landing noise considerations became a bigger factor, the configuration—by then called the AS2—retained its unusual trapezoidal wing as Aerion went through partnerships with Airbus and, in 2017, Lockheed Martin. The same basic wing shape, though now supporting engines slung under the wing and mounted on the upper fuselage, also continued as a feature until recently, well after the company's pivotal new partnership with Boeing.

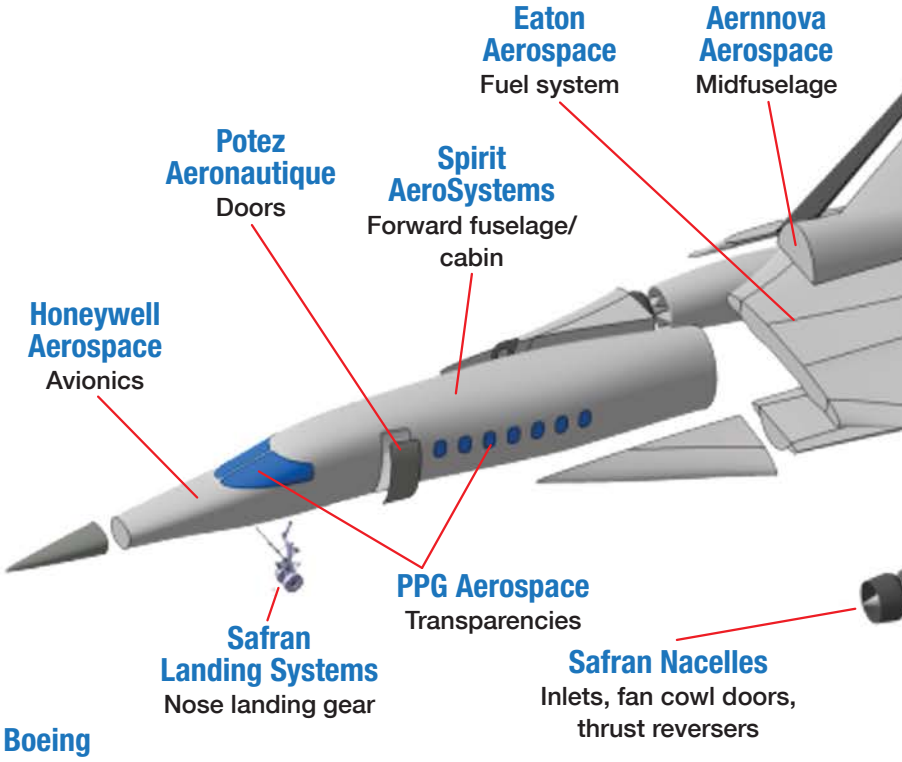
The teaming with Boeing, unveiled in February 2019 just a few months after Aerion signed up GE (GE Aviation) as engine supplier with the Affinity, helped dramatically accelerate the AS2 project. In addition to Boeing, which will support engineering, manufacturing and flight testing, a raft of other partners and suppliers have joined the program. These notably include Honeywell, which is providing the avionics, and Safran for landing gear and nacelles. UK-based GKN Aerospace and Fokker Technologies, which that company acquired in 2015, are providing electrical wiring and the empennage structure. Spirit AeroSystems will supply the forward fuselage.

Spain-based Aernnova will provide the midfuselage structure, while Potez Aeronautique of France is supplying doors. Systems and components will also be provided by Eaton and Parker, and Siemens Digital Industries Software has been selected to support design and development. "We intend to announce others fairly soon as we finalize a couple of last systems," says Vice.

The latest design update also reflects Aerion's decision to increase the AS2's overland speed capability with a technique it calls boomless cruise. With competition stirring, including potential low-boom designs that in the future may build on technology being tested in NASA's X-59 demonstrator program, the company is keen to make the AS2 equally attractive for transcontinental as well as transoceanic missions. Aerion therefore aims to offer a boomless cruise capability up to around Mach 1.2 by exploiting the Mach cutoff phenomenon in which thicker air at lower altitude refracts the boom away from the ground under particular atmospheric conditions.

Achieving this speed regime with a wing optimized for SNLF was a challenge. "You're going to fly an airplane in the highest drag region, which is Mach cutoff. To do that, you've got to be a very efficient aircraft in virtually every segment of the flight," says Vice. "So when we started to look at this, we had to think of every element of drag—not just wave drag, but pressure

Aerion Industry Team



AERION SUPERSONIC

drag, skin friction, lift-induced and of course all the miscellaneous. You have to solve all of those problems."

As a result, no one technology could dominate, says Vice. "So you see a lot less supersonic natural laminar flow on this airplane because we had to get an aircraft that could meet all of the different competing flight regimes," he says. "This [new delta wing configuration] just turned out to be an extremely high-performing design for us." The look of the AS2 is therefore transformed, with a more substantial cranked arrow delta wing planform and pronounced area-ruling around the midfuselage.

The 79-ft.-span wing has large actuated leading and trailing edges for improved low-speed flight and field performance—an important factor for meeting noise regulations with reduced engine power for takeoff. Although no details are being given about the movable surfaces, the trailing edge is believed to support a set of high-speed flaperons inboard, midspan flaps and low-speed ailerons outboard. The leading edge is made up of fixed sections inboard that appear to incorporate laminar flow treatment, while the movable devices extend from the engine nacelle to almost the wingtip.

Two wing-mounted GE Affinity turbofans project forward, enclosed in slim Safran-supplied nacelles. The third engine is mounted in the tail and exhausts through a nozzle directly below the horizontal stabilizer—now mounted immediately aft of the tailfin rather than on top, as in earlier iterations. "The tail sizing allowed us to get to a much shorter airplane," says Vice, who notes the AS2 is now 144 ft. 11 in. long, compared to almost 180 ft. in earlier iterations.

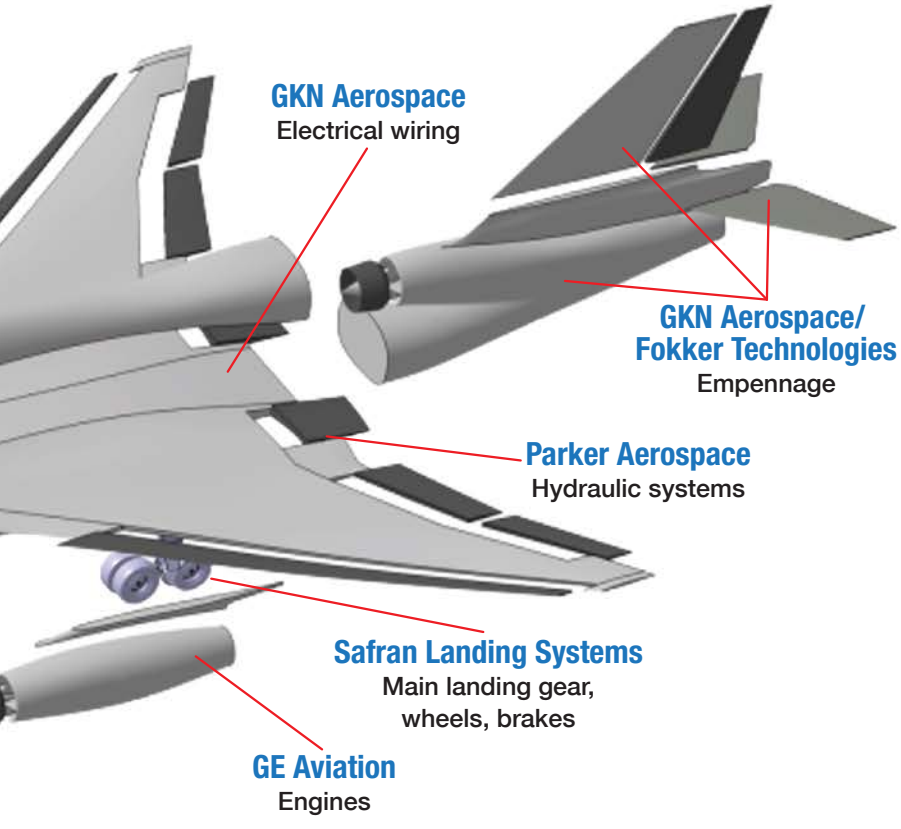
The shortened length is an outcome of "a combination of the wing sizing, the trailing edge and the tail itself," he adds. "We didn't need a big moment arm to get the nose back down at low speed." The new configuration, which will not require a foreplane, will also allow landing approaches at a shallower angle of attack compared to the Concorde, which relied on vortex-generated lift at low speed. The AS2 will have better visibility over the nose during approach, but, even though it will not require a droop nose like the retired airliner, it will be fitted with an enhanced vision system for improved crew situational awareness.

With a gross weight of 139,000 lb., the aircraft will carry up to 70,000 lb. of fuel and a payload of 8,000 lb. As in the Concorde, the AS2 fuel system will be used to redistribute weight and balance during flight to maintain trim and compensate for changes in the center of pressure, which occurs during the transition to supersonic flight. The aircraft will feature a fly-by-wire flight control system and a 3,000-psi hydraulic system.

Unlike the previous design, in which the engines were shown enclosed behind relatively thick-lipped subsonic-type inlets, the AS2 now features axisymmetric spiked, external compression inlets. "I won't say a lot about what we do with that inlet, but it meets all of the really tough requirements for inlet distortion for engines that try to be all things to all speed regimes," says Vice. The spike, which shocks the flow down to subsonic speeds for inlet recovery, forms part of what Vice describes as a "quite sophisticated inlet."

Although Aerion declines to comment, the front of the inlet is thought to include an automatically controlled variable-geometry section. This may be actuated by translating the spike longitudinally to vary the cone ramp angle, thus controlling the flow area and the shock system. Without describing the specific movement of the inlet ring, Vice says only that "if you watch this aircraft go through about Mach 0.4, I think you'd find it quite an interesting ballet."

He adds: "We really wanted to have an aircraft that was superefficient at Mach 0.95 and supereefficient at Mach 1.4, while at the same



time minimizing noise. These are not loud [aircraft]. In fact, they meet the most stringent noise rules." Vice was speaking shortly after the FAA proposed noise certification regulations that, in the case of the AS2, would set a noise limit at the lateral certification measurement point of 96.5 EPNdB, a flyover limit of 94 EPNdB and an approach limit of 100.2 EPNdB.

To minimize noise on takeoff, the proposed rules would allow use of "variable noise reduction systems," or dynamic systems such as variable geometry inlets. It would also allow for a programmed lapse rate, which the FAA says is "a fully automated feature incorporated into the engine controls as part of the engine thrust rating structure, as a means of reducing noise."

Work on the Affinity, the world's first purpose-designed nonafterburning commercial supersonic engine, is meanwhile underway at GE Aviation, where a product design review is scheduled for later in 2020. "We're working closely on that timeline," says Brad Mottier, vice president and general manager of business and general aviation and integrated systems for GE Aviation. "This is a real program; it's not just a paper exercise. We have hundreds of engineers who are assigned to this full-time, and that number is going to probably triple by the end of the year."

The company, which launched the Affinity in 2017, has completed the initial design review with Aerion and is assessing benchmarking noise data from a "first-of-its-kind acoustic test on an engine to give us the sound reference for a multistage fan design for aeroacoustics and environmental impacts," says Mottier. "We ultimately have to build this, so we're also started to engage with our supply chain."

Citing competitive reasons, GE and Aerion remain deliberately vague over the heritage and architectural details of the core, which Vice describes simply as off-the-shelf. "The reason why I don't talk about the core is because it is an incredibly high-performance engine that gives us enormous competitive advantage," he says. "It is also the basis of the first of a family of Affinity engines, and Aerion is going to be the first of a family of supersonic aircraft. And the last thing either Brad [Mottier] or I want is for our competitors to understand what we are really doing."

Now thought to be based on a modified version of the high-pressure core of the F110, itself derived from the same F101 core at the heart of the CFM56, the medium-bypass 20,000-lb.-thrust-class Affinity incorporates a new low-pressure system with features not previously seen on any commercial engine. In early renditions, these included a distinctive two-stage fan made up of wide-chord titanium blisks in place of the usual single-stage fan and low-pressure compressor, or booster, found in conventional subsonic engines. Novel features, possibly including a fore-and-aft translating variable geometry system, are also thought to be integrated into the exhaust system to optimize performance and reduce noise.

"Since the end of last year and early this year, we've been doing testing on our exhaust system," says Joel Kirk, advanced systems design and technology leader at GE Aviation. "The work includes acoustic testing and performance testing, as we are trying to optimize those two. There's obviously a trade there between them, so we are in the process of gathering the data and we'll continue through mid-year. Then we'll be in a good position to downselect on our exhaust configuration," he adds.

As part of its push for sustainability Aerion is also designing the AS2 to use 100% alternative jet fuel, rather than a blend. Much of the initial focus for this is at GE. "We'll be doing combustion testing this summer," says Kirk. "We've already completed a round in February, and we'll be doing more to show a best-in-class combustion technology."

Aerion meanwhile aimed to hold an aircraft-level preliminary design review (PDR) in October as part of plans to make first flight in 2024 and debut the AS2 in service in 2026. However, Vice says the COVID-19 pandemic may well change the timeline. "Like every company in the world today, we're stepping back and taking a hard look at the economic impact of the coronavirus," he says. "We have a solid liquidity position that takes us well into the middle of next year, even into the fall if necessary, and we are watching closely the volatility and uncertainty in the marketplace."

The company is also watching the impact on the supply chain. "We're likely to have to slow things down, and we're going through that replanning now," he adds. "But we are on a good solid footing for the overall plan, and we will see what the impact is to the PDR as we get through the next four or five months."

Aerion has "taken very prudent actions to look at every element of cost," says Vice. "We've cut costs, but the one thing that we will not do is lay people off or furlough. We have built one of the most incredibly talented creative teams, I think, anywhere in the world. And our liquidity position is such that we don't have to do anything like that. So we're in good shape. Although there are likely to be some impacts on the program, which will be pushed out, we are very confident that we'll get through this virus and the economic impacts with it. We'll come out the other side stronger and get through PDR and get the airplanes delivered."

Military Option

AERION IS OFFERING A MILITARY AS2 derivative dubbed the High-Altitude Supercruise (HASC) platform to serve as a U.S. high-altitude surveillance and eavesdropping aircraft for the Army, Air Force and Navy. The concept includes new capabilities such as a high-altitude testbed platform for a powerful new class of high-energy lasers with power levels of 500 kW or more.

Aerion's novel approach also cedes ownership of the design to the military. The baseline concept builds on the commercial-certified empennage, engines, wing and centerbody but adds a customized forward fuselage that would house a government-owned mission system and payload, says Stew Miller, Aerion's executive vice president of strategic systems. Allowing military control of the design, production and sustainment of a fully modular forward fuselage section "changes the model and it empowers the customer," Miller says. "This is not a [military] modification," he adds.

Aerion hopes to propose the idea for the Army's Aerial Intelligence, Surveillance and Reconnaissance aircraft program, which seeks to acquire up to 10 modified business jets for the role.

SURVIVAL OF THE SMALLEST

AIRBUS

> AMID EXPECTED PRODUCTION SLUMP, THE AIRBUS A220 MAY BENEFIT

> BOEING/EMBRAER JOINT VENTURE APPROVAL IS KEY FOR E2 OUTLOOK

> OPPORTUNITIES LIE IN RIGHTSIZING TO MARKETS ONCE AIRLINES RESTART ORDERS

Guy Norris Los Angeles and **Jens Flottau** Frankfurt

As fleets of widebodies fly into storage around the world, many of them never to leave, the coronavirus crisis poses equally challenging questions about the future of the smaller single-aisle aircraft at the other end of the capacity scale.

But what will that impact be? While it is virtually impossible to predict with any certainty, there appears to be a growing consensus that smaller is better—particularly as operators struggle over the more near-term recovery period forecast for the next two years. To further complicate matters, some observers believe not all small airliners are created equal and that the recovery scenario may favor the fortunes of some models and families over others.

In this context and given the relative state of health of the two biggest manufacturers—Airbus and Boeing—going into the COVID-19 pandemic, it seems the European company with its A220 and smaller A320/A320neo may be better positioned. Boeing's long-stalled efforts to recertify the troubled 737 MAX, added to the scenario in which airlines will face acute overcapacity problems even without taking any of the large numbers of MAX aircraft in storage, do not appear to bode well for a speedy recovery.

Air Canada started Airbus A220 commercial flights in January.

Compounding the issue for Boeing is the 737 production halt, which seems likely to extend beyond even the provisional "worst-case" conditions originally considered last December. Growing delays to recertification of the aircraft and the termination of deliveries in 2019 have significantly affected the company's cash flow, forcing it to consume a $13.8 billion drawdown loan much faster than the financial markets expected. Wall Street's subsequent reaction to Boeing's increased debt and lowered credit rating, exacerbated by the onset of the COVID-19 pandemic and its impact on air travel, triggered a collapse in the company's share price in March. Later the same month, Boeing also appealed for state aid.

Not surprisingly, the signs of an accelerating erosion of the impressive MAX order backlog have begun to show. Following order losses in 2019 largely connected to the collapse of India's Jet Airways, the latest figures show that by the end of February, before the full impact of the pandemic was felt outside of Asia, Boeing had already had a net loss of 43 orders for the year.

In early April, Avolon offered a strong indication of what may come from the global leasing community in the next few years. Avolon canceled an order for 75 737 MAXs that would have been due for delivery between now and 2023, reducing its own exposure to what is likely to be a very weak airline market. The lessor also deferred deliveries for nine A320neos from 2020 and 2021 to 2027 or later.

But even as the backlog takes a hit, there is the possibility that order substitutions may also take place as airlines attempt to adjust for mid-term capacity needs. Whether this is reflected in an uptick for orders of the slow-selling 737-7 variant of the MAX remains to be seen. Though Boeing does not provide a breakdown of MAX orders, the smallest member of the family is thought to currently account for only around 50 aircraft against 3,000 for the -8, more than 450 for the -9 and more than 520 for the yet-to-fly -10 stretch.

For now, deliveries—and even less so, orders—do not indicate that small aircraft are doing better. In fact, the Aviation Week Intelligence Network Fleet Discovery database shows such aircraft were worse off going into the COVID-19 crisis than the larger narrowbodies, although the numbers reflect previous market trends more than the impact of the crisis. But those numbers cannot be ignored either.

From January to March, Boeing delivered just two narrowbodies (both 737-800s); Airbus handed over 104 single-aisles in the period, already well below its targeted average output of 63 aircraft per month. But they included no A319s or A319neos and only eight A220s.

The A220 could be a winner in relative terms, as its combination of relatively small size, low unit costs and long range not only enables it to fly in secondary markets but also to replace larger narrowbodies on primary, longer-haul routes on which demand is temporarily suppressed. An Airbus production forecast by Agency Partners analysts envisions the A220 as the only model that can sustain increased production rates over the next seven years, albeit at lower numbers than initially planned.

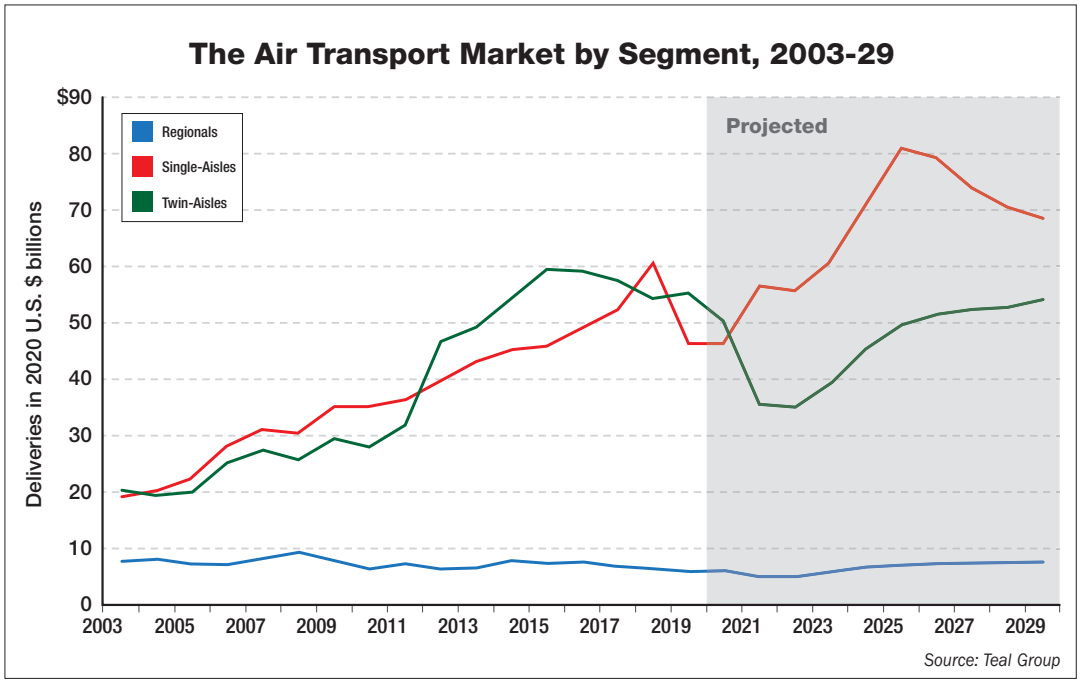
Analysts Sash Tusa and Nick Cunningham forecast that Airbus will be able to deliver 65 A220s in 2020, compared to 48 in 2019. The number will rise to 97 in 2022 and stay around that level for several years, they say. Airbus had hoped to bring the A220 up to the current maximum possible rate of 14 aircraft per month, or close to 170 a year, by the middle of the decade, a target that now seems elusive.

But it is growth, at least. According to Agency Partners, Airbus will still be able to deliver 541 A320neo-family aircraft this year, roughly in line with 2019, but production will fall to just 319 in 2021 and not recover to precrisis levels until 2025.

The situation is even worse for Embraer, which delivered only six commercial jets in January-March—one E175 for American Airlines, one 190-E2 each for Air Kiribati and Helvetic Airways and one E195-E2 for Azul. While the E2 is generally accepted as a very efficient, well-designed aircraft with good seat-mile cost and even better trip-cost performance, its sales have been disappointing, with too few key orders from AerCap, Azul and KLM Royal Dutch Airlines, the type of orders that meet Embraer's hopes of moving the E2 more into the mainline market.

For Embraer, timing and the market environment were horrible. In the years of high growth, business was too good for airlines to buy in to Embraer's rightsizing argument in a meaningful way. It was still OK to fly an A320 or 737-800, even if that one midday flight was not generating profits. In the overall scheme of things, it did not matter. Then Airbus bought the former C Series program from Bombardier, forcing Boeing and Embraer to react.

The resulting joint venture, Boeing Brasil-Commercial, in which Boeing plans to own an 80% stake, has not yet received regulatory approval from the European Commission. While most observers agree it will ultimately get the green light even in Europe, the pre-COVID-19 deadline for the decision



was the end of June, and Boeing and Embraer had hoped to close the deal at the end of 2019.

There has been much speculation as to whether the transaction was being held hostage in the wider trade dispute between Europe and the U.S., which has led to tariffs on Airbus aircraft imported into the U.S. But people with close knowledge of the matter say the issue has more to do with internal commission matters and how to exit an investigation that has gone too far in a face-saving way.

But even if Boeing Brasil-Commercial were to receive the last missing approval this summer, it would be cleared to go at the worst possible moment. Boeing would have to pay $4.6 billion for the commercial part of a company that the stock exchange currently values at $1.5 billion including its defense and business aviation segments. The low valuation may be temporary. But Boeing is asking for a government bailout on the order of $60 billion for itself and the supply chain, and may face political opposition to spending a significant amount on an acquisition in Brazil.

"Strategically, it is still a great partnership, and we have to get through the regulatory hurdles," says Boeing Chief Financial Officer Greg Smith. "We will see how long that takes, but it still remains a priority for us." Without the deal, Boeing will struggle to come up with an offering to compete with the A220, and Embraer would be left to compete on its own against Airbus and Boeing, a situation it has tried to avoid from the initial design of the latest E-Jet generation.

"My feeling is that this new climate will favor smaller aircraft, as long as they have necessary range and equivalent economics," says Richard Aboulafia, vice president of analysis for the Teal Group. "For single-aisles, the A220 will be more relevant than ever, particularly now that Airbus is getting its costs in line with the rest of its product line." Whether the same positive push also applies to the Embraer E-Jet family is still to be determined. "Much depends on Embraer being able to get its production economics in line with Airbus'. If they aren't, this is a 75% Airbus market," he adds.

According to Bert van Leeuwen, managing director and head of aviation research for MUFG Bank's global aviation finance division, the industry may well be facing two possible scenarios, both of which point to significant downsizing across both single- and twin-aisle sectors. "After the COVID-19 crisis, the world will experience a major economic recession. With high unemployment, pensions and so on will be under pressure due to the collapse of the stock markets and some major corporations in bankruptcy, while Italy and other countries will be in crisis."

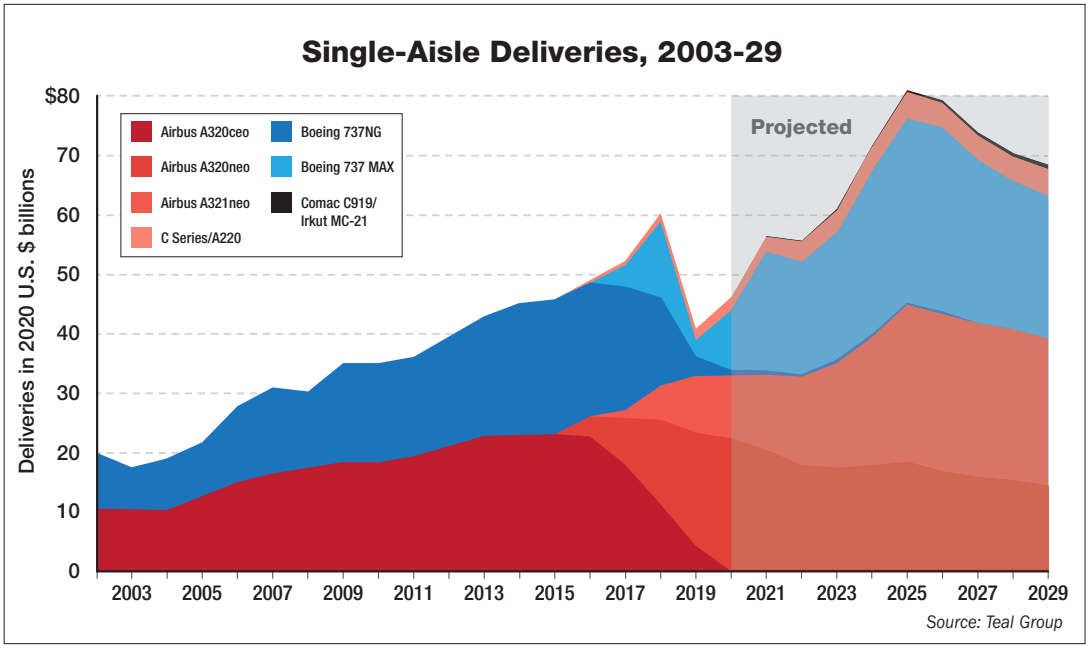
He says one result will be that a fear of flying, along with economic issues, will reduce the number of passengers significantly. "[A]irlines will have to compete more intensely for passengers," he says. "This may imply higher frequencies and smaller average aircraft sizes. With low fuel cost, the less favorable fuel burn per seat-mile for smaller planes won't be that much of an issue for the airlines. Ultimately, A321s or 737-900s may even be parted out to support A319 or 737-700 fleets, as airlines won't be in buying mode for new planes."

Leeuwen adds: "Another element to consider could be that passengers will strongly prefer smaller aircraft and point-to-point services rather than connecting through busy megahubs, to reduce the risk of contagion and crowded boarding areas."

The second, equally gloomy, scenario builds on the premise of the first. "Now, let's assume there will be more airline defaults or consolidation," he says. "The few surviving airlines may compete on price, mainly to stimulate demand, less so to gain market share. This would imply that airlines will not increase frequencies but will focus on lowering seat-mile costs. They can achieve this by consolidating flights and deploying larger aircraft, like the MAX 9/10, A321. On long-haul [transatlantic] routes this may imply the A321neo XLR will replace even more twin-aisles."

This sentiment is shared by Aboulafia. "The A321neo will continue to be hugely relevant as a widebody replacement. The 787, too, but if you don't need its range and capacity, the A321neo will win," he says.

"Initially, we will see increased utilization of smaller airplanes," Leeuwen says. "But by 2023 we may slowly return to normality. As it stands right now, I don't expect airlines to go out on a shopping spree to buy additional [smaller] aircraft. Leasing may be an option."



DRONES JOIN THE FIGHT

DRONETOOLS

Spain's Military Emergencies Unit is using the Dronetools Dronehexa-AG agricultural drone to spray disinfectants in that hard-hit country.

Bill Carey Washington

Medical logistics was already a growth market for small unmanned aircraft systems before the COVID-19 pandemic pressed the case for using drones in a variety of ways to benefit public health.

As the novel coronavirus that causes COVID-19 radiated beyond China to Europe, the Americas, the Indian subcontinent and elsewhere, media accounts surfaced of drones being deployed to move medical parcels, enforce social-distancing rules and disinfect streets and buildings.

While some public health officials questioned the utility and safety of dispersing chemical disinfectants by drone, many nations adopted the tactic, typically by repurposing agricultural drones used for precision spraying of pesticides and fertilizers.

Early in the crisis, Chinese agriculture technology company XAG deployed its XPlanet agricultural drone and R80 robotic ground vehicle, sometimes working in tandem, to disinfect coronavirus-hit outdoor areas and epidemic-prevention vehicles.

On Feb. 2, XAG called for drone users to "voluntarily engage" in disinfection operations and announced a 5-million-yuan ($710,000) fund to cover the cost of spare parts and maintenance. By late February, 370 teams and 2,600 drones had joined the effort, the company said.

India's Atom Drones operated multirotor spray drones to disinfect Delhi's crowded Nizamuddin neighborhood, identified as a coronavirus hot spot. Garuda Aerospace deployed 300 drones and 500 pilots to disinfect public spaces, colleges, hotels and hospitals across 26 cities in India, according to its domestic media.

Spain's Military Emergencies Unit (UME) tested the DJI Agras MG-1 and Dronetools' Dronehexa-AG agricultural drones to disinfect outdoor areas, the *South China Morning Post* reported.

The UME is among 2,500 troops participating in disinfection operations in 172 locations across Spain under Operation Balmis, named after Francisco Javier Balmis, a military doctor who delivered the smallpox vaccine to overseas territories of the Spanish Empire in 1803-06.

A U.S. oil-spill response company, OMI Environmental Solutions, of Belle Chasse, Louisiana, says it has lined up multiple clients for its drone disinfection service for large indoor areas, including stadiums, convention centers and warehouses. OMI's eight-rotor drone disperses a mist of Environmental Protection Agency-approved agents that kills the novel coronavirus and nearly all bacteria, the company says.

Surveillance, enforcement of social-distancing rules and remote monitoring for COVID-19 symptoms—uses that could be considered intrusive in normal times—are among other active or planned applications of drones in the pandemic battle.

In Kazakhstan, Terra Drone group company KazUAV operated a fixed-wing surveillance drone to monitor borders and enforce a quarantine of Nur-Sultan, the country's locked-down capital.

Canada's Draganfly, the University of South Australia and health care data company Vital Intelligence announced a partnership on March 26 to develop a "pandemic drone" enabled with cameras and computer vision. The aim is to ferret out infections in crowds by monitoring the body temperatures and heart and respiratory rates of individuals.

Despite U.S. government policies that prohibit federal agencies from using Chinese-made drones, Shenzhen, China-based DJI said it would loan or donate drones and accessories to police, fire and public safety agencies in 22 states.

The Daytona Beach Police Department in Florida reported receiving two drones from DJI, including a Mavic 2 quadcopter equipped with a loudspeaker that it was using to enforce social distancing in city parks.

"We've had great success with it," stated an officer with the department's unmanned aviation systems unit. "We've put it in pretty much all of the city parks in the last week or so. We've had 100% compliance."

Apparently unauthorized was a loudspeaker-equipped drone that was filmed skirting a river in New York City, instructing people below to keep their distance on behalf of the Anti-Covid-19 Volunteer Drone Task Force.

Prominent in an effort to deploy drones in the pandemic response in the U.S. is Zipline, which launched a long-range service in 2016 to deliver units of blood to hospitals in Rwanda, and in 2019 to deliver vaccines, blood products and medications to health centers in Ghana.

The South San Francisco, California-based company now operates two distribution centers in Rwanda and four in Ghana; the fixed-wing, catapult-launched aircraft it uses delivers an order to a distance of 50 mi., drops the parcel by parachute and returns to its base.

Zipline has been collaborating with Novant Health of North Carolina and had plans to launch a delivery service in the U.S. this fall to convey supplies to health facilities and at-home patients.

Now, because of the novel coronavirus outbreak, the company hopes to expedite the regulatory approval process. The FAA was working with a dozen companies and government agencies seeking to use drones outside its current regulatory framework. "We are making these requests a priority and considering options for accommodating such operations consistent with our safety mission," the agency stated.

"We believe there's a lot we could do here," says William Hetzler, who cofounded Zipline in 2014. "We have already received requests from the community level to accelerate our launch to help with the response to the coronavirus. We're ready to go. We believe that as soon as we receive the green light, we could be operating in as little as a few weeks."

Such an operation in the U.S. could help ensure continuity of access to supplies such as blood and vaccines that may not be directly tied to the pandemic, Zipline asserts. Additionally, its services could help keep vehicles off the street, allow illnesses to be treated at home and keep hospital beds open for critical-care patients.

More directly, Zipline drones could deliver laboratory reagents and other supplies used to diagnose COVID-19 cases, treatments used to manage symptoms of the disease, and targeted supplies of personal protective equipment for healthcare workers, the company says.

The payload capacity of a Zipline drone is 3.9 lb., but the company says it can perform 150 deliveries in a day.

"Over a week, we might distribute several tons of product, but in a hyper-targeted, just-in-time-supply way," Hetzler says. "We can do a thousand deliveries over that week of exactly what's needed to exactly the point where it is needed. It's a different way of thinking about supplies than many people are conditioned to—full truckloads dropping off a giant delivery on an infrequent basis."

Stuart Ginn, a head and neck surgeon and former airline pilot, was instrumental in developing the UPS Flight Forward drone-delivery service at WakeMed Health and Hospitals in Raleigh, North Carolina. Launched in March 2019 under the FAA's UAS Integration Pilot Program (IPP), the service uses the Matternet M2 quadcopter to transport blood samples across a busy street from an outpatient surgery center to the main hospital laboratory.

The WakeMed operation was not directly supporting the COVID-19 response, but the topic of applying IPP projects to battle the pandemic arose in March, Ginn says. He recalls: "Everybody's first thought was, What about testing? What about using this technology to ship test samples to the labs so we could amplify the testing response?"

Just as the virulence and spread of the virus caught nations unprepared, Ginn believes the U.S. would have to ramp up the infrastructure for drone deliveries in a major way to make a difference in the fight.

"If we had a national level or industry level asset in place, there are so many models where you could deploy this technology to scale, amplify testing and make an absolute impact on a public health crisis," Ginn says.

"You could set up distributed testing sites all over a county, much closer to people's homes, and have those samples flown very rapidly to where [they] need to go to get testing done," Ginn adds. "But we're not quite there yet."

ATOM DRONES

A team with Atom Drones flew a multirotor spray drone to disinfect New Delhi's crowded Nizamuddin neighborhood.

SCALING DOWN

> RADAR SYSTEMS READIED FOR LARGE AND SMALL DRONES

> LEGACY MANUFACTURERS EYE UAM MARKET

Bill Carey Washington

The size, weight, power and cost considerations that drive avionics design apply as usual for small drones and compact urban air mobility vehicles that will be expected to perform like traditional aircraft in managed airspace.

Visibility to surveillance systems, an ability to self-separate from other traffic and a high degree of flight automation will be among the avionic attributes drones and urban air mobility (UAM) vehicles will need.

Aircraft operating in most controlled airspace in the U.S. as well as in designated airspace in other parts of the world now require transponders and satellite-positioning receivers to transmit their precise location to controllers by automatic dependent surveillance-broadcast (ADS-B), a method that adds another surveillance layer along with ground-based radar.

Small unmanned aircraft systems (UAS) will need to signal their position in the U.S.—although likely not by ADS-B—in lower-level airspace up to 400 ft. above ground level (AGL), keeping them below the FAA's minimum safe altitude for manned aircraft of 500 ft. over uncongested areas. UAS Traffic Management Systems will coordinate multiple, simultaneous flights of commercial drones.

UAM vehicles will inhabit a middle layer of 500-1,000 ft. AGL or higher, flying within defined airspace corridors that Uber has named "Skylanes." Service providers will coordinate flights within what Embraer calls an urban air traffic management system.

Five years ago, inventor and entrepreneur Paul Beard founded uAvionix, a company focused on scaling down an ADS-B system to provide small drones with collision-avoidance capability.

A model aircraft enthusiast, Beard is credited with developing digital spectrum modulation (DSM) in the 2.4-GHz band for radio-controlled hobby aircraft and cars. Using DSM, a transmitter scans the band for unused channels to send a unique encoded signal to a receiver that is "bound," or programmed to recognize the signal, a technique that reduces the possibility of interference with other nearby devices.

Testers with the Virginia Tech Mid-Atlantic Aviation Partnership carried a Titan X8 multirotor drone equipped with the Echodyne EchoFlight metamaterial electronically scanning array radar (the small white panel fitted below its front) during NASA's Raavin project.

"It was pretty simple back then—it was ADS-B for drones," recalls uAvionix President Christian Ramsey about

AMY ROBERTSON/VIRGINIA TECH

the company's founding. "Paul in particular comes from Silicon Valley and has a history of understanding how to miniaturize and put things on chips and move that into production."

With venture capital funding, uAvionix built its first product: an ADS-B core radio chip capable of transmitting and receiving at 1090 MHz and 978 MHz, frequencies the FAA specifies to interact with its ground radio stations. From its "ping" series of ADS-B transceivers weighing as little as 26 grams (0.9 oz.), the company branched into command-and-control data link radios for drones, GPS modules and ADS-B transceivers and transponders for general aviation (GA) aircraft and airport ground vehicles.

In October 2019, uAvionix acquired AeroVonics of Albuquerque, New Mexico, a manufacturer of digital primary flight and multifunction cockpit displays for the GA market. That month, the company also settled a patent infringement lawsuit brought against it by Garmin, which had accused uAvionix of using patented ADS-B technology without permission. Under terms of the confidential settlement, uAvionix was allowed to continue offering specific products.

In the GA market, uAvionix specializes in easily installed systems that take advantage of existing lighting locations and access to aircraft power. In February, it announced TailBeaconX, a 1090-MHz Extended Squitter ADS-B "Out" transponder, GPS position source and dipole antenna, which it hailed as the first commercially available avionics solution developed with the needs of UAM vehicles in mind.

The TailBeaconX, with an integrated light-emitting diode position light, replaces an aircraft's rear position light. uAvionix expects FAA technical standard order and supplemental type certification of the transponder in the second quarter; it plans to introduce a wingtip version in mid-2020.

With manufacturing facilities in Bigfork and Columbia Falls, Montana, uAvionix essentially builds radios, "and radios need antennas," says Ramsey. "The antennas go on the external part of the aircraft, so why not build a whole system that can be installed on the externals of the aircraft? You don't need internal avionics bay space—you put it all on the edges of the aircraft."

He adds: "If you can combine that with [aircraft] lighting, then you've got a power source already available, ready for use. That's the direction that we're taking a lot of our systems with urban air mobility in mind. We're taking the core component and building it into what traditionally would be considered the antenna footprint."

In late December, the FAA released a long-awaited notice of proposed rulemaking describing remote identification requirements for small drones. The proposed regulation would prohibit drones from using ADS-B Out transponders to send identity and position data, out of concern for radio frequency saturation and lack of ground infrastructure to receive ADS-B data at lower altitudes.

While the rulemaking "affects our initial vision of ADS-B on drones," a strong business case remains for drone pilots to be informed of nearby air traffic through ADS-B In reception, says Ramsey. "We've known it's been coming for quite a time in order to pivot in other directions," he notes.

The uAvionix TailBeaconX ADS-B Out transponder replaces an aircraft's rear position light.

While manned aircraft have a pilot aboard to see and avoid other aircraft and have traffic alert and collision-avoidance systems (TCAS) as a last resort to prevent midair collisions, drones and pilotless UAM vehicles will need sensor-based detect-and-avoid (DAA) systems.

In concert with NASA and the FAA, General Atomics Aeronautical Systems (GA-ASI) has built a DAA system for the Predator B over the past several years that combines an active, electronically scanned array (AESA) air-to-air radar to detect "noncooperative" aircraft targets with a TCAS computer processor to track nearby, transponder-equipped "cooperative" aircraft replying to transponder interrogations.

The system is based on performance standards developed by RTCA Special Committee 228 and referenced in FAA technical standard orders C211 (DAA systems) and C212 (Air-to-Air Radar for Traffic Surveillance), which provide guidance to manufacturers planning to build FAA-authorized equipment.

Last September, GA-ASI awarded the L3Harris Technologies and Thales joint venture ACSS a five-year contract to supply 200 DAA processors for aircraft fitted with the collision-avoidance system. The processor supports the latest TCAS II, DAA and ADS-B functionality in a compact, lightweight unit, says ACSS.

But an electronically scanned phased-array radar comparable to one designed for military fighters or for a Predator-sized UAS that will fly in controlled airspace is not a size or cost option for a small drone intended for package deliveries or some other mission at low altitude.

Around 2013, entrepreneurs at Intellectual Ventures, a technology incubator founded by former Microsoft Chief Technology Officer Nathan Myhrvold, initiated development of a scaled-down electronic phased-array radar based on metamaterials—engineered microstructures that can be arranged in patterns to manipulate electromagnetic waves.

Military-grade AESA radars are structured from hundreds to thousands of transmit-receive (T/R) modules. A T/R module consists of phase shifters that change radio frequency (RF) signal phases to drive a radar wavefront in different directions, circulators that switch between transmit and receive modes, amplifiers and other electronics, explains Eben Frankenberg, cofounder and CEO of Echodyne Corp.

Based in Kirkland, Washington, Echodyne spun off from Intellectual Ventures in 2014 to build metamaterial electronically scanning array-based radars sized for small drones and ground-based DAA systems as well as radars for security systems and autonomous cars.

While a beam-steering radar "costs hundreds of thousands of dollars at the low end," Echodyne's radars are priced


BELL TEXTRON

Garmin is leading avionics development for Bell Textron's Nexus eVTOL air taxi.

at "tens of thousands of dollars," says Frankenberg.

"The whole concept around it is the ability to make a beam-steering radar like a phased-array radar but without using phase shifters," says Frankenberg. "By eliminating those and all the complicated electronics, we can create a true beam-steering radar at commercial price points."

Echodyne's metamaterial electronically scanning array radars use multilayered printed circuit boards to create a software-controlled, beam-steering radar antenna driven by standard radar transceiver electronics. "This is not a chip technology; it is essentially an antenna technology with our own radar in the back end of it," says Frankenberg.

Echodyne's EchoFlight airborne radar operates in the K band at 24.45-24.65 GHz. The company sells the radar in single panels measuring 7.38 X 4.75 X 1.6 in. and weighing about 26 oz. The panel's field of view is 120 deg. in azimuth (plus or minus 60 deg. from straightforward) and 80 deg. in elevation. Three panels positioned around an aircraft provide 360 deg. in azimuth.

Cooling fins on the antenna panels allow air flow to cool radars that are mounted externally. If an array is contained within a fairing or cowling, "you may need to move the air around inside there, but it doesn't have significant airflow requirements," says Frankenberg.

The typical detection range of EchoFlight is at least 2 km (1.2 mi.) for a Cessna aircraft, 1 km for a DJI Inspire 2 quadcopter, and 750 m (2,500 ft.) for a smaller DJI Phantom 4, the company says. Search-while-track capability enables the radar to track a specific object with a high refresh rate while continuing to scan the rest of the field of view for intruders.

In 2018-19, Echodyne participated in NASA's "Raavin" project to analyze the radar's DAA performance on a Titan X8 multirotor drone.

Managed by the Virginia Tech Mid-Atlantic Aviation Partnership, the project paired the radar with NASA's Icarous (Independent Configurable Architecture for Reliable Operations of Unmanned Systems) software to test collision-avoidance maneuvers. Testers flew encounter scenarios against another drone and a Liberty University Cessna 172 Skyhawk.

As yet, there is no standards-based DAA system specification for small UAS comparable to what industry and government have developed for Predator B-class aircraft. "Everything that's happening for DAA on smaller drones is still considered testing" and requires exemptions from the FAA, says Frankenberg.

On April 6, San Francisco-based Iris Automation, a company founded in 2015, announced the commercial release of an optical DAA system for drones, the Casio 360. Weighing 4.7 lb. with enclosure, the system is an embedded computing platform combined with onboard controllers and five machine-vision cameras that provide a 360-deg. field of view.

Frankenberg contends that radar will be essential to any future DAA specification for drones and also will serve as an integral component of UAM sensor suites. "A number" of UAM vehicle developers are testing Echodyne's radar, says Frankenberg.

"It's very much the same thing as the drone market, which is to provide airspace surveillance in front of an urban air mobility vehicle," observes Frankenberg. "The good news there is they are big platforms with plenty of power that can carry weight. Trying to put three of our radars on a small drone would be really hard. Even one is viewed as a parasite on both power and weight."

Among legacy manufacturers, Honeywell is prominent in developing avionics for UAM vehicles (*AW&ST* Oct. 14-27, 2019, p. 74) as well as for drones. The company has revealed plans to produce components including a fly-by-wire flight computer, a phased-array radar, automatic landing and navigation systems, electromechanical actuators and environmental and cooling systems for companies such as Vertical Aerospace, Jaunt Air Mobility, Eviation and Pipistrel.

In recent months, Honeywell has teased on social media "the world's smallest and lightest" satellite communications system for beyond-visual-line-of-sight connectivity with drones, but says it is not ready to officially launch the product.

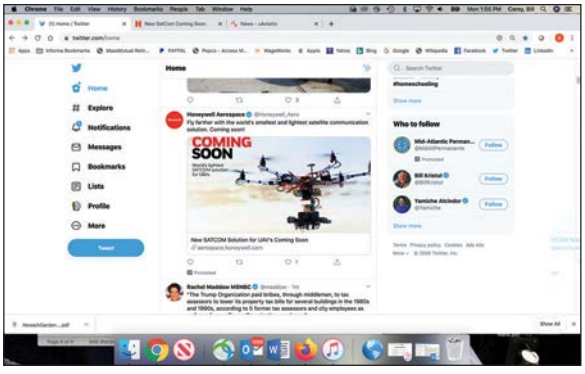
Another manufacturer—Cobham—has developed the high-bandwidth Aviator UAV 500 satellite terminal for video streaming by larger drones. Collins Aerospace expects to be the first to market with a certified C-band command-and-control data link ra-

dio for drones (*AW&ST*, Feb. 24-March 8, p. 26).

Airframer Bell Textron has selected Garmin to lead the design, development and production of avionics hardware and software for its Nexus electric vertical-takeoff-and-landing (eVTOL) air taxi, first revealed as a concept in 2018. Garmin will provide primary flight information, navigation and communications capabilities and flight guidance and management systems, says Bell.

Bell's website depicts a Nexus glass cockpit with four large-format displays—a derivative of Garmin's touchscreen-controlled G3000 integrated flight deck fitted on small jets including Embraer Phenoms and HondaJets as well as Daher TBM single-engine turboprops.

"They're essentially leveraging a very similar system that is currently flying in light business jets," says Bill Stone, Garmin Aviation senior business development manager. "Sharing a lot of that development and being able to leverage off-the-shelf hardware instead of bespoke solutions allows us to keep the development cost [and] production costs down and leverage what's currently being used in manned aviation."



HONEYWELL AEROSPACE

Honeywell is teasing "the world's smallest" satellite communications system for drones on social media.

Both Bell and Garmin declined to provide specifics on which stage of development the Nexus program is in or its first-flight milestone.

"The hardware is very mature, and we're working with Bell to refine the user interface and systems on board the aircraft, which is somewhat of a moving target as they finalize subsystems and propulsion systems," says Stone.

Similarly, Stone declined to specify which other UAM vehicle manufacturers Garmin may be working with, or what role the company's new Autoland system may play for the new aviation segment. Unveiled with fanfare on Oct. 30, 2019, Autoland will be introduced on G3000-equipped Cirrus Vision Jet and Piper M600 SLS light aircraft.

Whatever the future platform, the same avionics design considerations apply, says Stone.

"Many of these future aircraft that are being developed like the Bell Nexus—that's twice the weight of a [Cessna] 172, which is more weight-conscious," observes Stone. "They all kind of share the same desired requirements for smaller, lighter weight, less power consumption and lower cost, which is something we've been spearheading for many years now."

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Aerospace Calendar

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~~**April 20-21**~~ **Now Dec. 14-15**—Aero Montreal. Palais des Congres. Montreal. See aeromontreal.ca

~~**April 20-23**~~ **Now Aug. 24-27**—Defense Services Asia Exhibition & Conference. Malaysia International Trade and Exhibition Center. Kuala Lumpur. See dsaexhibition.com

~~**April 21-23**~~ **Canceled**—Asian Business Aviation Conference & Exhibition (ABACE2020). Shanghai Hongqiao International Airport. Shanghai. See abace.aero/2020

~~**April 22-26**~~ **Now June 24-28**—Eurasia Airshow 2020. Antalya International Airport. Muratpa/Antalya, Turkey. See eurasiaairshow.com

~~**April 28-30**~~ **Postponed/TBD**—World Aviation Training (WATS) Conference & Tradeshow. Orlando, Florida. See wats-event.com

~~**May 5-7**~~ **Now Aug. 10-12**—Association for Unmanned Vehicle Systems International (AUVSI) XPONENTIAL 2020. Boston Convention Center. Boston. See xponential.org/xponential2020

~~**May 5-7**~~ **Canceled**—National Business Aviation Association (NBAA) Maintenance Conference 2020. Hartford, Connecticut. See nbaa.org/events/2020-maintenance-conference

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~~**April 27-28**~~ **Now Apr. 27-28, 2021**—Urban Air Mobility Americas. Orlando, Florida.

~~**April 27-29**~~ **Postponed/TBD**—Routes Europe 2020. Bergen, Norway.

~~**April 28-29**~~ **Now Sept. 2-3**—Military Aviation Logistics & Maintenance Symposium. Dallas.

~~**April 28-30**~~ **Now Sept. 1-3**—MRO Americas. Dallas.

~~**May 1**~~ **Now Nov. 12-13**—CAPA LCCs in Asia Summit. Sentosa Island, Singapore.

~~**May 7-8**~~ **Now Oct. 15-16**—CAPA Americas Aviation & LCCs Summit. San Juan, Puerto Rico.

~~**May 12-13**~~ **Now Aug 25-26**—Speednews Aerospace Manufacturing Conference. Charleston, South Carolina.

~~**May 19-21**~~ **Now Oct. 27-29**—ap&m Europe Summit & Expo. Manchester, England.

~~**June 2**~~ **Postponed/TBD**—ATW's Airline Industry Achievement Awards. Vienna.

~~**June 3-4**~~ **Now Spring 2021**—MRO BEER (Baltics, Eastern Europe and Russia). Istanbul.

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VIEWPOINT

The Elephant in the Room

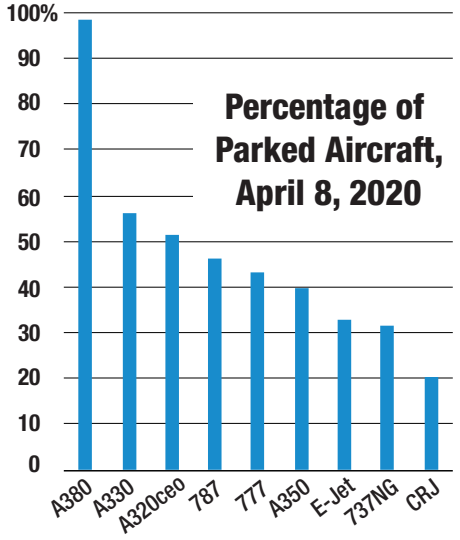
By **Kevin Michaels**

The COVID-19 crisis has created one of the largest aircraft fleets in the history of the jet age—the parked aircraft fleet, unfortunately, which is rapidly evolving and comprises somewhere between 12,000 and 15,000 aircraft. What will happen to these aircraft? Which will return to service and when? How many will be permanently retired or parted out? The answers to these questions will shape commercial aviation for years.

The number of aircraft that return to service depends, of course, on how the COVID-19 pandemic plays out. There are a variety of possible scenarios—including "V-," "U-" and "L"-shaped recoveries—but the truth is no one knows how deep or long the aviation depression will be. Despite this uncertainty, there is an emerging consensus that it will be 2-3 years or more before the active jetliner fleet returns to its pre-COVID size.

AN UNPRECEDENTED WAVE OF AIRCRAFT RETIREMENTS AND PART-OUTS IS ON THE WAY.

Twin-aisles, particularly larger and older models, will face the biggest headwinds, given the lockdown on international travel. The situation is exacerbated by the industry's overproduction of twin-aisles in recent years, too. The recovery of twin-aisle production will be tepid as governments and consumers will need to be convinced that it is safe to spend 8-12+ hr. on a long-haul flight. This means that smaller, more efficient twin-aisles will be favored. Lufthansa just announced a complete fleet realignment including the retirement of six Airbus A380s, seven A340-600s and five Boeing 747-400s as well as discontinuation of Germanwings operations. Similar decisions are forthcoming by the likes of International Airlines Group, Air France/KLM and many other airlines as they plan for a future with reduced long-haul demand.



Source: CAPA – Centre for Aviation

The least affected twin-aisles will be newer-generation aircraft like the Boeing 787 and Airbus A350XWB. Airbus already announced significantly lower production rates for A350s and A330s; Boeing will undoubtedly follow suit.

Single-aisles, in contrast, will return to service much faster. Large countries with sizable domestic markets such as Australia, Canada, China, Russia and the U.S. as well as the EU single market depend on air travel to connect their populaces and operate their economies. Moreover, governments of these countries will promote domestic travel recovery and sponsor rescue packages to ensure the survival of their airlines. Low-cost carriers should also pick up market share in a more price-conscious environment. These positives aside, with more than 6,000 older A320ceos and 737NGs parked, there still will be thousands of excess single-aisles for the foreseeable future, no matter the pace of recovery. Nor can we forget the 400 737 MAXs that were built but not delivered. Airbus already slashed A320 production to 40 per month and may need to make further adjustments while Boeing slowly brings the 737 MAX production online after recertification.

The aircraft least affected by COVID-19 are expected to be regional jets, as airlines downgauge to maintain flight frequencies. According to CAPA – Centre for Aviation, just 20% of the Bombardier CRJ fleet and 33% of the Embraer E-Jet fleet are parked. The A220 is also faring well, with 43% parked.

An unprecedented wave of aircraft retirements and part-outs is on the way, no matter which COVID-19 recovery scenario one believes. Aviation was already headed for a retirement tsunami before the coronavirus crisis. As I wrote in *Inside MRO* (February 2019, p. MRO29), fleet demographics were forecast to drive a surge in retirements in the early 2020s. The 5,460 jetliners more than 18 years old are now prime candidates for retirement as airlines reset their fleet plans. So are some of the 2,300 aircraft aged 15-17 years.

This will reduce aircraft maintenance cost—welcome news for airlines—but will punish OEMs and maintenance, repair and overhaul (MRO) suppliers. We could soon see 1,000 or more retirements per year, with the capacity of part-out specialists and MROs the only limit to how fast parts come on the market. Why overhaul an engine, for example, when there are large numbers of surplus engines with available "green time" that can be used instead? Why conduct an expensive maintenance check when there is an ample supply of younger aircraft that require less maintenance? The MRO sector is about to go through unprecedented structural change, and OEM commercial aftermarket revenues—their economic lifeblood—are set to plunge by 50-60% or more.

It's unclear how many parked jetliners will return to service how fast. What is clear is that the current crisis will have a profound impact on production rates and MRO activity well into the 2020s and beyond.

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

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