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32 | *The U.S. Marine Corps is recommending deactivation of three aviation units.*

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COMMERCIAL AVIATION

SPACE

DEFENSE

FEATURES

PROPULSION

HYPERSONICS

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ON THE COVER

The U.S. Marine Corps has proposed a massive force structure shift, the largest for the amphibious force in nearly two decades, as it focuses attention on the Pacific. A number of squadrons and groups would be deactivated, and the planned purchase of aircraft including the CH-53K, being developed to replace the CH-53E, could be curtailed. Pentagon Editor Lee Hudson's report begins on page 32. U.S. Navy photo.

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AVIATION WEEK NETWORK
By Informa Markets

How can we help you navigate, recover and grow?

The daunting challenges that currently face humanity will leave an indelible mark, but there will come a point when the COVID-19 crisis begins to fade and we adjust to life in the aftermath of this pandemic.

The Aviation Week Network has helped to keep our industry abreast of global developments during every major crisis since we launched the first edition of *Aviation and Aeronautical Engineering* on Aug. 1, 1916, in the middle of the World War I.

And today — more than at any point in our history — the Aviation Week Network is uniquely positioned to help the world's aviation community make sense of seemingly overwhelming challenges.

Recent additions of CAPA, ASM and Routes to our team mean that we have the entire information spectrum covered in all regions, from daily news to detailed analysis from the industry's most experienced and connected team of experts, a unique portfolio of data and forecasts and all forms of face-to-face and digital events. The Aviation Week Network can help the industry through the coming weeks and months by supporting situational awareness, critical decision-making and, ultimately, a return to growth.

We are committed to action and are introducing more robust ways for you to know, predict and connect as we all navigate the crisis and position for the future.

Know. Predict. Connect.

The first step has been about situational awareness as the crisis unfolds and morphs every day around the world:

- So far, our global team of aerospace journalists and analysts have produced **more than 4,000 articles, podcasts and news briefs** covering the crisis, diving deep to help each of our customer communities: Air Transport, Defense & Space, Aerospace, Business Aviation and MRO.
- We have launched a **curated landing page** to help you navigate that content across our portfolio along with the first of an expert-webinar series to share predictions, advice, viewpoints and best practices.

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

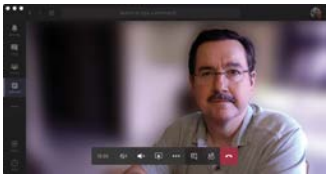
  Register for our webinar series: **AviationWeek.com/COVID19/webinar**

At the same time, we are ramping up our analytical and forward-looking intelligence and data. Finally, we are pursuing innovative ways to reestablish buyer-seller relationships in the absence of face-to-face platforms across the aviation community.

There is much, much more to come. Is it helpful? What can we do better? I'd love to hear from you.

As a recent Aviation Week editorial said: "This is without doubt the greatest crisis aviation has faced since the dawn of the commercial jet age more than six decades ago....The coming days will be dark, but rest assured the industry will recover and once again prosper." The Aviation Week Network is proud to stand alongside our partners during this unprecedented period of challenge, helping to keep the market informed and focused on a bright future.

I'll keep you up-to-date on new initiatives in this letter in the coming weeks.



Greg Hamilton,
President, Aviation Week Network

hamilton@aviationweek.com

FEEDBACK

MORE CARROT, LESS STICK

I just read with interest Helmut Kunz's letter "Local Languages" *(March 23-April 5, p. 6)*. I was a Royal Air Force navigator long ago, flying Canberras, Buccaneers and Tornados. I did two tours in Germany and am now a happily naturalized U.S. citizen—I just celebrated 35 years of very fulfilling life here in the U.S.

It is not "arrogance" to use one's native language in the air, as Kunz writes; it is merely natural and convenient.

I fully agree about the vital importance of everyone being "on the same page"—that is, in the same language—in aviation, but a lot more carrot, a lot less stick and some reasonable tolerance for the less gifted linguists among us aviators seems a more hopeful way forward.

Tim Price, Pittsburgh

THE MIDDLE SEAT

American Airlines recently announced that it would not be assigning the middle seat to help combat COVID-19 and achieve social distancing. This should be a permanent solution to the cramped quarters we are subjected to on every flight unless you are lucky enough to be in first class. In fact, the removal of every other row would be a good idea in the future as well.

With about a 20% load factor these days, and probably for a long time in the future, this will keep us safer and give us lots of legroom.

Bob Seelos, San Diego

AUTOMATION LOGIC

David Vecchi hits the nail on the head in his letter "Manual Proficiency" *(March 23-April 5, p. 6)*: The basic problem is "the inability or reluctance of some pilots to fly under manual control."

At the same time, we must recognize that the system complexity accompanying automation is placing unreasonable demands on the pilot to instantaneously recognize system failures, their cause and the best remedial action. The answer to that is to automate and expand the "pilot's notes," which reliability engineers, failure analysts and flight-test crews in the average large manufacturer are well equipped to program.

But that automated subsystem must never be given control authority over the airplane without the pilot having reviewed the conclusions and proposed course of action. There is always the possibility that the automation logic may fail under some rare unforeseen combination of circumstances, as with the Boeing 737 MAX's Maneuvering Characteristics Augmentation System.

To preserve the admirable Boeing philosophy of designing an airplane that can be flown satisfactorily under fully manual control, then we must ban automated gizmos that accommodate flaws in mandatory flight characteristics if we are to continue producing airplanes that will be flown by pilots of greatly varying experience.

Malcolm Bowden, McDonald, Tennessee

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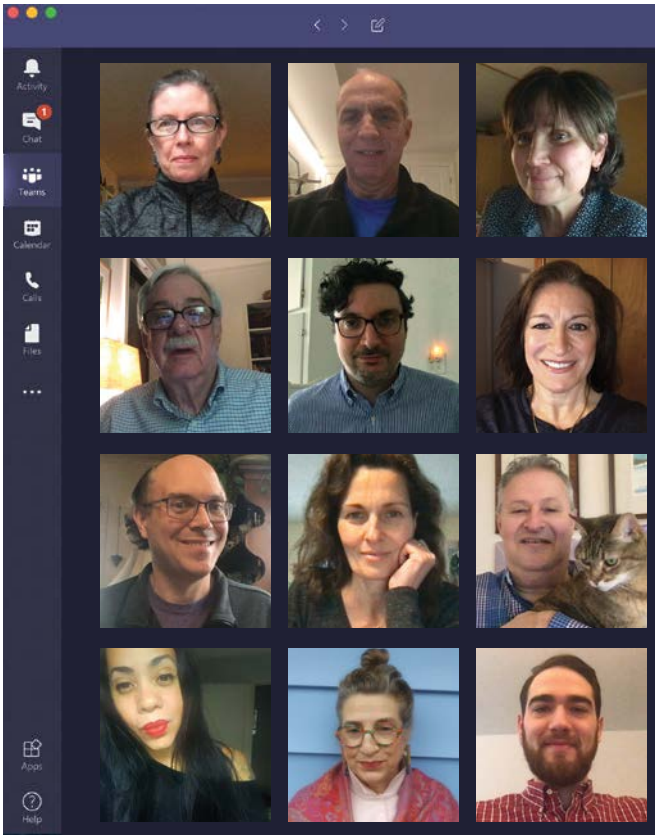


BEHIND THE SCENES

Forced to work from home since March 10 due to the novel coronavirus pandemic, the **New York-based *Aviation Week & Space Technology* editorial production team** produced the March 23-April 5 print issue of *AW&ST* from 12 home offices—or living rooms, dining rooms or kitchens—a first in the history of the magazine. The team has transferred their highly collaborative workflow online, substituting chat messages, screen-shares and calls via the Teams app for the immediacy of shouting questions across the newsroom and discussing edits and layouts face-to-face until it is safe to return to their office in Manhattan. The production crew (top row, from left): Andrea Hollowell, Michael Lavitt, Lisa Caputo; (second row, from left): Michael Stearns, Thomas DePierro, Theresa Petruso; (third row, from left): Colin Throm, Audra Avizienis, Arturo Mora (and Pretty); (bottom row, from left): Rosa Pineda, Michael Hayes and Jack Freifelder.

WHO'S WHERE

Dany Eshchar has been hired as CEO of *Orbit Communications Systems*, which provides maritime and airborne satcom terminals and mission-critical airborne audio systems. Eshchar was deputy CEO for the Israel- and U.S.-based Aeronautics Group.

Aeronautics Group has hired **Moshe Elazar** as CEO. He succeeds Amos Mathan. Elazar was Rafael Advanced Defense Systems executive vice president and general manager of Rafael's land and naval division. He also held senior positions in Israel's defense ministry and the Israel Defense Forces.

FlightSafety International has hired **Brad Thress** as president and CEO. He succeeds David Davenport, who has left. Thress was senior vice president at Textron Aviation and before that, president of Able Aerospace.

Spacecom has hired **Dan Zajicek** as CEO. He succeeds interim CEO Itzik Shnaiberg, who resumes his deputy CEO position. Zajicek was CEO of Satcom Systems, chief financial officer at Bezeq International and senior deputy director general of Israel's communications ministry.

Dunmore has promoted **Thomas S. Rimel, Jr.**, to president from chief operating officer. Dunmore produces laminated film substrates for the aircraft industry.

Motion Industries has promoted **Greg Cook** to executive vice president from senior vice president. He continues to serve as chief financial officer of the industrial parts distributor as well.

Mitsubishi Aircraft Corp. has shifted executive responsibilities in its push to obtain SpaceJet M90 certification. Senior Vice Presidents **Keisuke Masutani** and **Hiroyuki Tatsuoka** will become board directors with, respectively, oversight of governance and engineering development. **Hitoshi Kaguchi** becomes a part-time director, and **Hiroyoshi Kodama** a part-time statutory internal auditor.

HawkEye 360 has hired **Dennis Burnett** as executive vice president and general counsel. Burnett held leadership positions at LMI Advisors, Kymeta and EADS North America and serves as director and treasurer of the International Institute of Space Law.

Capella Space has hired **Dayna Anderson** as vice president of business operations and **Mack Koepke** as vice president of global sales. Anderson and Koepke previously worked for Maxar Technologies.

Rodney Frelinghuysen has joined *Greenberg Traurig* as a senior director for government law and policy. Former congressman Frelinghuysen had been chairman of the House Appropriations Committee.

Electro-magnetic motor company *ePropelled* has promoted **Tim Quaglieri** to head its human resources team in addition to his role as director of finance.

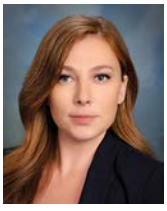
Mehtap Cevher Conti has joined *Hogan Lovells'* New York finance practice as a partner. Previously with Arnold & Porter Kay Scholer, she brings 15 years of finance experience across a variety of aviation transactions.

AE Industrial Partners has named **Kevin McAleenan** an operating partner of the aerospace, defense and government-services private equity firm. McAleenan was acting secretary of Homeland Security. He also will sit on the boards of portfolio companies *Gryphon Technologies* and *American Pacific Corp.*

Amit Musli has been hired as *Percepto* vice president of sales. Musli joins the autonomous industrial drone manufacturer from Kramer Electronics, where he was on the senior management team.

The University Research Foundation has hired U.S. Navy Vice Adm. (ret.) **David Architzel** as president. Architzel was with Naval Air Systems Command as his last active duty position. He succeeds Norris Krone, who passed in 2019.

Honeywell has elected U.S. Army Gen. (ret.) **Raymond T. Odierno** to its board as an independent director. Odierno was military advisor to former U.S. Secretaries of State Colin Powell and Condoleezza Rice.



Western Aircraft has hired **Jacqueline Rambacal** as regional sales manager. Prior to joining Western Aircraft, she served as vice president of aviation at Bank OZK in Little Rock, Arkansas.

AAR has appointed **H. John Gilbertson, Jr.**, to its board. Gilbertson is a former managing director and 27-year veteran of Goldman Sachs.

Clark Hill law firm has hired **Eduardo Alfonso Angeles** as managing director and senior counsel for government and regulatory affairs in Los Angeles. Angeles was general counsel and senior assistant city attorney at Los Angeles World Airports, which oversees Los Angeles International and Van Nuys airports.

HONORS & ELECTIONS

Mark Spangler has been selected to serve on the *Armed Forces Communications and Electronics Association International Cyber Committee*. Spangler is TriSept Corp.'s senior cybersecurity advisor, with 36 years of CIA and National Reconnaissance Office leadership experience.

The fifth *Martha King Scholarship for Female Flight Instructors* was awarded to **Anna Stanphill** at the annual Women in Aviation International Conference in Orlando, Florida, in February. It provides lifelong flight-instructor continuing education from King Schools, founded by National Aviation Hall of Famers John and Martha King.

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

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COMMERCIAL AVIATION

The $29 billion in loan guarantees for U.S. airlines, and $17 billion for the defense industrial base, available under a $2.2 trillion rescue bill to offset the coronavirus crisis come with restrictions including limits on layoffs (page 18).

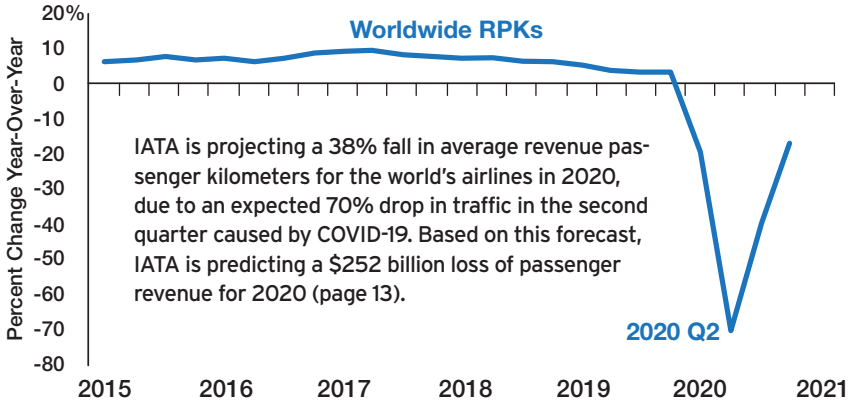
Facing delivery deferrals and substantial production cuts, Airbus has boosted liquidity to €30 billion ($32 billion) but is not asking European governments for help.

IATA is pushing for broad adoption of travel vouchers in place of requiring airlines to refund passengers when flights are canceled during the COVID-19 crisis.

British taxpayers have paid £156 million ($193 million) so far in response to the September 2019 collapse of leisure airline Thomas Cook.

Qantas pilots have voted to accept new contract conditions that would allow ultra-long-haul flying, although plans to order aircraft for such flights are on hold.

The Deep Drop: 70% Less Traffic Predicted Globally



Source: International Air Transport Association

VIEW FROM WASHINGTON

FAA Proposes Supersonic Standards

Responding to a congressional directive to exercise leadership in enabling the return of supersonic air travel, the FAA has proposed noise certification regulations for new supersonic aircraft. The proposed rules cover landing and takeoff noise and would not lift the prohibition on civil supersonic flight over land.

The notice of proposed rulemaking (NPRM) released on March 30 outlines landing and takeoff (LTO) noise standards for supersonic aircraft with a maximum takeoff weight no greater than 150,000 lb. and a maximum cruise speed up to Mach 1.8. The FAA defines such aircraft as Supersonic Level 1 (SSL1).

"This definition would include most of the proposed supersonic airplane design concepts that U.S. manufacturers have described to the FAA," the NPRM says. As defined, SSL1 would include Aerion's AS2 supersonic business jet but would not cover Boom Supersonic's larger Overture airliner, which is being designed to carry up to 75 passengers at speeds up to Mach 2.2.

"The FAA anticipates that when data is available to establish LTO-cycle noise standards for other weight and speed supersonic airplanes, other similar classes of airplane and noise level would be added . . . with separate definitions," the NPRM says.

"The FAA has indicated this is an initial step," says Boom. "We're actively engaged with U.S. and other international regulators and with ICAO to develop thoughtful, practical standards that will apply to larger and faster aircraft such as Overture."

SPACE

Broadband satellite constellation network operator OneWeb filed for Chapter 11 after its biggest investor, Japan's SoftBank, balked at providing additional financing because of the COVID-19 crisis (page 28).

Veteran astronauts Shannon Walker of NASA and Soichi Noguchi of the Japan Aerospace Exploration Agency have been added to SpaceX's first operational Commercial Crew flight.

NASA has selected SpaceX as the first to fly cargo to the planned lunar-orbiting Gateway in anticipation of spending $7 billion over 15 years with multiple companies to resupply the outpost.

TEXTRON AVIATION

GENERAL AVIATION

Textron Aviation has completed initial ground engine tests on its prototype Cessna SkyCourier twin-turboprop utility aircraft.

Dornier Seawings' prototype New Generation Seastar amphibious aircraft made its 31-min. first flight from Oberpfaffenhofen, Germany, on March 28.

DORNIER SEAWINGS

Electric air taxi developer Lilium has raised an additional $240 million from existing investors, taking the total raised so far by the German startup to more than $340 million.

Lynn Tilton has stepped down as CEO of MD Helicopters after a bankruptcy court ordered her to sell companies to repay loan obligations worth nearly $2 billion.

Embraer received Brazilian, European and U.S. type certification for its upgraded Phenom 300E light business jet on March 27.

DEFENSE

Bell and Sikorsky are to build competing prototypes of the U.S. Army's Future Attack Reconnaissance Aircraft to replace AH-64 Apaches used for armed reconnaissance (page 39).

Excessive leaks first identified in July 2019 in the fuel system of the Boeing KC-46A have been upgraded to a Category 1 deficiency in the U.S. Air Force's new aerial refueling tanker.

China appears to have deployed at least one of perhaps three direct-ascent anti-satellite systems under development, according to a pair of U.S. reports issued March 30.

Work on a hypersonic weapon concept, Thresher, is underway between the UK's Defense Science and Technology Laboratory and the U.S. Air Force Research Laboratory (page 14).

After receiving antitrust and other regulatory approvals for their merger, United Technologies and Raytheon planned to create the combined Raytheon Technologies on April 3.

Airbus has paused production of A400M and C295 airlifters and A330 tanker/transports in Spain because of a more restrictive lockdown to combat COVID-19.

The U.S. Space Force has awarded Raytheon $378 million to replace computers in its next-generation GPS ground system due to cybersecurity concerns.

Saab has cut metal on the first components for the two-seat JAS 39F Gripen, being developed for export customer Brazil.

The U.S. Space Force declared its Space Fence surveillance system operational on March 27, on Kwajalein Atoll in the Marshall Islands.

Germany will make a split buy of 45 Eurofighters and 45 Boeing F/A-18 Super Hornets to replace its Panavia Tornados, local media reports suggest.

The U.S. Marine Corps is to commission an independent study of a plan to redesign its force that would reduce the number of F-35s in its squadrons (page 32).

OBITUARIES

Jean-Marie Saget, former chief test pilot for Dassault, died March 19 at age 91. Born in Paris, Saget was a pilot with the French Air Force in 1954 when he won a Paris-Cannes air race in an Ouragan fighter. The following year, Marcel Dassault hired him as a test pilot. He was chief test pilot from 1955 to 1989. "He will remain, at Dassault Aviation, an example of the qualities that the aeronautical world requires to accomplish the greatest purposes," the company says.

DASSAULT AVIATION

Aviation entrepreneur Joe Clark, cofounder and CEO of blended winglet developer Aviation Partners (API), died in Palm Springs, California, on March 30 at age 78. Clark, who was born in Canada, also cofounded Horizon Air. He formed Seattle-based API in 1991 after selling Horizon Air to Alaska Airlines. "His legacy will long be visible on the thousands of business and commercial aircraft fitted with his winglets to increase performance and efficiency," says the National Business Aviation Association.

AVIATION PARTNERS

50 YEARS AGO IN AVIATION WEEK

Europe's first Boeing 747 was featured on our cover of April 13, 1970, flying over western Washington shortly before its entry into service with Lufthansa. The widebody aircraft, one of five 747s initially ordered by the German carrier, was scheduled to fly between Frankfurt and New York. But all was not well at Boeing, which was suffering from declining commercial sales and a slump in its defense and space businesses. The company's workforce—already projected to drop from 134,000 at the start of 1969 to less than 79,000 by the end of 1970—declined at nearly twice the expected rate during the first quarter, the magazine reported, with the heaviest hits coming in the Seattle area. Lufthansa ultimately ordered 81 747s between 1966 and 2006. Thirty-two of those are still in the airline's fleet, according to the Aviation Week Intelligence Network's Fleet Discovery database: 19 747-8s, 11 747-400s and two freighters.

Read every issue of Aviation Week back to 1916 at: **archive.aviationweek.com**

GOING CONCERNS
MICHAEL BRUNO

Bail Out Boeing?

Likely yes, but maybe not the way Boeing wants

UP UNTIL THE START OF MARCH, new Boeing CEO and President David Calhoun's biggest challenge was getting the 737 MAX back in the air. Since then, the narrowbody's grounding and production halt has become quaint as Wall Street and others subtly but increasingly wonder whether Boeing can survive the post-COVID-19 world.

Boeing triggered the new skepticism March 17 when it formally asked Washington for a $60 billion-plus bailout of the U.S. aerospace manufacturing sector, ostensibly to flow through the Chicago-based OEM. So dramatic was the turn of events that Nikki Haley, a former official in the administration of President Donald Trump, quit Boeing's board in protest, asserting that companies should not receive federal handouts.

In response, Boeing thanked her for almost a year of directorship and removed her chair from the boardroom. Whether Haley has ulterior motives is a debate for another day, but it is clear why the manufacturer is seeking money. According to Jefferies analysts, Boeing Commercial Airplanes alone was burning through about $4.3 billion a month to fund its operations and support suppliers before the novel coronavirus outbreak.

Boeing has $15 billion in liquidity, Calhoun said March 24. But it ended 2019 with more than $27 billion in debt. By mid-March, it had fully drawn down a new credit line totaling nearly $14 billion. And by the time Calhoun spoke, Boeing had closed Puget Sound widebody manufacturing for health reasons, frozen hiring, suspended dividend payments—which on top of already frozen share buybacks is a doomsday for investors—and said Calhoun will forgo pay through 2020.

But as fellow Chicagoan and former Chicago Mayor Rahm Emanuel once said, you never let a good crisis go to waste. If there was ever a time to socialize the risks facing Boeing, this pandemic is the hook. The question for U.S. leaders then becomes: Is it worth taking Boeing up on its bailout bid?

The answer likely is "yes," but maybe not for obvious reasons—and probably not the way Boeing wants. Protecting Boeing's workforce of more than 150,000 employees and tens of thousands of suppliers is statistically significant as Washington tries to fend off a prolonged recession, but maintaining Boeing's payroll and supply chain could be accomplished other ways, such as direct payments to those employees or grants to suppliers.

Boeing will surely have to swallow some once-inconceivable conditions, starting with an ongoing lack of dividends and share buybacks. UBS analysts say there also likely will be executive pay regulation and incremental board governance oversight, including potential stress tests, minimum employment levels and/or labor controls. In turn, they say, Boeing's stock will trade at a discount.

While these conditions are the most prominent "strings attached" being discussed for Boeing, they may not be the last—nor should they be. As one Wall Street icon said recently about government bailouts, it is time for a better return on investment for the country.

Mohamed El-Erian, Allianz chief economic advisor and the former CEO of fixed-income investing company Pimco, says: "The notion of governments in different companies, that's going to be the case because a lot of companies are going to have to be bailed out. [It is] best to start with the technocratic approach, which is to define your objectives. Protecting jobs is one example; protecting national security is another. Then go through what it mean[s] for who you bail out and how you bail out, and importantly, how you get incentive alignment coming out of the bailouts."

"THE NOTION OF GOVERNMENTS IN DIFFERENT COMPANIES, THAT'S GOING TO BE THE CASE."

What do such incentive alignments with Boeing look like? It should go way beyond maintaining employment figures and shelving shareholder returns. Washington is desperate for U.S. aerospace and defense providers to innovate, but independent research and development (IRAD) spending has been emaciated over the last decade as public companies raced to reward shareholders. Getting Boeing to double or triple IRAD could be a good start.

At the same time, the Pentagon, NASA and Congress are exhausted with poor contractor performance on its major defense acquisition and space programs. Does anyone remember the Future Combat Systems or the recent Starliner failure? As government auditors have documented in countless reports, weapon programs are years late and often double-digit percentages over budget—assuming they ultimately deliver. With that in mind, Boeing could be "incentivized" to dramatically improve its results across the board.

Finally, there has been a lot of talk in the U.S. in recent years about a crisis of not producing enough science, technology, engineering and math (STEM) graduates. But as Aviation Week workforce studies have shown, industry acts as a poor pull on the demand for such graduates, with relatively few hired out of schools each year. Instead, companies have long preferred to poach talent from each other when needed. So make Boeing either more directly fund STEM education or hire an industry-leading ratio of cohorts each year.

There are likely many more ways to better align Boeing with U.S. interests, and they should be considered. After all, U.S. taxpayers already are being promised more bang for the buck—so let us get more Buck Rogers.

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The Warbirders

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THE NOVEL CORONAVIRUS HAS severely affected the aviation community, among countless others. Were it not for the pandemic, spring's arrival normally means many of us would likely encounter some deep-throated, octogenarian war veterans with surprising flash, noble character and clearly serious purpose. And with eyes drawn skyward, we would watch them rumble by.

These are members of the "warbird" fleet—all former military fighters, bombers, transports, trainers, observation and other aircraft now owned and operated by civilians. There were to be 100 such aircraft forming an aerial parade up the National Mall in Washington, on May 8 as part of the Arsenal of Democracy Flyover (*AW&ST* Feb. 10-23, p. 14), but COVID-19 forced a rescheduling to Sept. 25. Delaying or canceling air events has become a common practice since the virus took hold.

COURTESY AIRCRAFT

While there has been attrition over the decades—the loss of a B-17 in Connecticut along with seven on board last October is among the most recent and tragic example—there remain an estimated 6,000 warbirds in the U.S. alone, though not all are airworthy.

It comes as a surprise to many outside of aviation that an individual or group of individuals can buy and fly a B-25 Mitchell bomber or MiG jet fighter. But it is perfectly legal . . . albeit with lots of restrictions.

Brian Hammer, vice president of transactions at the Mente Group, a business aircraft sales company and consultancy in Dallas, oversaw the sale of a MiG-29 late last year. Furthermore, he's got a Northrop F-5 on the market right now. The price? It's "Make offer."

Should that offer come from a foreign customer and be accepted, the aircraft would have to comply with federal International Traffic in Arms Regulations. And any foreign-registered warbird must receive an import permit from the Bureau of Alcohol, Tobacco, Firearms and Explosives to enter the U.S.

Furthermore, explains Mark Clark, a well-known warbird specialist and president/owner of Courtesy Aircraft in Rockford, Illinois, such aircraft must be absent any guns or cannons, bombs or targeting systems and any drop tanks must be permanently secured. With the exception of some light aircraft, most warbirds fall under the "experimental" airworthiness category. As such, they have specific operational restrictions imposed by the FAA.

There's more. Clark, who has facilitated the private sale of thousands of warbirds, including 80 P-51 Mustangs, says: "Anybody with enough money can buy one of these things." But, he adds, if the aircraft is heavy, complex or a jet, the purchaser will need appropriate piloting experience and training and to demonstrate a high level of skill to win government approval to go fly it.

And more. Even with the FAA's blessing of the aircraft and pilot, a warbird operator still needs insurance. According to Lance Toland, a prominent aviation insurance broker and pilot who at one time owned 38 warbirds, coverage for such aircraft is hard to find and becoming "exorbitant."

As far as the Mente-marketed F-5 is concerned, Toland says, "I wouldn't touch that with a 10-ft. pole." Such a negative outlook is concerning for warbird operators since "without insurance they risk everything they own on a single flight," he added.

Then there's the matter of maintenance and parts. The production of many warbirds ended 60 or more years ago, and those with the skills required to keep them flying have steadily declined in number. Clark says there remains "a pretty good network of shops" able to service the fleet. However, in any market, scarcity affects pricing.

For all those reasons, Toland has a frank assessment of the appeal of warbird ownership: "I think it's waning."

And yet there are those with a special passion for the winged vets. They see the machines as fabric and aluminum symbols of bravery, determination, selflessness and love of country. They are iconic artifacts and, by the way, fun to fly and put on display.

Steve Craig, a lawyer, real estate investor and hotel man from Lawrence, Kansas, is one such person. A seasoned aviator—and owner of the Beaumont Hotel, a favorite Kansas nexus among pilots—he has owned a variety of warplanes including a Grumman F4F Wildcat, Boeing Stearman PT-17 and a Buecker Jungmeister. He loved them all.

In Craig's experience, the warbird appeal is threefold. First is the welcoming fraternity of fellow enthusiasts who have included Harrison Ford, Bob Hoover, Baron Hilton and Robin Olds, among many. Second is the thrill and satisfaction of piloting such unique aircraft. And third is "doing my part in a small way to preserve history."

William Garvey is Editor-in-Chief of Business & Commercial Aviation

AIRLINE INTEL
JENS FLOTTAU

BEFORE THE NOVEL CORONAVIRUS began to dominate events in aerospace and air transport, the most heated political debates took place around how much government support should be allowed in the industry. There was no shortage of disputes: The long and bitter trade conflict between the U.S. and the EU about subsidies for Boeing and Airbus began in 2004 and is still going strong. For years, the big three U.S. legacy airlines argued that market access for the big three Gulf carriers should be limited because they received state support—a claim Emirates has always denied. In Europe, bailouts of Alitalia have been a never-ending story, as have been airport subsidies and "marketing support" for whenever an airline opened a new route (the least contentious issue since everyone benefited at some point).

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Now that COVID-19 is changing life as we know it, some of those that have been most outspoken against state support, such as Boeing, could be big beneficiaries of it, via government loans or guarantees aimed at ensuring their survival. In the airline industry, even the healthiest carriers now say they cannot survive for an extended period without state aid. An industry that likes to routinely criticize governments for failing to recognize its strategic importance to the world economy is now fully dependent on them. In most countries, governments appear willing to help, debunking some of the routine complaints that have become commonplace at industry conferences in recent years.

That is not to say that the case for government aid for aviation is spurious. The economic crisis that has waylaid airlines is partially the result of government-imposed travel restrictions to deal with the initial health crisis. And given aviation's critical role in the global economy, there is a strong case to be made that it is in the public interest to preserve a critical mass that can ramp back up once the COVID-19 pandemic subsides.

The industry undoubtedly will look different after the crisis. To start with, it will be smaller, though analysts vary widely in their estimates of how much. Whether airlines live or die will depend not on their performance, but on which has access to government money and which does not. Even airlines that might survive without government aid will apply for it, because they know their competitors will be seeking similar infusions. Governments will then pick winners and losers.

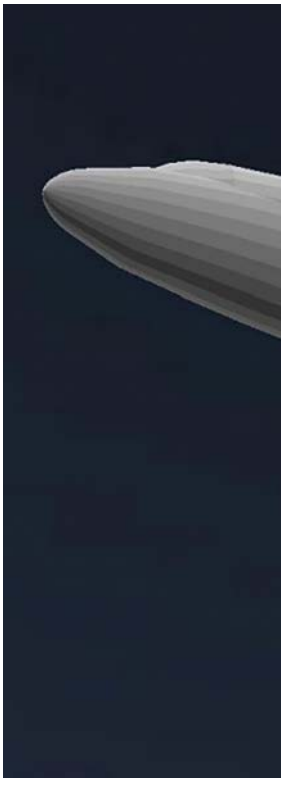
In the U.S., for instance, a massive coronavirus bailout signed into law by President Donald Trump includes $29 billion for airlines to keep their workers employed through Sept. 30, even if most of their fleets are grounded. While that's good news for the carriers and their employees, that level of support is highly concerning for airlines elsewhere.

Consider that before the coronavirus crisis the five largest U.S. airlines already made about half of the industry's profits worldwide. Most of those profits were directed back to shareholders (leaving a thin cushion for hard times). But there was still enough money left for Delta Air Lines to begin building a global empire by investing in Virgin Atlantic, Air France-KLM, LATAM Airlines, Aeromexico and China Southern, among others. Delta even seriously considered buying a stake in notoriously unprofitable Alitalia.

While the case for taxpayer support exists now, governments need to realize they cannot be long-term players in the industry and should define their support as emergency relief. Unfortunately, there is no coordination among nations, even those inside the EU. France has said it will do whatever is needed to rescue companies in which the government has stakes—among them are Airbus and Air France. It is inconceivable that Germany would let Lufthansa Group fail, even though it is a fully private company. Meanwhile, airlines in the UK have been told not to expect a direct government rescue.

To be sure, the industry's playing field was never completely level in good times. Italy spent billions of euros on Alitalia over decades. The airline, now nationalized, still exists but is no longer relevant. Etihad Airways was propped up with billions by Abu Dhabi but has been retrenching after it became abundantly clear that its strategy did not work. Those examples show that in the past, even the biggest subsidies ultimately did not rescue unfocused or flawed business models. But they pale in comparison to the market distortions that will be caused by the COVID-19 bailouts.

HYPERSONIC THRESHOLD



> UK/U.S. THRESHER PROJECT EXPERIMENTS CONTINUE TO 2022-23

> PROJECT ADDS TO UK-FRENCH HYPERSONIC MISSILE WORK

> UK IDENTIFIES BOOSTERS, AERO DATA AS HYPERSONIC NEEDS

Steve Trimble Washington, **Guy Norris** Los Angeles and **Tony Osborne** London

The disclosure of a new U.S./UK collaboration on a hypersonic weapon concept highlights proposals within the British government and industry to leverage decades of research and expertise in high-speed flight and propulsion to rapidly emerge as the latest country to weaponize hypersonic technology.

Extensive experimentation for a new weapon concept called the Thresher—originally an acronym for Tactical High-Speed, Responsive and Highly Efficient Round but now simply a name—is underway between the UK's Defense Science and Technology Laboratory (DSTL) and the U.S. Air Force Research Laboratory (AFRL), the UK Defense Ministry confirms to Aviation Week.

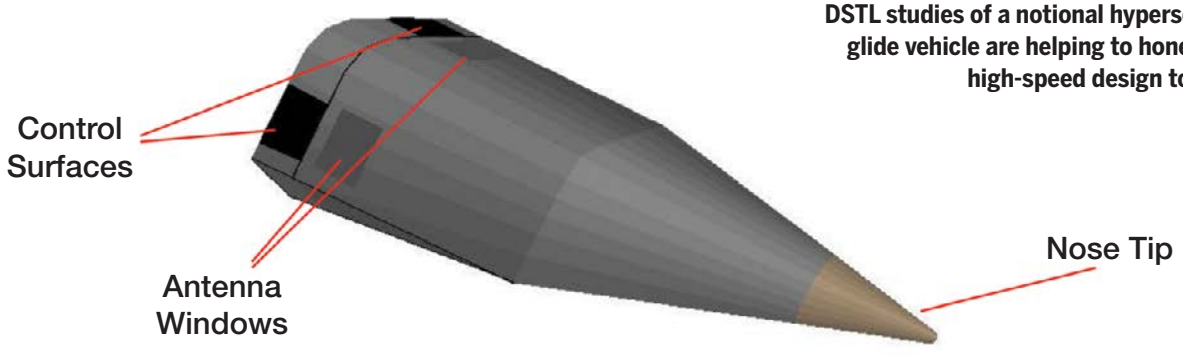
The previously undisclosed joint Project Arrangement, which expires in fiscal 2022 or 2023, is "maturing technologies within the context of a comprehensive weapon system concept," with science and technology-level activity for the Thresher over the next 3-4 years focused on the aerodynamics, warhead and propulsion, the Defense Ministry says.

The two-year-old collaboration was launched as the U.S. laid plans for a $10 billion investment in a broad portfolio of conventional hypersonic weapons, responding to moves last year by Russia to field the nuclear-armed Avangard and by China to deploy the intermediate-range DF-17 hypersonic glide vehicles by year-end. Last year, France also committed to fielding a hypersonic, nuclear cruise missile by the mid-2030s.

The UK, a pioneer in the field since a Queen's University professor developed the hypersonic waverider concept in 1951, has quietly remained active as basic research has shifted to weapons development. Air Vice Marshal Rocky Rochelle, leader of the Royal Air Force's (RAF) Rapid Capabilities Office, committed in July to study the feasibility of fielding a hypersonic weapon within four years.

"The RAF, in particular, has been clear about its desire to obtain hypersonic munitions for air launch in the early 2020s if at all possible," says Justin Bronk, a research fellow for the Royal United Services Institute.

The existence of the collaborative



DSTL studies of a notional hypersonic glide vehicle are helping to hone UK high-speed design tools.

DSTL

DSTL

DSTL

For its concept study, DSTL employed a Boeing 747-400-based airborne-launch system similar to the Virgin Orbit's underwing-location (inset) method.

Thresher and Rochelle's feasibility study may suggest that the RAF is preparing multiple projects to advance the science and technology, says James Bosbotinis, a UK-based defense and international affairs analyst. A final decision may await the conclusions of the still-pending review of the UK's defense, security and foreign policy, he says.

Any commitment that emerges from the review would build on decades of UK hypersonic science and technology research.

In the early 2000s, a team of UK engineers from Qinetiq performed trials of a scramjet engine called the HyShot 3, developed jointly with Australian researchers. Fitted to a sounding rocket, the HyShot successfully achieved speeds of 9,000 kph (5,600 mph), prompting the UK to consider follow-up trials. Two flights of the Sustained Hypersonic Flight Experiment, a Mach 6 ramjet, were scheduled, with the first set for August 2009. But the plans were scrapped as the UK reconsidered its deep-strike aspirations.

The technology was being mulled for the Defense Ministry's Future Long-Range Cruise Missile, later renamed the Future Long-Range Deep Fires Capability, which has also been shelved.

Despite a rich history of hypersonic research within the UK, a senior DSTL official acknowledges collaborations are necessary to transition the technology to an operational weapon. For example, the UK lacks the industrial capacity to manufacture large solid rocket motors, which must by supplied by international partners, DSTL Principal Scientist David Hunter said at a Royal Aeronautical Society conference on hypersonics in late November. The UK also needs access to high-speed wind tunnels, as limited hypersonic flight-test data to date reduces the quality of predictions for aerodynamic control over Mach 5, Hunter says.

A notional air-launched hypersonic glide vehicle outlined at the conference by Hunter also offered a glimpse of one possible pathway toward an affordable offensive tactical weapon system using existing technology.

Based loosely on Lockheed Martin's High-Performance Maneuvering Reentry Vehicle of the 1990s, which was related to the common air vehicle concept, the blended body study was used to exercise DSTL's new design capability in the hypersonic realm. "DSTL is developing tools and expertise to understand this new class of vehicles, and we are on the road to do that," says Hunter.

Designed for a maximum speed of Mach 5 and impact speed of Mach 2-plus, the configuration that emerged from the study was 3.6 m long (12 ft.) and 1.2 m wide, with a small nose radius of only 10 mm (0.4 in.). "That keeps drag down, but that will have a thermal penalty," says Hunter. The vehicle's mass of 900 kg (2,000 lb.) was "sufficient to fit a [350-kg] warhead in it for a medium-range [2,500-3,000-km] hypersonic glide vehicle."

Carbon-carbon material was selected for the nose tip and control surfaces, with carbon or silica phenolic used in a heat shield to protect the interior. Navigation would be provided by an integrated GPS/inertial system with support from a ground-scanning synthetic aperture radar. The vehicle itself would be designed for direct insertion into its glide phase, thereby eliminating the complexity of an exoatmospheric reaction control system for post-boost reorientation.

Computational fluid dynamics analysis indicated that at Mach 7.5, 5 deg.

alpha (angle of attack) and an altitude of 30 km, the vehicle had a lift-to-drag ratio of 3.5. "That's not quite as good as we hoped. But the good aspect of that is we have quite a wide peak on the lift-to-drag curve, which means we should be able to fly at higher lift-to-drag ratio for a wide range of operational conditions," Hunter says.

The results indicated the vehicle can get "600-km cross-range and change heading by up to 90 deg. azimuth. That means defenders would have to protect across a huge range, which would be a big challenge," he adds.

The glide vehicle would be boosted to a deployment altitude of 65 km by air-launch on a two-stage solid rocket from beneath the wing of a Boeing 747-400. The 747 design incorporates a built-in structural hardpoint, originally designed for carrying spare engines, which provides a convenient location for a mounting for rocket launching.

The same design forms the basis of Virgin Orbit's 747-based LauncherOne smallsat delivery system. The complete DSTL concept stack is 13.5 m long and weighs in at 16,300 kg, "so it does fit on the 747," Hunter says.

"[The study shows] it would be possible for the UK to develop a hypersonic glide vehicle, but there would be significant challenges including acquiring the rocket technology, aerodynamic prediction and control, and thermal protection systems," Hunter says. "If we did it, the weapon would be highly capable."

International hypersonic development partnerships are the most likely option for the UK, says Air Marshal (ret.) Simon Bollom, CEO of Defence Equipment and Support, the keynote speaker at the conference. "The cost associated with developing a weapon or air vehicles would probably be prohibitive at a single-nation level, and if we are going to get into this technology, we are probably going to have to collaborate," he says.

While the UK is beginning its initial forays into potential hypersonic weapons projects with the U.S., the bulk of the nation's missile investment is with France through MBDA. "Much of the hypersonic subject-matter-expert knowledge in this partnership resides in MBDA France, and the UK is working with France to develop a future cruise anti-ship weapon for entry into service in the late 2020s," says Bollom.

Launched in 2017, the joint program is targeted at replacing British and French cruise/long-range precision-strike and anti-ship missiles, including the air-launched SCALP/Storm Shadow as well as the air- and ship-launched Exocet and Harpoon anti-ship missiles. "The program is early in the concept stages and represents an opportunity for the UK and France to build on the hugely successful family that has produced Storm Shadow, Meteor, Brimstone, Perseus [and] Sea Ceptor—to name a few," says Bollom.

"We are studying some concepts at present, and this brings an interesting trade-off into play between speed and low observability," he says. "The program has down-selected to two main concepts with a number of derivatives: one based on high speed and the other on low observability. The two workstreams are probably not compatible in a single system at this stage, and it is likely we'll have to take one or both paths to deliver the full capability across a demanding set of requirements."

His comments support speculation that the program is moving toward development of a subsonic, low-observable, air-launched weapon to replace the SCALP/Storm Shadow missile and a higher-speed missile to replace the air- and surface-launched anti-ship Exocet and Harpoon missiles. It remains unknown whether the high-speed option, currently baselined on supersonic capability, could be extended to hypersonic speeds of Mach 5-plus.

Peter Hall, head of aerodynamics

Hypersonic Defense Concept Targets Air Volumes

AS GOVERNMENTS AND THE AEROSPACE INDUSTRY GRAPPLE with the challenges of developing hypersonic countermeasures, even outline details of concepts for missile defense have remained classified. However, a notional system dubbed the Quartet Interceptor, unveiled at the Royal Aeronautical Society's recent hypersonic conference, provides clues as to how some architectures may evolve.

Conceived by Cranfield University researcher John Markow, the Quartet is designed to use current or near-term propulsion, systems and seeker technology to meet the challenges of very brief engagement timelines and geometries, hard-to-detect targets and precise fuse and warhead timings. The ground-launched system would be based on large, 5-6-m-long (16-20-ft.) vehicles incorporating a booster and multiple rocket-boosted subinterceptors.

"The idea is to launch when the target is still relatively far away, on the order of 10s of kilometers," says Markow, who modeled the system on inbound hypersonic missiles approaching at Mach 6-8 and altitudes up to 15 km (9 mi.). Assuming a head-on engagement, the missile would require around 35 sec. detection time—or around 200 km distance—prior to launch, providing time for last-second propagated targeting coordinates to be uploaded and sufficient time for intercept. The first stage would boost for 6 sec. to place the missile at an altitude and speed at which the subinterceptors would separate, spread out and begin flying preprogrammed trajectories toward a target air volume.

With a rocket burn time of around 10 sec., each interceptor would fly at up to Mach 8 toward the air volume and activate a seeker with a detection range of around 15 km. "The subinterceptors decelerate to about 2000 m/sec. and home in on their assigned section. At least one will find the target and intercept it," says Markow. To compensate for the short time available for the end-game intercept, he says various solutions could be considered, including linking the warhead fuser to merger cues from Doppler changes in the pulse repetition frequency of the seeker.

for MBDA UK, stresses the importance of leveraging existing European partnerships to advance hypersonic missile developments in a timely and cost-effective manner. The company, which is studying hypersonics for the UK's Complex Weapons Program, "sees a lot of benefit from working with other nations," says Hall. The pan-European partnership avoids duplication, pools resources and reduces costs, he adds.

MBDA, which is evaluating the ASN4G, a high-supersonic or hypersonic successor to the French ASMP-A supersonic stand-off missile, "is heading toward having full-scale hypersonic [liquid] ramjet test facilities available," says Hall. "Germany has similar test facilities for solid rocket ramjets." The company also has access to a "wealth" of high-temperature-capable materials across Europe and to specialist seeker and missile control system technology in the UK. MBDA's European arm, led by France, is also working on Twister (Timely Warning and Interception with Space-based TheatER Surveillance), an endoatmospheric interceptor designed to tackle ballistic missiles and next-generation threats including hypersonic glide vehicles.

Aside from national research efforts through DSTL with British industrial aerospace and defense contractors, the UK has "some dialog with the U.S. from an exploitation and countering viewpoint," says Bollom. "At this stage, our spending is relatively modest within the research program, but as opportunities within hypersonics emerge, we'd look to weigh them against many competing defense priorities."

At the same time the UK's interest and involvement in hypersonic weapons systems is in its very early phases. "We are literally in the proof-of-concept stages, and the research as it stands at the moment is to understand the technology that's out there and the range of requirements we would need to put together to counter these weapons," says Bollom.

The UK also has the potential for collaboration in hypersonic defense through its close relationship with the U.S. Missile Defense Agency (MDA) says Paul Dack, chief scientist of the UK Missile Defense Center (MDCT), a Defense Ministry-led government-industry partnership. Established in 2003 to address requirements, issues and opportunities related to ballistic missile defense, the MDCT's remit has been expanded in recent years to "include maneuvering reentry vehicles and latterly hypersonic systems and more specifically hypersonic glide vehicles," Dack says.

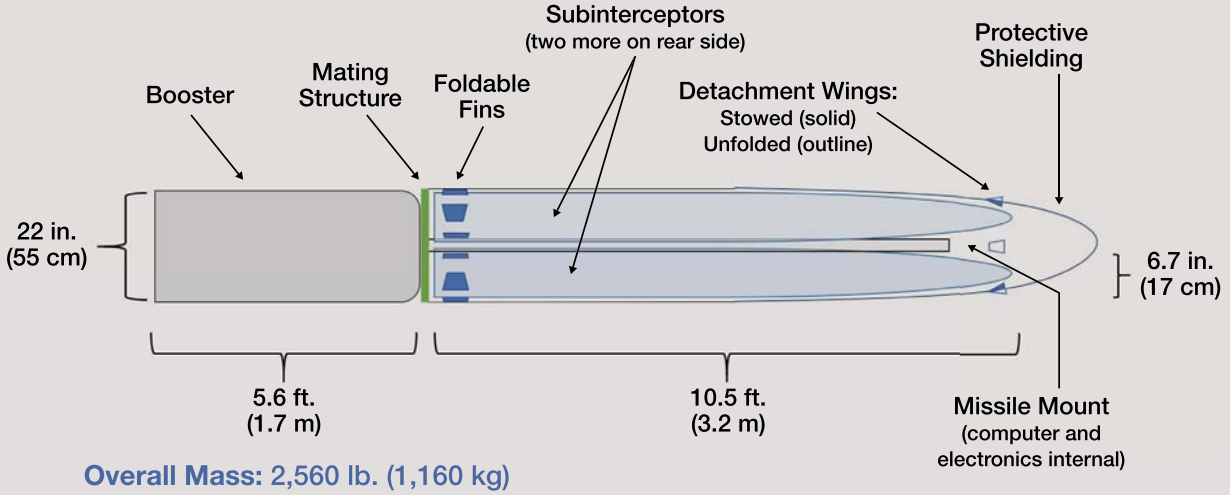
There is currently no specific time frame to develop a defensive capability. "[But] through our collaborative efforts, particularly with MDA, there is clearly an opportunity and an area of significant interest to MDA," Dack says. "That is the lead organization in research and development in the U.S., particularly for hypersonic glide vehicles, and there are UK players supporting the U.S. mission."

He adds: "Multinational engagement is key to our work, [as is] the strong relationship with the U.S. MDA enabled through a [memorandum of understanding] signed in 2003 between the UK and U.S. . . . This arrangement had allowed us to undertake many collaborative activities and generated data analysis for the benefit of both our nations."

"Hypersonic missile defense may well be the most effective area to invest in, and it may well be this that becomes the limit of our ambition in terms of taking a program forward," Bollom says. "The defense against cruise challenging and difficult, since they remain in the atmosphere throughout their flight times."

Pointing out that the U.S. already fields a number of anti-cruise missiles including the SM-2, SM-6, NIADS and Evolved Sea Sparrow systems, he notes that none are designed for countering hypersonic missiles.

Quartet Interceptor Concept



Overall Mass: 2,560 lb. (1,160 kg)
Stage 1 Mass: 1,365 lb. (620 kg)
Subinterceptor Mass: 4 X 2,000 lb. (100 kg)
Mating, Mounting and Shield: 310 lb. (140 kg)

Source: Cranfield University

Life Support

- U.S. AIRLINES AND AEROSPACE COMPANIES TO RECEIVE GRANTS AND LOANS
- EUROPE, ASIA-PACIFIC GOVERNMENTS LAUNCH MULTITUDE OF RESCUE PLANS

Ben Goldstein, Michael Bruno and **Sean Broderick** Washington, **Helen Massy-Beresford** Paris, **Adrian Schofield** Auckland and **Jens Flottau** Frankfurt

Airlines are grounding thousands of aircraft as air travel comes to a halt.

As air traffic began to move toward a level of zero in key markets the past few weeks, the major players in aerospace and air transport were soon very clear on one point: For this industry to survive, bailouts would be needed. And they would have to be big bailouts, to support the supply chain, aircraft manufacturers and airlines globally.

Within days—often as part of general economic rescue packages—financial support at an unprecedented scale was firmly on its way in some countries, first and foremost in the U.S., which has been clear that it will do whatever is needed to keep the sector intact. This includes measures unthinkable less than a month ago. But globally the picture is less clear. Some countries—many with a legacy of an active government industrial policy, such as France—appear equally committed to aviation, while other important players such as the UK are telling their airlines not to expect special treatment.

As has been the case in past disputes over state aid, there is a major risk of it distorting competition if the measures are not harmonized. They have not been—and the financial volumes of the aid packages will make market distortion an even more pressing issue post-COVID-19, as state-sponsored carriers compete with privately funded airlines in markets that have been vacated by those who fell by the wayside.

Major conflicts are already emerging between airlines. Virgin Australia is requesting a loan guarantee of A$1.4 billion ($2.3 billion) from the government so that it can survive, as part of a broader industry package. But its much larger rival Qantas opposes a bailout specifically for Virgin. If money is allocated nonetheless to Virgin Australia, Qantas wants three times that amount, given the size difference between the carriers. In the UK, Virgin Atlantic is lobbying hard for state support, but International Airlines Group (IAG) and its UK unit British Airways say they are not asking for public funds and are lobbying behind the scenes against aid for their rival.

The International Air Transport Association (IATA) estimates airlines will need $200 billion globally in rescue funds to avoid a collapses on a major scale.

Beyond the dearth of traffic, passenger refunds are the single biggest near-term threat to liquidity. IATA is pushing for broad adoption of travel vouchers in place of passenger refunds when flights are canceled. IATA warned that the refunds are a potential liability for the industry of up to $35 billion in the second quarter alone. If all customers were to use the refund option in that time frame, the industry would burn up to $61 billion in cash in the next three months (see graph, page 20). IATA Director General and CEO Alexandre de Juniac says he is "fully conscious of the inconvenience" the introduction of vouchers would mean, as customers would not get their money back at least in the short term. "But for us it is a matter of survival," he says.

IATA expects the industry as a whole to lose $39 billion in the second quarter, versus a $7 billion profit in the same period a year earlier. Revenues for the quarter will be down 68% (and 38% for the full year) from the same periods a year ago, according to the latest estimates. For the quarter, IATA expects the industry to reduce capital expenditures, including for new aircraft, to zero from $17 billion in 2019. As a result, Airbus and Boeing will basically be unable to find airline customers willing to accept aircraft in the next three months. And de Juniac says no airline will be ready to buy new or used aircraft "in the next 6-9 months."

In the U.S., President Donald Trump signed into law a sweeping $2 trillion coronavirus rescue package, including up to $58 billion in financial aid to help airlines blunt the financial impact of the COVID-19 pandemic.

The 883-page Coronavirus Aid, Relief, and Economic Security (CARES)

Aviation and COVID-19

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Check 6 *AAR Corp. CEO John Holmes joined the company just before the Sept. 11 terrorist attacks and helped lead it through the global economic meltdown and a dire workforce shortage. Hear how AAR is preparing for the COVID-19 downturn:* **AviationWeek.com/podcast**

Act will provide $29 billion in workforce grants for airline workers, averting the possibility of mass furloughs for the next six months.

The grants include $25 billion for passenger carriers, $4 billion for cargo airlines and an additional $3 billion for contractors such as caterers and airport workers. All of the money must go toward employee pay and benefits. Airlines that accept the funds will be barred from involuntarily furloughing employees through Sept. 30.

Carriers receiving federal assistance will also be prohibited from repurchasing stock or paying out dividends through Sept. 30, 2021, and will have to abide by certain limits on executive pay increases. The act includes a provision that would allow the federal government to receive warrants, debt securities or equity in exchange for the aid, although it is still unclear how this measure will be implemented.

The aid package also makes a further $29 billion in loans and loan guarantees available to cover losses unrelated to labor expenses, although analysts question whether carriers will opt for the loans, given the restrictive terms and conditions in the legislation and airlines' ready access to private capital markets. Airlines also secured suspension of a host of aviation taxes through the end of the year, including taxes paid on domestic tickets, international arrivals and departures, award-mile purchases, cargo and kerosene.

American Airlines Chairman and CEO Doug Parker said in a video message that the Fort Worth-based airline—the country's largest by fleet size and passengers flown—will be eligible to receive $12 billion of the total $50 billion in financial aid available for passenger carriers.

"We are confident that those funds, along with our relatively high available cash position, will allow us to ride through even the worst potential future scenario," Parker said.

United Airlines CEO Oscar Munoz and President Scott Kirby said in a candid message to the company's 100,000 employees that there will be no furloughs or layoffs through Sept. 30 as per the law but added that some downsizing may still be needed following that date if air travel demand fails to rebound in a meaningful way. "If the recovery is as slow as we fear, it means our airline and our workforce will have to be smaller than it is today," they said.

The legislation provides U.S. airports $10 billion in additional FAA Airport Improvement Program funds, authorized "for any purpose for which airport revenues may lawfully be used."

"The funding and flexibility provided by Congress will help airports cover new operating costs, avoid defaults on their bonds and keep people working during these challenging times," says Airport Council International-North America President and CEO Kevin Burke.

An additional carve-out will provide $17 billion to national security contractors, likely including aerospace companies such as Boeing and General Electric, the former of which has separately called on Congress for $60 billion spread out across the aerospace supply chain.

Boeing proffered itself as the clearinghouse for all of the $60 billion-plus it originally asked for, meaning Boeing ostensibly would dole out funds to suppliers as appropriate. Also, Boeing sought the funds without strings attached. President and CEO David Calhoun contends that aid to Boeing, and secondarily its suppliers, is a government imperative for numerous reasons. He also insists that the future of commercial aviation remains bright, the long-term business case holds, and if the government will not step in, other funders will.

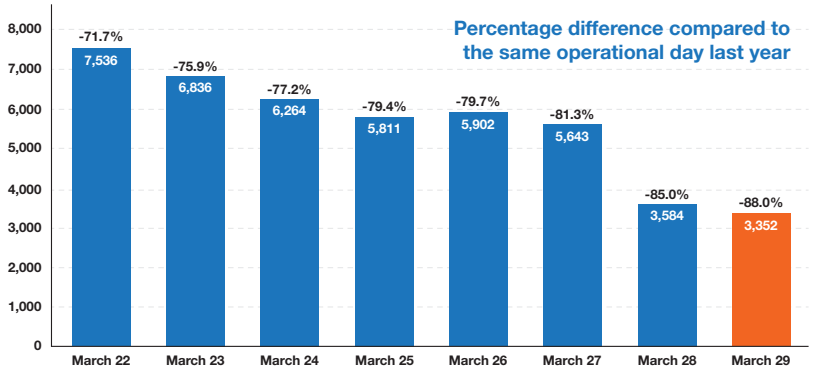
By contrast, Airbus—like Boeing faced with an avalanche of delivery deferrals and preparing for substantial production cuts—is asking that European governments not step in directly to aid it but instead focus on support for suppliers and airlines.

Airbus CEO Guillaume Faury stressed that the company has a strong balance sheet and "significant liquidity available to cope with additional cash requirements related to COVID-19." The company now has access to a new €15 billion ($16 billion) credit facility that increases its available liquidity from €25 billion as of the end of 2019 by almost another €5 billion. This is despite a €3.6 billion compliance penalty payment to authorities, €500 million for the acquisition of Bombardier's share in the Airbus Canada partnership and the funding of operations in what normally is a low-delivery time of the year.

European airlines have been slashing their flight schedules, by the end of March leaving only the bare minimum of services operating to bring home stranded nationals or maintain essential transport links. In addition, calls for support from national governments and the European Union intensified.

Italy, where the novel coronavirus has hit hardest so far in Europe, acted decisively. Its national carrier Alitalia was already in trouble before the outbreak, three years into an unsuccessful search for a route out of bankruptcy. Italy plans to nationalize the airline. According to Italian media, the new Alitalia could see its fleet reduced to 25-30 aircraft, around a quarter of the current total, therefore making it

Daily European Network Traffic Evolution



Source: Eurocontrol

JEFF SWENSEN/GETTY IMAGES

an entity of negligible size. The move to nationalize Alitalia is part of a €25 billion economic support package approved on March 16 aimed at helping the country, which is still in lockdown, recover from the COVID-19 crisis.

French authorities have promised to do whatever it takes to support the big companies in France, including Air France-KLM, in which it holds a 14.3% stake. Economy Minister Bruno Le Maire said March 19: "We have several options on the table for all big industrial companies that could be under threat on the market. They include increasing or taking a stake, or even nationalizations. All options will be studied and presented very soon to the president. We will then take action as and when it is needed according to market conditions, with the sole strategic aim of preserving our key industries."

The French government will have to work out a way to coordinate help for Air France-KLM with the Netherlands, which owns a 14% stake in the airline group. The Dutch government made the controversial purchase of the stake a year ago to give it a voice in strategic decisions for the group.

In Germany, too, the government has launched a multibillion-euro rescue package from which airlines, OEMs and aerospace suppliers can benefit. Lufthansa is in talks with the government about loan guarantees and other options, including a minority shareholding after the airline has cut back. Like other businesses, it benefits from recently passed legislation that allows the state to partially take over employee salaries for a period of up to 12 months if they are forced into part-time work. Condor and TUIfly have asked for government-backed loans to bridge the period during which essentially no flights are taking place. Industry sources say they are likely to be helped. Condor could be taken over temporarily by the government through the KfW development bank.

Norwegian Air Shuttle was in trouble before the COVID-19 crisis hit, but the long-haul low-cost carrier said March 24 that it had reached an agreement with banks that would allow it to unlock an initial tranche of state-backed aid. The Norwegian government launched a 6 billion Norwegian krone ($580 million) loan guarantee package for the country's airlines, with up to half of that earmarked for Norwegian. But the government said its provision of 90% of the total sum was contingent on the financial sector supplying the remaining 10%. Finland has also proposed a €600 million statutory pension premium loan guarantee for Finnair.

Meanwhile in the UK, the government has effectively told the country's airlines that they must exhaust all other avenues to shore up their cash reserves and protect their liquidity before turning to the treasury for assistance. UK Finance Minister Rishi Sunak wrote to airlines and airports March 24 insisting that they first tap their own shareholders for additional funding to get them through the current crisis.

Asia-Pacific governments also are taking steps to support the airline industry during the crisis. Some moved early to introduce packages based on waivers of fees and charges, and state-backed loans for airlines have been offered. Some governments are considering additional forms of financial aid for carriers, with more likely to follow.

The Singapore government is a leader in this regard, unveiling significant measures to help aviation and other sectors on March 26. These include funding 75% of up to S$4,600 ($3,200) of aviation workers' monthly pay and providing S$350 million in fee relief for airlines. This is part of a massive S$48 billion economic stimulus package announced by the government.

Singapore Airlines (SIA) is raising up to S$15 billion through the issue of new shares and bonds, with the backing of its majority shareholder, state-owned Temasek Holdings. SIA will offer shareholders S$5.3 billion in new equity and up to S$9.7 billion through 10-year mandatory convertible bonds. These will be offered to them on a pro-rata basis, and both issuances will be treated as equity on the company's balance sheet, says SIA.

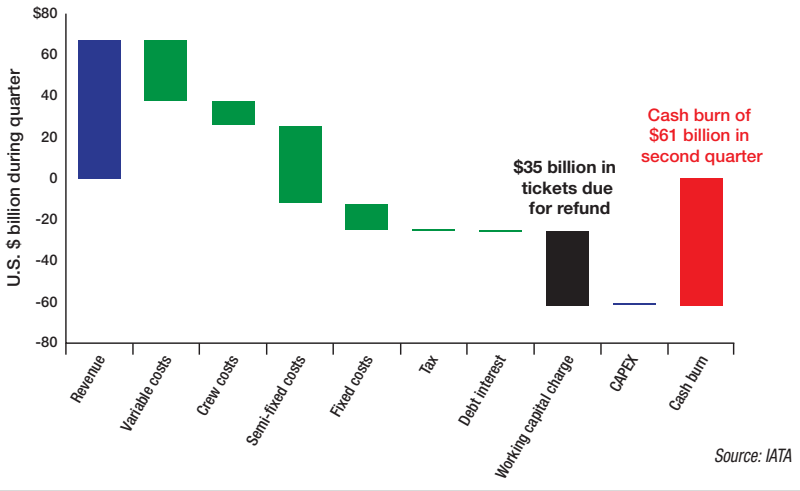
SIA has also arranged a S$4 billion bridge loan facility with DBS Bank, which it said will support "near-term liquidity requirements."

South Korea has deferred payments of airport landing, parking and facility fees. State-run banks have also agreed to provide 300 billion won ($245 million) in unsecured loans to help low-cost carriers that have been hard-hit by plummeting air traffic. The most recent step is a proposal for a 30-50% aircraft property tax reduction for major airlines including Korean Air and Asiana Airlines, although it has yet to be finalized by the government.

South Korea's Ministry of Infrastructure, Land and Transport has met with airlines to explore measures to help the industry. Airlines also held a separate meeting to discuss potential options for government aid and are likely to push for further assistance.

The Hong Kong Airport Authority, backed by the government, has rolled out an HK$1 billion ($129 million) package of financial relief to the aviation industry. About two-thirds of this comprises a government waiver of air traffic control charges for the 2019-20 year, which will be passed on to users. Other forms of airport fee relief for airlines and airport users make up the remaining third of the package.

Airline Industry Expected Second-Quarter Cash Burn



Source: IATA

The Aerospace Supply Chain's Worst Falloff Ever

> ANALYSTS SEE 25% HITS TO NARROWBODIES AND WIDEBODIES

> FACTORIES STRUGGLE UNDER HEALTH QUARANTINES AND WORKER FEARS

Michael Bruno Washington and **Thierry Dubois** Lyon

A year ago, many commercial aerospace suppliers were wondering how they were ever going to meet rising production rates set by leading OEMs as industry faced historic backlogs of airliners to build. Now some suppliers might be wondering if they can even survive in the post-COVID-19 world.

For the aerospace manufacturing sector, the novel coronavirus pandemic and ensuing economic falloff combines the sudden shock of lost business after the Sept. 11, 2001, terrorist attacks with the drip-drip of worsening news during the 2008 financial crisis and Great Recession. It is shaping up to be the worst collapse in business that commercial aerospace and the aftermarket have ever seen, while other corners of aerospace and defense (A&D) struggle through related challenges such as liquidity crunches and closed factories. Industry consultants note conversations with corporate clients where Friday's worst-case scenario becomes Monday's best-case desire.

Each business day seems to bring an announcement of another commercial supplier in Tier 2 or below laying off staff, shelving investments, cutting pay and taking other actions aimed at shoring up balance sheets. Triumph Group, Astronics, CAE and more in March announced workforce cuts, following those of TransDigm Group, Spirit AeroSystems and others in January and February. Wichita aerostructures giant Spirit warns more tightening could be coming. General Electric Aviation has furloughed workers.

Several suppliers also announced that they have drawn down lines of credit available to them. And while Tier 1 defense primes and OEMs apparently are not cutting workforces yet, many—Boeing for one—have frozen hiring. They also are rushing to secure billions of dollars in new financing as a short-term liquidity freeze roils every market. In the latter half of March, Northrop Grumman priced $2.25 billion in debt, General Dynamics unveiled $4 billion in long-term notes, and Honeywell International announced a $6 billion loan agreement.

"The biggest question is what is going to happen with air travel, and here the spread of scenarios is quite wide, from a 'decent recovery by the end of the year' to 'we'll never get back to where we were before the crisis' because behaviors will have changed, attitudes will have changed," says Manfred Hader, co-head of Roland Berger's global A&D practice.

He says the pandemic is the "second black swan to hit in a row," following the Boeing 737 MAX's production halt. Hader predicts Airbus and Boeing will announce new, lower, 2020 production rates for airliners in April—and later this year, lower long-term rates.

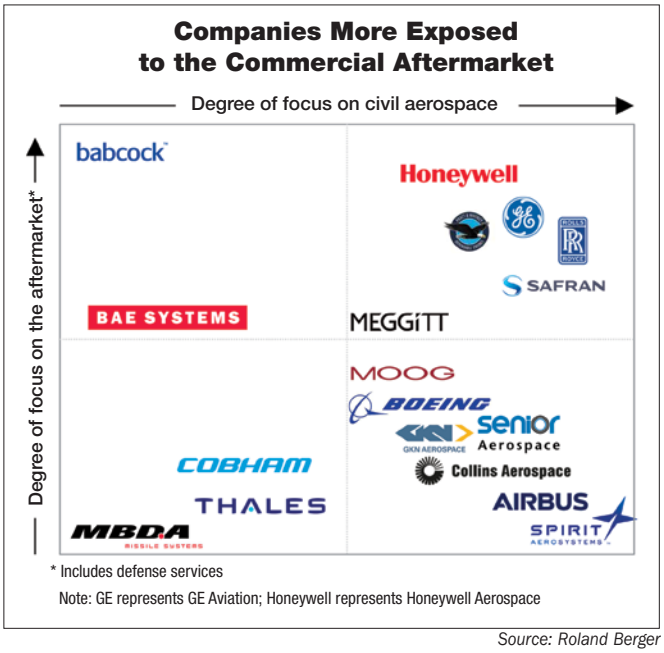
He has lots of company in thinking that. "With airlines globally effectively parking the vast majority of their fleets and an airline industry recovery likely to take several years, we expect aircraft production rates at Airbus and Boeing to fall materially," says analyst Cameron Doerksen of National Bank of Canada Financial Markets. "Demand for new aircraft will collapse in the near term."

Analysts Rob Stallard and Karl Oehlschlaeger of Vertical Research Partners foresee a 40% plummet in revenue passenger miles (RPM) this year, the largest RPM drop in the history of commercial aviation. Looking beyond that, they see a revised requirement for around 6,300 new aircraft over the next five years, compared with their previous forecast of about 8,300 aircraft. By type, they envision about 1,540 fewer narrowbodies and roughly 380 fewer widebodies, both roughly 25% cuts versus their prior demand model. The market for widebodies will be hurt more than for narrowbodies, cementing the latter as the unrivaled airliner for decades, according to multiple analysts and consultants. The biggest risk for delivery cuts are to the Boeing 777 and 787, and the Airbus A330 and A350.

Delivery drop-offs also would be exacerbated by an expected sharp increase in aircraft retirements. Aging, larger models are especially vulnerable for several reasons, including fuel inefficiency and looming maintenance check costs. Targeted fleets could include Boeing 747s, 757s and 767s and Airbus A380s. Even middle-aged A320s and 737 Next Generation airframes might be retired.

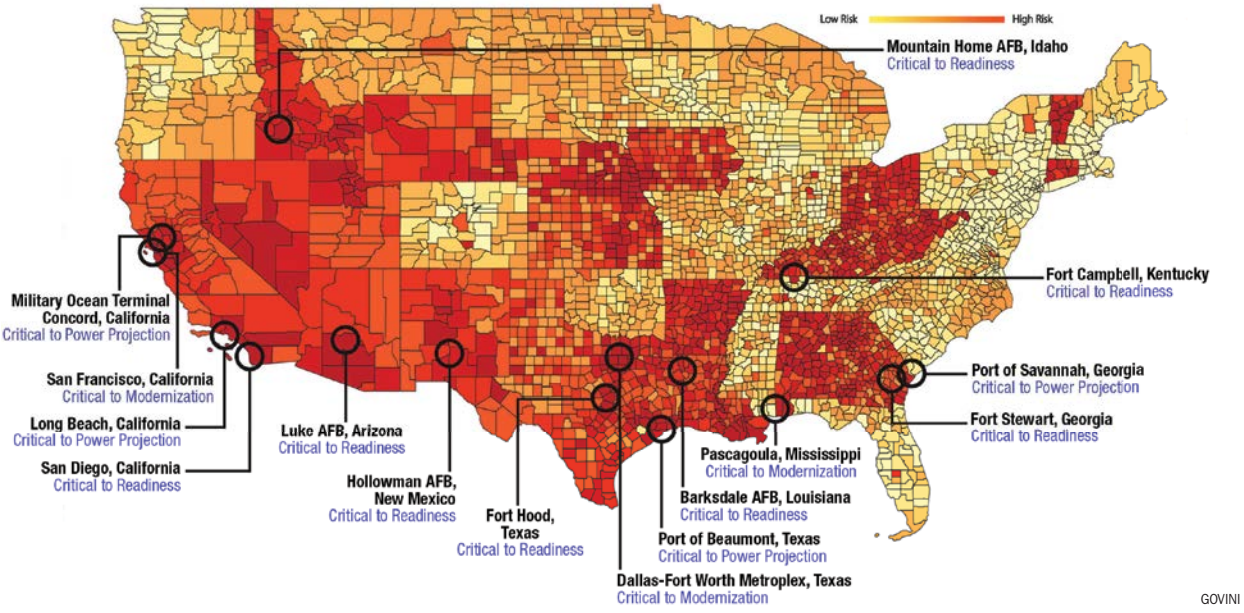
The effect is a double whammy for many suppliers, particularly those that boosted their focus and revenue generation around commercial aftermarket opportunities (see graphic). Roland Berger, Oliver Wyman, JP Morgan analysts and others have warned of a hit of up to 40% to aftermarket revenue streams this year.

There are few places to hide. Suppliers will not be able to diversify much into business jets, for instance, as an-



Source: Roland Berger

U.S. Defense Industrial Base Hot Spots



GOVINI

alysts continue to sour on the prospects for Bombardier and Embraer as stand-alone business aircraft-makers due to the potential for a permanent reduction in business travel from infection fears and recession cutbacks. "Demand for business jets is historically linked to the broader business cycle, so the coming recession will almost certainly hurt demand for new business jets," Doerksen says.

The defense industrial base—now widely considered the best end-market in which to be across A&D, due to longer-term procurements and government protection of contractors—is not beyond risks either. Primes and suppliers are anxious about the possibility of having to close facilities due to health quarantines or because workers just fear becoming infected, Eric Fannings, Aerospace Industries Association CEO and president, tells Aviation Week.

While trade representatives managed to help push U.S. Defense and Homeland Security department officials in March to declare the defense sector part of the nation's critical infrastructure—helping defense primes and suppliers to convince state and local officials to allow them to stay open while most other businesses shutter—a heat-map by consultancy Govini of risks to major defense contracting communities shows reason for concern (see map).

For instance, the key centers of major defense contractors, such as Lockheed Martin Aeronautics, are in the Dallas-Fort Worth metroplex, as is the final assembly facility for the F-35, Govini notes. The latest monthly survey of local businesses from the Federal Reserve Bank of Dallas, released March 30, found plenty of angst. "Business closures are causing supply-chain disruptions/stoppages and must end quickly—within two weeks—or the impact will last a decade in my opinion," one manufacturing executive told the bank.

It sounds the same in France. For the supply chain, the bottom line is uncertainty. CEOs face difficulties planning on the number of employees who will show up in the morning.

"People are scared," says Safran CEO Philippe Petitcolin. "We do not ask 100% of [our] workers to come to work; we only ask that production lines keep operating to deliver our products to those customers who are still open for business."

But some smaller businesses have halted operations. "Some small suppliers have paused for 2-4 weeks," says Petitcolin. "If they do not resume work after that period, we will have a hard time." Safran has an estimated 2-3 weeks of production inventory.

Unions have expressed reluctance about resuming work. When Airbus announced it was partially resuming production at its French factories, unions reacted negatively or, at best, cautiously. Some, like the CFE-CGC executive employees union, did not oppose the resumption, as long as the required health protection measures were taken. Others, such as the CGT union, do not see a problem in a 2-3-week production suspension, comparing it to a business-as-usual holiday period. Despite protection measures on site, a CGT representative would rather avoid hundreds of workers propagating the virus.

Still, unions stopped short of using the so-called right of withdrawal, seen as their "nuclear option." Under that clause, if an employee perceives a "serious and imminent" danger to their health, they may legally stop working.

"Unions know a complete stop of production activity is not in their interest. They are walking a fine line," says a French analyst, speaking on condition of anonymity.

For some companies, the conundrum is more about technical needs versus financial risks. Some production facilities are based on continuous processes, as opposed to the manufacturing of discrete objects. After a shutdown, restarting is complex.

"Take a 3-hectare [7.5-acre] facility with a convoluted network of ducts; every gate setting and configuration is critical for the quality of the final product," says Stephane Albernhe, Archery Strategy Consulting president. If the facility is shut down, impurities may form in the ducts and cause "non-quality" problems, says Albernhe. Every setting would have to be redefined.

Companies operating such factories may have to choose the lesser of two evils. Continuing production may cause rocketing inventory costs. Stopping it may create even greater problems.

MITSUBISHI AIRCRAFT

The sixth SpaceJet prototype made its initial flight from the program's final assembly base at Nagoya.

Mitsubishi Aircraft Flies First SpaceJet of Revised Design

> THE NEXT STEP IS TO SEND THE AIRCRAFT TO MOSES LAKE

> AFTER THAT, THE SCHEDULE SHOULD BECOME CLEARER

Bradley Perrett Beijing

Flying a sixth SpaceJet prototype on March 18, Mitsubishi Aircraft took a big step toward certification of the regional jet, though the company is not saying when exactly it hopes to reach that milestone.

The flight came 1.5 months after the company announced a sixth program delay—and for the first time did not even name a target date for completing development. The extension will be at least nine months long, however. Mitsubishi Aircraft expects to narrow down its outlook once the new prototype has joined the program's flight-testing operation in the U.S.

The aircraft that flew on March 18 is the first that conforms to the new, certifiable design of the regional jet, formerly called the MRJ. The prototype, FTV10, will be the one used most heavily for the remaining test-flying for the program, the company says.

Two more aircraft of that design are in the final stages of production, a spokesperson says. Mitsubishi Aircraft intends to use them mainly for ground tests. "With the completion of FTV10's first flight, Mitsubishi Aircraft Corp. is prepared to enter the final phase of certification flight testing for the SpaceJet M90," the company says.

FTV10 was in the air for 1 hr. 47 min. after taking off at 2:53 p.m. local time from Nagoya Airport, the location of the program's final assembly plant. The aircraft is a SpaceJet M90—the version designed for 88 passengers in a standard, all-economy configuration; it was previously called the MRJ90.

Most SpaceJet testing is taking place in the U.S. at Moses Lake, Washington. "Our next priority becomes preparing for the FTV10 ferry flight to the U.S., joining the flight-test fleet and beginning the final phase of certification flight test," the spokesperson says.

The previous five SpaceJet prototypes were built before Mitsubishi Aircraft discovered in 2016 that design changes were necessary to achieve certification. Avionics and wiring needed to be moved to improve survivability in case of water ingress or explosions. This prompted the company to defer scheduled first delivery from mid-2018 to mid-2020.

But that outlook became highly doubtful in November 2019, when Mitsubishi Aircraft majority owner and SpaceJet airframe contractor Mitsubishi Heavy Industries (MHI) said the schedule was under review. Also, FTV10 was clearly running late by then; it had been expected to join the flight-testing effort in late 2018. Delays in receiving parts were to blame, according to the *Nikkei* newspaper.

Mitsubishi Aircraft finally narrowed down the outlook on Feb. 6, saying the aircraft would not be certified in the financial year ending March 31, 2021. First delivery follows certification, so the delay must be at least nine months. Looking toward the transfer of FTV10 to Moses Lake, the spokesman said then: "We will have a better understanding of our schedule once this happens, because as it begins its portion of our flight-test program, we will enter the final phase of TC [type certification] flight test."

The twin-engine SpaceJet is powered by the Pratt & Whitney PW1200. When the program was launched in 2008, first delivery was scheduled for late 2013. All Nippon Airways is the launch operator.

FTV10, at first called 10010, was tested for basic aircraft performance in normal operating conditions over the Pacific Ocean. The pilots were Hiroyoshi Takase and Akira Udagawa. It handled as expected, Takase says.

Four SpaceJets of the superseded design are at Moses Lake. The fifth has been kept at Nagoya for ground testing.

All these are also SpaceJet M90s. To better suit major U.S. airlines' pilot contracts—which, contrary to expectations in 2008, have not become less restrictive—the second version will be the M100. Despite its designation, it will be smaller than the M90, with standard all-economy seating for 84. Within the weight limits that the U.S. airlines' pilot contracts impose on outsourcing carriers, the M100 achieves a better combination of payload and range than the M90 and former MRJ70.

The program lost a major customer in October, when Trans States Holdings canceled an agreement to buy 50 SpaceJets and take options on 50 more. That company, the owner of several carriers in the U.S., has since decided to close one of them, Trans States Airlines.

The contract was replaced by one from Mesa Airlines in the previous month for the same order and option quantities and specifically covering the M100 version. Another U.S. customer, SkyWest Airlines, ordered 100 SpaceJets (MRJs at the time) in 2012 and took options on 100 more.

Mitsubishi Aircraft is reshuffling executive positions. In April, President Hisakazu Mizutani will become chairman, replaced in his current role by Takaoki Niwa, president of MHI America.

Domestic Networks Provide Safety Net for Asia-Pacific Carriers

> SIA, CATHAY ARE MORE VULNERABLE TO INTERNATIONAL DECLINE

> DOMESTIC TRAFFIC IS EXPECTED TO BOUNCE BACK FASTER

Adrian Schofield

The COVID-19 crisis shows that while it is good to have a globally diverse network, a strong domestic operation is a major advantage for carriers when a shock disrupts international traffic flows.

Industry logic holds that a broad spread of international routes lessens an airline's reliance on any single market, including its home patch. So if a downturn occurs in one country or region, carriers can divert resources to unaffected areas. Many successful airlines have built their models around this concept.

And that approach makes sense—until something such as a pandemic appears out of nowhere to trigger global border closures. Then domestic networks become a godsend, and carriers that depend on connecting international traffic look more exposed.

While international travel was the first to be hit, the coronavirus crisis has caught up with many domestic networks as governments increasingly lock down internal movement. But domestic networks can be expected to return sooner, and demand likely will recover more quickly.

The Asia-Pacific region provides case studies of the benefits and limitations of different approaches. Singapore Airlines (SIA) and Cathay Pacific are examples of airlines that rely exclusively on international networks, and lean heavily on connecting international markets via their hubs.

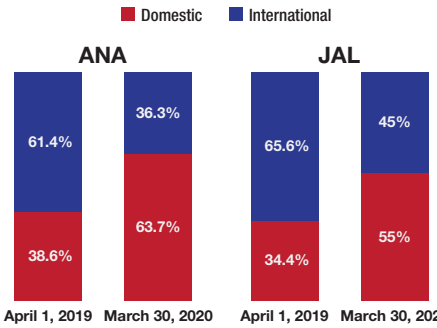
At first both carriers were hurt due to their relatively high number of routes to mainland China, which was the first market affected. Then other international markets were progressively closed off due to tightening travel restrictions.

SIA has been forced to ground 138 of its 147 aircraft and suspend 96% of its capacity through at least the end of April. SIA notes that "without a domestic [operation] the group's airlines become more vulnerable" when countries restrict or ban international travel.

Cathay Pacific likewise plans to cut its passenger capacity by 96% in April and May. The airline will operate just a "bare skeleton" schedule, and even this could be under threat if more travel restrictions are imposed.

Japan Airlines (JAL), All Nippon

Changing Domestic/International Split for Japanese Carriers*



*Measured in available seat kilometers.

Sources: CAPA – Centre for Aviation and OAG

Obeying Orders, Chinese Airlines Lift Capacity

> CAPACITY HAS BEEN FLAT AND MODERATE

> INDUSTRY MANAGERS HOPE FOR FUTURE GOVERNMENT SUPPORT

Bradley Perrett Beijing

Chinese domestic airline activity is not as good as it looks. The airlines are doing national service: facilitating economic recovery and creating the impression of a return to normality to suit government policy—not their profitability.

Domestic capacity is more or less holding up at a moderate level reestablished early in March, when the country was well on its way to bringing the COVID-19 pandemic under at least temporary control. But the carriers have not followed through on plans to surge the offered number of seats by more than a third in the week of March 30. Also, aircraft are only about two-thirds full and fares remain low.

Loads are edging higher, however.

The industry is evidently flying unnecessary capacity because the government has been trying, for about six weeks, to get the country back to normal. And Beijing expects all industries to cooperate. Reasonably high flight frequencies send a signal to the country that commercial aviation is operating more or less normally. They also make business travel easier, helping to improve national output a bit.

The Civil Aviation Administration of China has said several times that the government will help airlines recover from the effects of the pandemic, especially those that make an extra effort to assist the country. There are no specifics on future support, but airline managers are hopeful.

The government expects little from international operations. Although airlines are presumed to keep open minimal connections to foreign countries, they are forbidden from increasing capacity because China fears reimportation of the coronavirus that began in Wuhan.

Domestic capacity for the week of March 30, measured by seats offered, should be 60% of 2019 levels, according to OAG and Aviation Week Network's CAPA – Centre for Aviation. Since growth for 2020 was expected before the coronavirus hit, the airlines are flying roughly 55% of the capacity they would have offered in the absence of the pandemic.

Expected domestic capacity for the week of March 30 was down about 8% from a week earlier—contrasting enormously with the 35% surge that the airlines had planned.

The reasoning behind the decision not to surge capacity is clearer than the impetus to do so in the first place. The average flight was only 66% full on March 25 and 26, according to a compilation of industry-wide load factors obtained by Aviation Week. This data includes international operations but is dominated by domestic. The load factor was about 57% for the first nine days of the month and 83% for March 2019.

Comprehensive data for yields is unavailable, but casual checks with travel agencies reveal that fares are deeply discounted; for example, normally, the price for a one-way flight

Airways (ANA) and Korean Air are other examples of airlines for which international connecting traffic is a key part of their strategies. However, unlike Cathay and SIA, these carriers also have domestic networks. And their domestic operations have taken on greater importance since the COVID-19 outbreak began, as they have shrunk far less than international services.

This dynamic has caused the share of domestic operations to increase for all three of the airlines. In fact, the two Japanese carriers now have more domestic capacity—as measured in available seat kilometers (ASK)—than international, reversing the trend from a year ago, according to data from CAPA - Centre for Aviation and OAG. For the week of March 30, 63.7% of ANA's total capacity was domestic, compared to 38.6% for the week of April 1, 2019. For JAL, domestic comprises 55% now compared to 34.4% a year ago.

Korean Air's domestic ASK share for the week of March 30 has risen to 8.1% of its total, compared to 3.1% a year earlier. South Korea does not have as extensive a domestic network as Japan, and routes are mostly shorter. But it does have the Seoul-Jeju route, which is the world's busiest domestic market. In terms of seats rather than ASK, domestic capacity has increased from 25.5% to 60.6% of the total for Korean.

Garuda Indonesia typically has more domestic seats than international—by a factor of three in 2019. The airline has noted that its extensive domestic network, spread over many islands, gives it an advantage over other carriers more reliant on hubs.

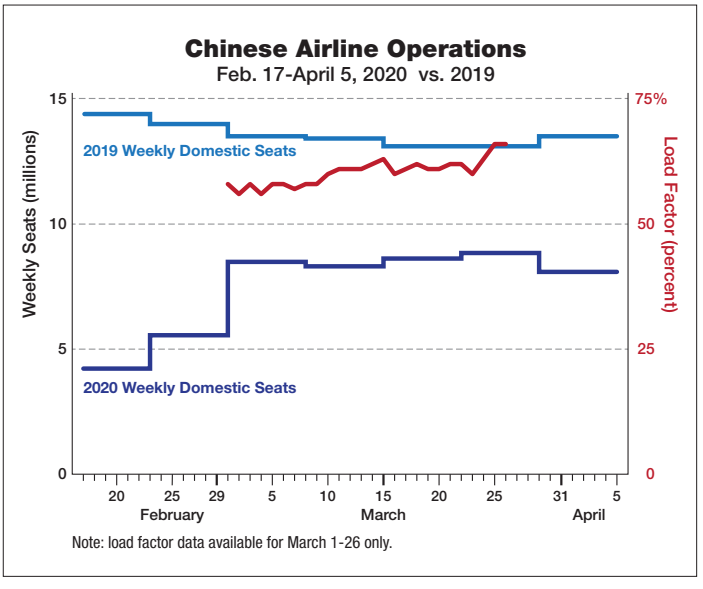
Airlines based in Australia also had a distinct advantage when COVID-19 struck due to their broad domestic networks, which remained in operation after international services were shut down. However, their domestic services have now also been dramatically cut back as restrictions on local travel tighten.

Qantas will cease all international service from the end of March through at least the end of May, and will reduce domestic capacity by 60%. Qantas CEO Alan Joyce predicts the domestic market will recover far faster than the international side. Domestic restrictions are likely to be lifted earlier, and consumer confidence may also be more easily restored on flights within the country.

As recently as March 13, Virgin Australia said it was "insulated" to some extent from the international market decline, since it is a "predominantly domestic airline" with 78% of its revenue from that part of the business. Since then, however, it has been forced to suspend 90% of its domestic capacity.

Carriers in Vietnam also have had to shut down most of their domestic routes due to government restrictions. Vietnam Airlines has canceled all of its domestic flights except for one flight per day on its three core trunk routes. Vietnam's Hanoi-Ho Chi Minh City route is usually one of the busiest domestic routes in the region, and likely will be again when the pandemic eases.

Air New Zealand has reduced its international capacity by 95% and on April 2 raised domestic cuts to the same level. Domestic demand and services will likely increase when the country's internal travel lockdown is lifted. But CEO Greg Foran notes the carrier is heavily reliant on international tourism, and because this traffic will not bounce back for some time; there will be "a flow-on effect on our domestic network."



Sources: CAPA – Centre for Aviation and OAG; and internal industry statistics

between Beijing and Shanghai is about CNY1,200 ($170), but the airlines are now typically asking for around CNY400.

Anecdotally, almost no leisure travel is happening in China right now. One obvious reason is that it would not be much fun. Amusements such as night clubs and karaoke bars are still generally closed—the rules vary from city to city—and though some scenic attractions reopened a few weeks ago, last week the operators were told to close indoor facilities. No doubt many potential tourists, fearful for their jobs, prefer to save their money.

After the government in mid-February called for the country to get back to work, tens or hundreds of millions of people began returning to offices and factories in big cities from their hometowns where they had been spending the Lunar New Year when the coronavirus emergency was recognized in late January. Some demand for flights still appears to be coming from people returning to work, industry managers say. But after so many weeks, that effect is surely dwindling.

That leaves business travel as the likely main support for domestic demand in the industry, although even in this activity it is easy to see restraints. Anecdotes suggest that many companies are keeping belts tight and have embraced video conferencing. State enterprises have less to fear from financial losses than private businesses do, but they must pay particular attention to government demands to minimize travel to help prevent a recurrence of contagion. (This policy is at odds with expecting airlines to offer so many seats.)

The industry load factor began picking up on March 10, when it jumped to 60%. Then it tended higher, reaching 63% by March 24, followed by two days at 66%. More recent information is unavailable, but the upward trend is clear.

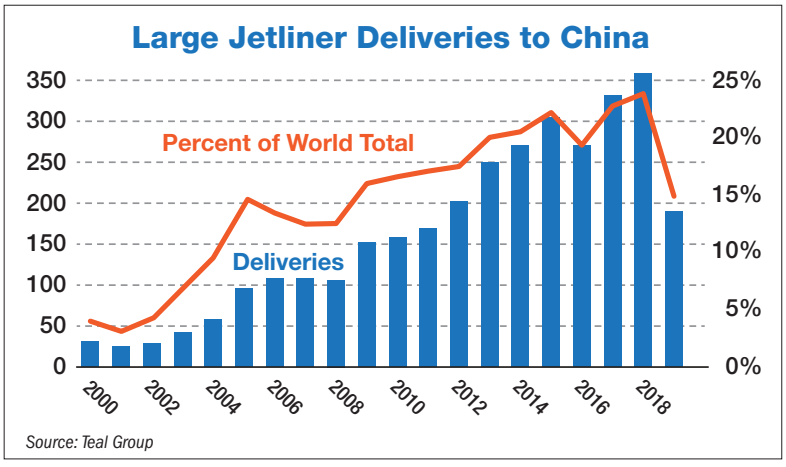
Domestic capacity has been less stable, but the trend can be characterized as flat: The weekly number of seats offered wandered from 8.5 million in the first week of March to a peak of 8.8 million three weeks later, then dropped to 8.1 million planned for the week of March 30.

China's Appetite for Aircraft May Disappoint

By **Richard Aboulafia**

Jetliner market recoveries for the past few decades have greatly benefited from the rise of China, whose market was the only one that combined fast demand growth with sheer size. Over the past two decades, the country grew in importance to our industry, taking 2% of total Airbus and Boeing output in 2001 and rising to a peak of 23% in 2018. The graph below indicates this dramatic increase in China's importance to the market.

Our industry is clearly headed into a bust cycle, we hope to be followed by a recovery. But this time, the industry might find that post-coronavirus Chinese demand is not what it was before and that the recovery side of a V-shaped market downturn is a bit less steep. There are two reasons to be concerned.



Source: Teal Group

First, China's economic problems and its air traffic slowdown started months before COVID-19 was identified. Nominally, GDP growth last year was 6.1%, but there were plenty of indicators of a less robust reality. For example, car sales actually fell more than 8%. And according to the International Air Transport Association, China air travel demand fell from 12.2% year-over-year growth in late 2018 to just 5.3% by October and November 2019.

Typically, air travel demand for a fast-growth market like China is roughly twice GDP; that late-2018 12.2% figure is clearly supportive of 6.1% GDP growth, capping many years of double-digit growth. The single-digit growth in the second half of 2019 would be typical for an emerging economy growing at 2.5-3%.

China's recent economic figures reflect a much worse reality. Its economy contracted in January and February for the first time in over half a century. Industrial production fell 13.5% from a year earlier. China domestic air travel in January fell by 6.8%, which was just the start of the COVID-19 impact.

Second, China's jetliner market downturn started a year before COVID-19, in line with the country's air travel demand drop. While 2018 saw a record of 355 jetliners delivered to Chinese customers, this was cut almost in half in 2019, to 180 jets. Some of this decrease was due to the cessation of Boeing 737 MAX deliveries. But Airbus did not exactly pick up the slack: Deliveries from Airbus fell 12% in 2019, despite a capacity expansion at the European company's Tianjin A320 final assembly line.

Even before the coronavirus-related traffic collapse, scheduled deliveries in 2020 were slightly lower than 2019's already low level. In relative and absolute terms, the China market has been halved, and given the coronavirus situation, it is quite likely that demand will fall further before it resumes growth, hopefully in the next few years. But it might not get back to the 2018 peak until 2023 or later.

The situation is not completely bleak. China can provide state aid for airlines and lessors more readily than most other countries, although that is just a stabilization measure. It is not the same as returning the country and its air travel industry to the remarkable growth track it was on as it transformed from a poor country to a middle-income one. In terms of its economy and its air travel market, China might be plateauing out.

This crisis has worsened China's relations with the U.S. and the West, which were already deteriorating. Looking beyond the post-coronavirus recovery, as economic nationalism increases and Western supply chains move away from China—and as state aid plays a bigger role in many economies due to the coronavirus economic downturn—China might pursue an increasingly autarkic future.

Building jetliners is already a priority in the country's 2035 plan, and while the results so far have been poor, that problem could be solved with trade barriers: Chinese airlines would be forced, against their will, to buy local jets.

This bigger concern about China's aviation future is more of a post-2030 problem. But for the coming few years, the important conclusion is that China likely will not play the same big role in a steep V-shaped recovery. The country probably will stay at a somewhat muted level of growth in its economy, air travel demand and the jetliner market even after the COVID-19 crisis passes. There might be a robust China traffic recovery, but we are unlikely to see the kind of strong, sustainable growth numbers that benefited the aviation industry for the last two decades.

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

No, Nationalism and Protectionism Will Favor China

By **Peter Harbison**

Since the first aircraft took flight, aviation has moved in lockstep with politics and national security and has been a major global socio-economic force for good. It is no coincidence that the economic and political rise of China and Asia in this century has created a major power shift in aviation geopolitics, too. Later in this decade, China is projected to overtake the U.S. as the world's largest aviation power. The coronavirus crisis will either accelerate or slow this transition. The smart money would have to be on China's preeminence.

Government leaders are increasingly describing the coronavirus onslaught as a world war. In fact, it is both much bigger than World War II and very different from it. This time, there are 185 countries fighting it, with more still to join, and every country is a battlefront.

Moreover, a collection of allies worked more or less in concert in World War II to defeat the common foe, a fight led in its later stages by the U.S. Today, there are few signs of a similar level of cooperation; faced with this invisible invasion, most countries have focused almost entirely inward, with no sign of leadership from the world's largest economy.

The coronavirus has arrived at a time when nationalism, with its adverse effects on globalization, has been rising. Rather than vanquishing nationalism, as happened in 1945, winning this war appears likely to entrench it. That is bad news for the airlines.

Hopefully, the virus war will not last as long as World War II did. But even if it is over in a matter of months, the world into which we emerge will be very different from the one we left a few weeks ago. Many airlines will have died, and most survivors will have their government bailouts to thank, with overhanging obligations.

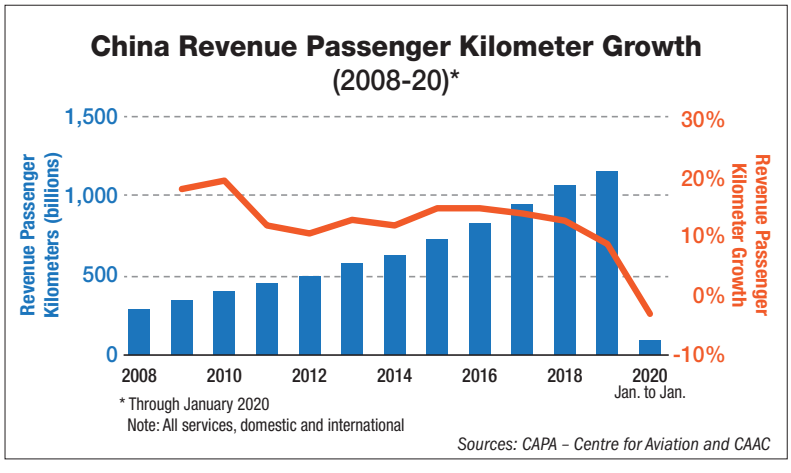
In 2021, we will be confronting a deep economic recession that the International Monetary Fund expects will be "worse" than the one following the global financial crisis of 2008-09. Back then, it took the U.S. airline market until 2014 to recover to pre-recession levels. China's system, by contrast, bounced back with annual double-digit growth in revenue passenger kilometers every year for the decade starting in 2009, only slipping below, to 9.3%, in 2019. But these data scarcely offer a basis for extrapolating this time.

In the new world we are entering, populated mostly by government-supported airlines, the dynamics of aviation will have very different drivers from the previous supply-demand formula. The system is likely to resemble the restrictive profile of the 1970s, now overlaid by a vigorous trade war between the U.S. and China.

Aviation and the much larger tourism industry will emerge greatly weakened and reduced in size. The international market will lag domestic recovery markedly because there will be limited synchrony between the different markets' return to health and economic security. Combined with a likely pushback on market liberalism, the resulting constraint on airline network-planning freedom will create a further impediment to restoring the global system. The priority will be on direct links between major countries.

Network airlines rely on access to a wide range of markets around the world, and achieving critical mass depends on multiple feed routes. These factors will make life difficult for sixth-freedom operators with small or no domestic domain, particularly if liberal market access is in retreat.

China, however, has the great advantage of a massive and still growing government-supported domestic market, ensuring both a substantial airline industry and a wide range of international point-to-point connections. Its geographical positioning sets it up as a massive transfer hub—with many large transit points—straddling the major markets of Asia-Pacific and Europe, and even much of North America.



In a less liberal aviation marketplace, China is consequently likely to be the big winner. Herein lies a paradox for U.S. policymaking. The current administration's nationalistic attitude, strongly prompted by airline unions, is likely to confine its airlines even further within an international network reliant on a low-growth—albeit historically valuable—North Atlantic market as well as Latin America, both of which appear fragile now.

Alternatively, there is a great opportunity, emulating the optimism of the post-World War II governments, to reformulate the aviation regulatory system. That would at least mean removing foreign ownership controls on airlines to allow rationalization and consolidation in a liberal framework. But that would require vision and cooperation.

Peter Harbison is chairman emeritus of CAPA – Centre for Aviation, which is part of the Aviation Week Network.

OneWeb Falls

- COMPANY GOES BANKRUPT AFTER PRIME BACKER EXITS
- 74 SATELLITES ARE ALREADY IN ORBIT

Irene Klotz Cape Canaveral

ARIANESPACE PHOTOS

One of OneWeb's first six satellites during integration onto its payload dispenser.

Eight weeks ago, OneWeb was riding high, confident after the successful kickoff of a 20-flight sprint to build out its broadband internet satellite network in low Earth orbit.

But by the time the next batch of satellites reached orbit on March 21, the company's financial situation had turned grim. Its primary backer, Tokyo-based SoftBank—already stinging from a troubled investment portfolio—saw its market value collapse as the COVID-19 coronavirus crisis engulfed the planet.

The SoftBank conglomerate, which reported ¥9.1 trillion ($84 billion) in revenue in 2018, announced an emergency asset sale to raise funds, buy back shares and reduce debt. For OneWeb, the situation proved fatal.

SoftBank, which had spent about $2 billion on OneWeb, balked at providing additional financing—though as majority shareholder, the Japanese conglomerate retains the power to set terms under which potential new investment could come in. Since its founding in 2012, OneWeb has raised about $3 billion in four rounds of financing.

So on March 27, with its 34 newly launched satellites still climbing into operational orbits, OneWeb filed for relief under Chapter 11 of the Bankruptcy Code in the U.S. Bankruptcy Court for the Southern District of New York.

Thirteen months after a Soyuz rocket delivered its first six satellites into orbit, OneWeb has filed for bankruptcy.

"Today is a difficult day for us at OneWeb," OneWeb CEO Adrian Steckel said in a statement after the filing. "It is with a very heavy heart that we have been forced to reduce our workforce and enter the Chapter 11 process."

Before filing, the company cut 90% of its 530-member workforce, located in London; McLean, Virginia; and Mountain View, California.

OneWeb also is part owner of OneWeb Satellites, a manufacturing arm it operates with Airbus adjacent to the Kennedy Space Center in Florida. OneWeb Satellites is not part of the bankruptcy proceedings, but on March 30 it, too, furloughed an undisclosed number of employees.

"OneWeb Satellites is primarily implementing temporary furloughs to have the flexibility to respond to the changing environment and is still operating with no plans of filing for bankruptcy," the company said in a statement.

"We continue to work with both shareholders—Airbus and OneWeb—while OneWeb negotiates its financing," added OneWeb Satellites CEO Tony Gingiss. "We are deeply saddened to see our friends at OneWeb being so significantly impacted, and we stand behind them and their families as they go through this difficult period."

OneWeb is hoping its days in bankruptcy proceedings will be short. "Our current situation is a consequence of the economic impact of the COVID-19 crisis," Steckel said. "We remain convinced of the social and economic value of our mission to connect everyone everywhere."

OneWeb said it had been in advanced negotiations since January for investment to fully fund the company through the deployment of its initial 648-member constellation. "While the company was close to obtaining financing, the process did not progress because of the financial impact and market turbulence related to the spread of COVID-19," OneWeb said.

In addition to 74 satellites in orbit, OneWeb has global spectrum rights and has completed or is in the process of developing half of 44 planned ground stations. The company also is working on a range of user terminals for different types of customers and has demonstrated data transmission speeds greater than 400 Mbps and a latency of 32 millisec.

"We are confident that our recent successes have created a strong foundation for future owners," the company said. "It is important to know we are looking at several paths under the Chapter 11 process, and it is too early to know the exact outcome of the restructuring process."

OneWeb continues to operate and test its 74-member network. "We are committed to being responsible space stewards," OneWeb noted.

OneWeb's top creditor is Arianespace, which was owed $238 million as of the March 27 filing. OneWeb in 2015 signed a $1.1 billion contract with Arianespace for 21 Soyuz launches. So far, three of the launches have taken place, all successfully. The next flight had been targeted for May.

Other unsecured creditors include Qualcomm Technologies, which is owed $8 million; Deloitte Touche Tohmatsu, $6.9 million; Hughes Network Systems, $5.4 million; and Deutsche Bank, $5.2 million.

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NASA Picks Tops Priorities As Centers Shut Down

> SLS STATIC TEST FIRE ON HOLD

> WORK CONTINUES ON MARS 2020 ROVER

Irene Klotz Cape Canaveral

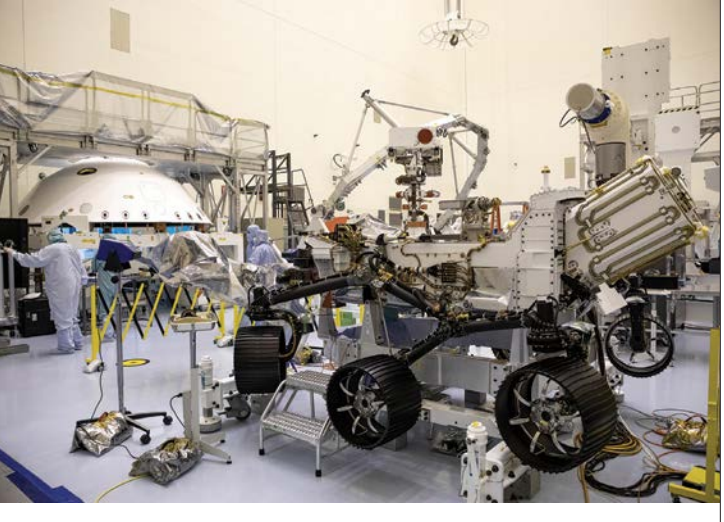
With 10 NASA centers shuttered, the U.S. space agency is reassessing every program in its portfolio in light of employee safety amid the growing threat from the highly contagious COVID-19 coronavirus, which has infected nearly 1 million people worldwide and more than 216,000 in the U.S. as of April 2.

Among the earliest programs to be mothballed was the seemingly unstoppable Space Launch System (SLS) program. Prime contractor Boeing overcame all kinds of adversity over the last nine years to develop and deliver the first SLS core stage to NASA for testing, but now the program is stopped dead in its tracks.

NASA Administrator Jim Bridenstine suspended work on the SLS and Orion deep-space capsule at the agency's Michoud Assembly Facility, located outside New Orleans, and the Stennis Space Center in southern Mississippi, effective March 20.

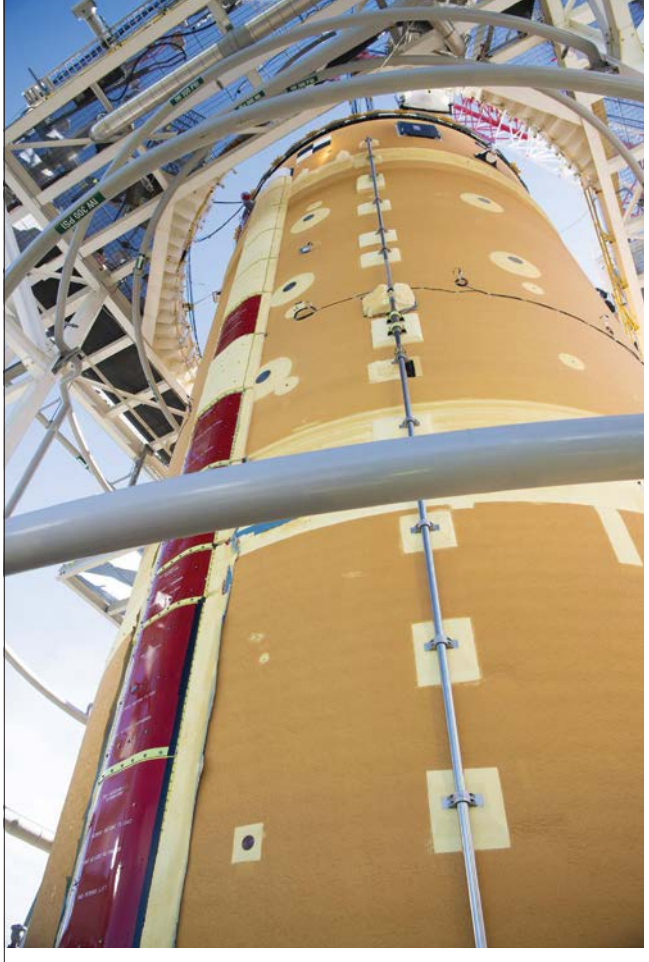
With the number of COVID-19 cases rising in both communities—and the first confirmed case of the disease at Michoud—Bridenstine closed the centers to all personnel except those needed to protect life and critical infrastructure. Access to NASA's Ames Research Center at Moffett Field, California, was similarly restricted on March 17.

A week later, the shutdown list had expanded to include Glenn Research Center in Cleveland, Goddard Space Flight Center in Maryland and Wallops Flight Facility in Virginia, as well as the Goddard Institute for Space Studies in New York. By April 1, the Armstrong Flight Research Center at Edwards, California, and Marshall Space Flight Center in Huntsville, Alabama, were added to the shutdown list.



CORY HUSTON/NASA

Processing on the Mars 2020 rover Perseverance remains underway at the Kennedy Space Center's Payload Hazardous Servicing Facility.



NASA

The core stage for the first SLS booster underwent modal testing at NASA's Stennis Space Center in Mississippi on Jan. 30. Data from the test will be used to verify structural vibration modes and verify flight control parameters. The test is part of a Green Run series of integrated testing prior to the SLS debut flight.

The Glenn-operated Plum Brook Station in nearby Sandusky, Ohio, stayed open long enough to ship out the Orion spacecraft earmarked for a lunar flyby flight test in 2021. The capsule, built by Lockheed Martin, completed four months of thermal vacuum and electromagnetic environment testing at Plum Brook and arrived at the Kennedy Space Center in Florida on March 25.

Kennedy, NASA headquarters in Washington and the rest of the agency's field sites remained open for mission-critical personnel as of April 2. Those facilities include: the Johnson Space Center in Houston; Jet Propulsion Laboratory in Pasadena, California; Langley Research Center in Hampton, Virginia; and White Sands Test Facility in New Mexico.

The Orion capsule may have an extended stay in Florida. The SLS rocket expected to launch Orion on a flight test around the Moon was finally shipped from its Michoud manufacturing facility to Stennis for integrated testing in January, following two years of delays to resolve technical problems.

A full-duration static test firing of the core's four RS-25 engines, now on hold, was scheduled for this summer. The "Green Run" test campaign had been approaching avionics power-on, SLS prime contractor Boeing writes in an email to Aviation Week.

Still to come before the SLS hot-fire test are a countdown demonstration and wet dress rehearsal.

Completion of the Green Run sets the stage for SLS'

CORY HUSTON/NASA

Technicians test the small helicopter that will accompany the Mars 2020 rover as part of a technology demonstration.

long-awaited flight test, a mission now known as Artemis 1 that will send an uncrewed Orion capsule around the Moon. Originally targeted for 2017, SLS' debut was delayed to 2019 and, most recently, to November 2020.

However, even before Michoud and Stennis were shuttered due to COVID-19 concerns, NASA was not going to make the 2020 launch date. The agency in April had planned to announce a new target launch date for Artemis 1 of mid-to-late 2021.

"We realize there will be impacts to NASA missions," Bridenstine said in a statement announcing the Michoud and Stennis closures. "But as our teams work to analyze the full picture and reduce risks, we understand that our top priority is the health and safety of the NASA workforce."

Current plans call for Artemis 1 to be followed in 2022-23 by Artemis 2, a crewed flight test around the Moon, and in 2024 by Artemis 3, which would land astronauts on the south pole of the Moon. The expedited schedule to land on the Moon was set by President Donald Trump in March 2019.

NASA and Boeing are negotiating a production contract covering 10 more SLS cores for missions beginning with the Artemis 3 Moon landing.

The core stage for Artemis 2, currently under construction at Michoud, is part of Boeing's original development and production contract—work that NASA's Office of Inspector General estimates will have cost the agency more than $17 billion through the end of fiscal 2020, a March 10 audit shows.

NASA in October 2019 authorized Boeing to purchase long-lead materials and parts needed for Artemis 3, but the company does not yet have authorization to begin assembly. Boeing is aiming to establish a supply chain and a production line using its existing tooling to produce a core stage about every eight months.

The engine section, intertank, liquid oxygen tank, liquid hydrogen tank and forward skirt structures for Core Stage 2, which was due for completion in spring 2022, have been welded and built, says Boeing spokesman Jerry Drelling.

Meanwhile, in September 2019 Lockheed Martin, the prime contractor for Orion, signed a $4.6 billion production and operations contract with NASA covering manufacturing of six more spacecraft at Michoud. That work is now suspended.

The first Orion capsule was built under a $7 billion development and production contract. Including funds spent on Orion during the predecessor 2006-11 Constellation program, NASA budget figures show the project will have cost $18.5 billion by the end of fiscal 2020.

In addition to processing the first Orion spacecraft, Kennedy Space Center personnel are continuing to work on the Commercial Crew and Commercial Resupply Services programs in support of the International Space Station. NASA also is continuing to process the Mars 2020 rover at Kennedy for launch this summer. The opportunity to launch to Mars, which occurs every 26 months, is from July 17-Aug. 5.

"Mars 2020 is one of only two missions within SMD [Science Mission Directorate] that is the highest priority," Lori Glaze, director of NASA's Planetary Science Division, said at a March 19 town hall meeting. The forum was held virtually due to cancellation of the annual Lunar and Planetary Science Conference in Houston.

"As of right now—and even if we go to a next stage of alert—Mars 2020 is moving forward on schedule, and everything so far is very well on track," Glaze said. "We're also making sure that our personnel are healthy and safe."

NASA's other high-priority science mission was the James Webb Space Telescope (JWST), due to launch in 2021 from the European Space Agency's spaceport in Kourou, French Guiana.

France on March 16 suspended launch campaigns from the Guiana Space Center due to the COVID-19 pandemic. On March 20, NASA suspended work on JWST, which is located at prime contractor Northrop Grumman's facilities in Redondo Beach, California.

Work on the James Webb Space Telescope, already at risk of not making its March 2021 launch date, was suspended as part of shutdowns to stem the spread of COVID-19. The observatory is at Northrop Grumman's facility in Redondo Beach, California.

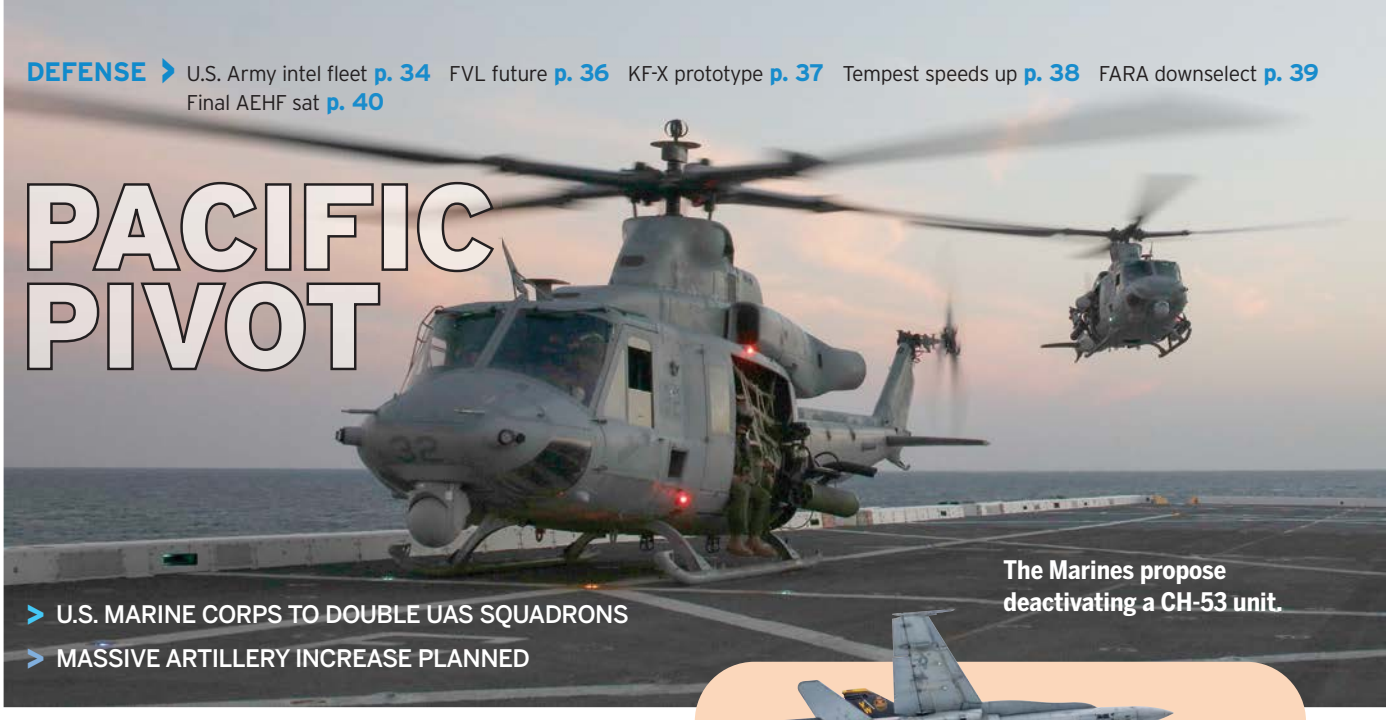
NORTHROP GRUMMAN

Northrop, as well as other aerospace companies designated essential suppliers, are exempt from the state's mandatory shelter-in-place orders intended to curb the spread of the novel coronavirus and COVID-19.

However, NASA said it could not ensure its employees and contractors could safely and effectively work under current social distancing protocols, which prohibit many people gathering in a tight place. Based on that assessment, NASA curtailed work on JWST on March 20.

"For most of the missions, there is nobody working hands-on anymore at NASA facilities," says NASA chief scientist Thomas Zurbuchen.

PACIFIC PIVOT



The Marines propose deactivating a CH-53 unit.

> U.S. MARINE CORPS TO DOUBLE UAS SQUADRONS

> MASSIVE ARTILLERY INCREASE PLANNED

Lee Hudson Washington

The U.S. Marine Corps is proposing sweeping changes to its force design with a single-minded focus—the Pacific—that may have major implications for the aircraft it will purchase in the next decade.

Eight months after Marine Corps Commandant Gen. David Berger issued planning guidance revealing force design as his top priority, the service released details about the future force.

"I have already initiated, and am personally leading, a future-force design effort," Berger writes. "We will divest of legacy defense programs and force structure that support legacy capabilities."

The central theme of his planning guidance is that the Marine Corps must be organized, trained and equipped for a high-end fight with China set at sea. This means a complete deemphasis of the types of counterterrorism missions the Corps has specialized in over the past two decades.

Going forward, the service should not focus on forcible entry. Instead, the Marine Corps will pivot and focus on distributed operations, where small groups of Marines fight independently and employ advanced technologies such as the Lockheed Martin F-35B, unmanned systems and long-range precision fires. Berger's plan also calls for developing the ability to "dominate inside the enemy's weapon engagement zone." To get within that engagement zone, China's "bubble of air, missile and naval power," the Marines will have to develop "low-signature, affordable, and risk-worthy platforms," writes Mark Cancian, senior advisor with the Center for Strategic and International Studies International Security Program.

The modernized design is envisioned to optimize the Marine Corps for the National Defense Strategy and will require significant changes over the next 10 years. The service proposes a 7% reduction in total force structure, roughly 12,000 personnel.

Specifically, for aviation, the service recommends deactivating Marine Medium Tiltrotor Sqdn. (VMM) 264, Marine Heavy Helicopter Sqdn. (HMH) 462, Marine Light-Attack Helicopter Sqdns. (HMLA) 469 and 367, and Marine Wing Support Groups (MWSG) 27 and 37.

Those changes in force structure also include major revisions to the Marines' previous plans to develop and procure aviation and missile systems.

A Reduction in F-35 Squadron Size

2019 Marine Corps Aviation Plan

9 Squadrons of **16** F-35Bs
5 Squadrons of **10** F-35Bs
4 Squadrons of **10** F-35Cs

2020 Proposal

Reducing the maximum number of F-35B and C aircraft per squadron to **10**

U.S. MARINE CORPS PHOTOS

CH-53K

Deactivating HMH-462 may have significant consequences for the Sikorsky CH-53K King Stallion. "I think they're going to cut about one-third of the [CH-53K] buy," Cancian tells Aviation Week. Cancian served in the Marine Corps more than 30 years and has worked on force structure and acquisition issues in the Office of the Secretary of Defense and at the Office of Management and Budget.

"We suppose that implies 12 fewer CH-53Ks, though the program has not yet hit production, and a total of 196 are planned," says Byron Callan, managing director of Capital Alpha Partners.

If the commandant's plan becomes reality, the CH-53K will most likely trigger a congressional warning of a cost overrun for a major acquisition program, known as a Nunn-McCurdy breach. That occurs when the procurement unit cost increases 15% or more over the current baseline estimate, or 30%

U.S. NAVY

or more over the original baseline estimate.

"If the program weren't as far along as it is, I think this would also be up for cancellation. But I think it's probably just far enough," Cancian says.

The CH-53K is designed to: transport weapons, equipment, supplies and personnel; support forward arming and refueling points and rapid ground refueling; provide assault support in evacuation and maritime special operations; and offer casualty evacuation and recovery of downed aircraft and airborne control for assault support.

Development began in 2006, with initial operational capability (IOC) planned for 2015. The annual Marine Corps Aviation Plan delays IOC for seven years because the program has encountered many developmental hurdles. The three-engine design created several integration issues such as exhaust gas reingestion (EGR). EGR occurs when the hot engine gases are ingested back into the system, which can cause increased life-cycle costs, engine overheating and stalls, according to Debbie Cleavenger, chief engineer for the heavy-lift helicopter program office.

The heavy-lift helicopter is powered by three 7,500-shp General Electric T708 turboshafts. In late 2018, it was revealed that EGR into the No. 2 and No. 3 engines posed a significant challenge for the program and forced a restructuring. However, Sikorsky and Naval Air Systems Command modeled the EGR problem and redesigned flight components. Test results show all the issues were successfully addressed.

U.S. NAVY PHOTO

Deactivating Units

The Marine Corps is recommending the deactivation of three aviation units:

Tiltrotor Sqdn. 264
12 MV-22s

Light Attack Sqdn. 469
15 AH-1Z / 12 UH-1Ys

Heavy Helicopter Sqdn. 462
12 CH-53Es

U.S. MARINE CORPS PHOTOS

F-35

The Marine Corps proposes reducing the maximum number of Lockheed Martin F-35 Joint Strike Fighters in a given squadron from what it had planned a year ago. The 2019 Marine Corps Aviation Plan called for nine squadrons to each receive 16 F-35B short-takeoff-and-vertical-landing variants, five squadrons to each receive 10 F-35Bs and four squadrons to each receive 10 F-35Cs.

The new plan, prompted in part by a perceived pilot shortage, drops the maximum number of aircraft for any one squadron to 10. "[The reduction] comes out to about 45 in the squadrons and probably another 15 or so in overhead—I would guess a total of 60 fewer F-35s," Cancian says.

Callan says he does not expect a reduction in the planned purchase of F-35s to occur until after fiscal 2026-27.

And for now, Berger says the Marines are not planning to buy fewer of the fifth-generation fighters. "Right now, I'm not changing the program of record," Berger says. "But I am signaling to industry we have to be prepared to adjust."

V-22/AH-1Z

The Marines Corps has finished its buy of both the Bell-Boeing MV-22B Osprey and Bell AH-1Z Viper. Since the service is proposing to deactivate squadrons that operate these aircraft, Cancian says it could use the additional aircraft for overhead and attrition. For example, the Marines are still using MV-22As for V-22 training and could potentially replace those with the B model, he says. The service could also opt to use the surplus Vipers to replace damaged aircraft.

GROWTH OPPORTUNITIES

The proposed future-force design is not all doom and gloom for industry. Over the next 10 years, the Marine Corps intends to make investments in long-range precision fires, advanced reconnaissance capabilities, unmanned systems and resilient networks. "Future budget requests will include an expanded list of viable unmanned capabilities that will create significant opportunity for industries across the country," the service says.

For instance, the Marine Corps anticipates a 300% increase in rocket artillery capacity, doubling the number of unmanned aircraft system (UAS) squadrons, a new light amphibious warship and new mobile air defense and counterprecision guided missile systems. Some of the advanced technologies being considered are directed-energy systems, loitering munitions, signature management, electronic warfare and expeditionary airfield capabilities to support manned and unmanned aircraft.

The Navy is conducting market research to gauge industry interest in adapting a commercial ship design for a light amphibious warship in fiscal 2022-23. The new ship would operate in small, undeveloped ports and beaches, and secondary missions may include force sustainment and reconnaissance. The program executive office for ships plans to host two industry days for a more comprehensive discussion on the platform concept, capabilities and additional design methodology.

Cancian predicts the Corps will add three armed UAS squadrons. It is unclear what UAS the service will select, especially since it opted not to pursue a shipboard Group 5 UAS as part of the Marine Air-Ground Task Force UAS Expeditionary (MUX) program. "They could have bought Reapers if they really wanted to get the capability out there quickly," he says.

The Marines operate General Atomics MQ-9 Reapers from MCAS Yuma in Arizona to support Task Force Southwest in Afghanistan. The capability is intended to inform concepts of operations for MUX and is allowing the service to nurture its own cadre of UAS operators, according to Lt. Gen. Steven Rudder, deputy commandant for aviation.

"With a family-of-systems approach, my sense is we're going to have an air vehicle that can do some of the higher-end requirements from a land-based, high-endurance vehicle, but we're still going to maintain a shipboard capability. It may just not be as big as we originally configured," says Rudder.

Army Aims High

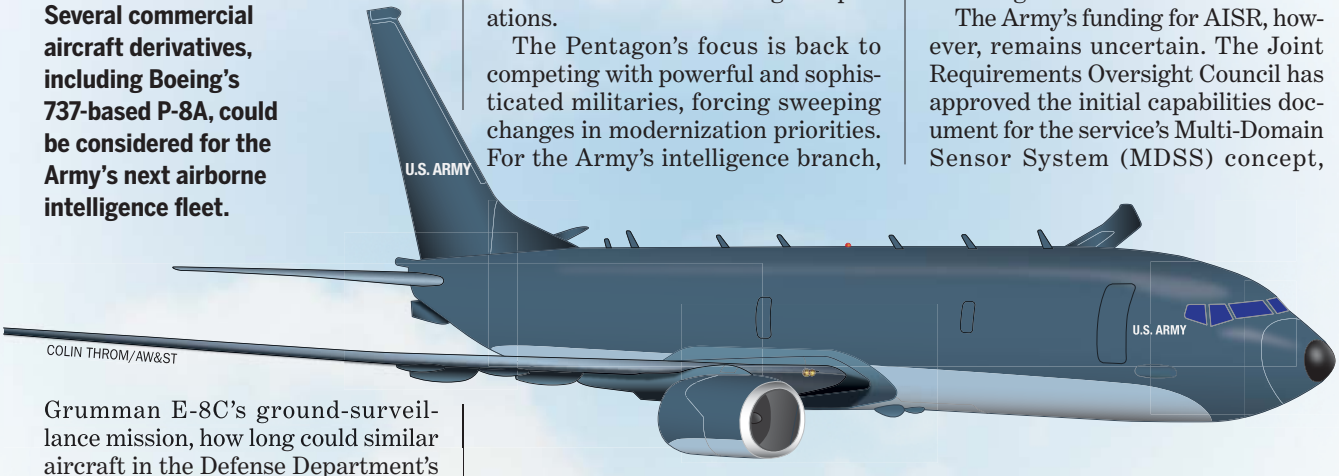
> THE SERVICE PLANS A SENSOR FLY-OFF IN 2021

> MODIFIED COMMERCIAL DERIVATIVES ARE BEING CONSIDERED

Steve Trimble Washington

Awkward questions arose two years ago when the U.S. Air Force chose to cancel the $6.9 billion J-Stars Recap program—while citing the Joint Stars fleet's vulnerability to projected advances in adversary air defense technology after 2025.

After all, if the Air Force doubted the ability of a commercial aircraft derivative to perform the Northrop Grumman E-8C's ground-surveillance mission, how long could similar aircraft in the Defense Department's fleet—such as the Navy's Boeing 737-derived P-8A or the Air Force's own Boeing RC-135—expect to continue operating with a reasonable chance of survival?



Several commercial aircraft derivatives, including Boeing's 737-based P-8A, could be considered for the Army's next airborne intelligence fleet.

A new program emerging within the Army's airborne intelligence branch raises the question again. If the Army's program proceeds as planned, a small fleet of fewer than 10 large derivatives of a commercial aircraft—potentially, a P-8, Gulfstream G550-derived C-37 or Bombardier Global 6000-based E-11—could be fielded by around fiscal 2028, performing a mission that combines many of the capabilities of the E-8C J-Stars and signals-intelligence-gathering RC-135 Rivet Joint.

The program revives and expands the concept for the Aerial Common Sensor (ACS), which attempted to package an advanced, multi-intelligence-gathering payload integrated by Lockheed Martin onto the Embraer 145 regional jet. But the sensor package proved to be more than 40% heavier than the payload limit of the ERJ-145, which forced the Army to cancel the $879 million engineering and manufacturing development program for the ACS in January 2006. Over the next decade, the Army's priorities for the fixed-wing intelligence fleet shifted to supporting counterterrorist and counterinsurgent operations.

The Pentagon's focus is back to competing with powerful and sophisticated militaries, forcing sweeping changes in modernization priorities. For the Army's intelligence branch, the technology priority has shifted from technology that can identify radio-frequency triggers for improvised explosive devices to electronic receivers that can eavesdrop on communications between an adversary's headquarters and field units, along with long-range radars that can detect mobile, high-value targets for a new class of surface-to-surface missiles with ranges far beyond the Army's current 185-mi. limit.

"As we started to pivot to that peer-to-peer threat, we realized that our ability to stand off and see deep was very limited," says Christian Keller, the Army's project director for sensors-aerial intelligence.

Last year, the Army quietly started searching for a new intelligence-gathering Aerial Intelligence, Surveillance and Reconnaissance (AISR) aircraft, which would be equipped with a new High-Accuracy Detection Exploitation System (HADES).

The Army wants a "business-jet-class" aircraft that can reach at least 41,000 ft., or 64% above the service ceiling of the de Havilland Dash 8-Q315 EO-5C Airborne Reconnaissance Low-Multifunction (ARL-M), which replaces the Dash 7-derived EO-5 fleet starting this year.

"[The Army is] looking at several different platforms," says Keller. "There are some efforts to look at [aircraft] the other services have that we'd be able to take and use as-is or with modifications to include our own sensor capabilities, or potentially a new platform altogether."

Asked if the P-8 or C-37 aircraft represent the performance the Army seeks for AISR, Keller replied: "You're in the right area."

The Army's funding for AISR, however, remains uncertain. The Joint Requirements Oversight Council has approved the initial capabilities document for the service's Multi-Domain Sensor System (MDSS) concept, which includes the AISR fleet as the most near-term priority. Follow-on plans include an Army-operated satellite constellation in low Earth orbit and stratospheric airships. So far, the Army has requested only about $50 million in the fiscal 2021 budget for the MDSS, requiring significant new investment in the service's fiscal 2022 spending request.

"It is a significant amount of money," says Keller. "From the perspective of [the intelligence branch] and the Army leadership, they look at this as a game changer and as something that could really enable us."

The newly developed HADES payload would provide many of the same onboard capabilities, but from a higher vantage point, extending the range of the Army's most sophisticated electronic eavesdropping equipment, along with a synthetic aperture radar

(SAR) that can track moving targets on the ground.

As planned, the Army's future AISR aircraft will match the performance of the Air Force's RC-135 and retiring E-8C but with a payload that performs the functions of both.

China and Russia have displayed anti-radiation missiles with ultra-long range, presenting a perfect weapon against a derivative of a commercial airliner or business jet with a radiating sensor. Despite the rising threat, the Army is not particularly worried about the relevance or survivability of such an aircraft.

A critical factor in the Air Force's decision to cancel the J-Stars Recap involved the range of the sensor. The APY-7 radar on the E-8C has a listed range of more than 96 mi. Russia advertizes the 40N6 interceptor in the S-400 air defense system, which has been exported to China, with a 400-km (250-mi.) range. If an aircraft such as the E-8C must be stationed beyond the range of the 40N6 or the 40N6e export version, the APY-7 radar would be unable to see into enemy territory.

Army officials recognize the problem but suggest there are workarounds, even for a nonstealthy, radiating aircraft.

"I could also see a case where you might be deploying other capabilities of a platform like this, such as air-launched effects and things of that nature," says Keller.

Air-launched effects (ALE) refers to a broad range of systems in development. Recoverable ALEs are essentially air-launched unmanned aircraft systems. Disposable ALEs represent munitions or nonkinetic systems such as decoys and jammers. If deployable ALEs become part of the AISR requirement, the manned aircraft could act as a mothership and preserve a capability to operate in the presence of long-range anti-radiation missiles.

"When the risk is high, they're probably going to fly this thing in a way where it's going to maintain a safe distance and still be able to do its job," says Keller.

The high-altitude AISR also is expected to perform other roles. Along with the smaller, King Air-derived RC-12, the EO-5 fleet maintains a vigilant presence on the Korean Peninsula, for example. The aircraft perform routine patrols, developing an electronic "pattern of life" of North Korean military emitters such as radars, communications systems and jammers.

"I see the [AISR] very much doing the same thing but on a more capable platform, with more capable sensors and flying higher and looking deeper," says Keller.

Responsibility for the AISR acquisition is divided within the Army acquisition system. The program executive officer for aviation is responsible for acquiring the aircraft, a process that will begin in fiscal 2022 or 2023. Keller's office is directing the acquisition process for HADES, the sensor payload. A fly-off to compare the capabilities of the companies seeking to supply the HADES package is scheduled for next year.

"From there we're going to select a set of sensors and be able to have that ready for whenever we do have a platform in place," Keller says.

As the acquisition unfolds, the Army is seeking to avoid the same errors that doomed the ACS program 14 years ago. The two key lessons it has drawn from the ACS experience are to be careful about how much authority to give the contractor over the aircraft and sensor integration process, and to select an aircraft with plenty of spare capacity.

"We gave the contractor full authority to pick the airframe and all the sensors," says Keller. "We had issues—a lot of it was [size, weight, power and cooling]. And then when we tried to make some adjustments on the [concept of operations], we didn't get a lot of support [from the contractor]. So we learned a lot of hard lessons that way. Those lessons were not lost on the Army, and [we're] making sure we pick a platform that has margin and the ability to grow."

The U.S. Army's focus on intelligence-gathering aircraft has shifted to sophisticated threats, marking a change from a decade of investment in low-end capabilities such as the RC-12 (pictured).

JOHN HIGGINS/U.S. AIR FORCE

GA-ASI Adapts Gray Eagle for FVL Future

> NEW SENSORS, STORES SET FOR JUNE DEMO

> ARMY'S AUAS REQUIREMENT REMAINS UNDEFINED

U.S. ARMY

The MQ-1C's mission is shifting from supporting counter-insurgent operations to filling a potentially critical role in the U.S. Army's emerging strategy for more sophisticated adversaries.

Steve Trimble Washington

As the U.S. Army quietly considers options for the Advanced Unmanned Aircraft Systems, General Atomics Aeronautical Systems Inc. (GA-ASI) is staging a series of demonstrations to prove the MQ-1C Extended-Range (ER) UAS is up to the task, with a few upgrades and perhaps additional production.

Public attention has focused on two intense competitions now underway by the Army's aviation branch: the Future Long-Range Assault Aircraft (FLRAA) and the Future Attack Reconnaissance Aircraft (FARA). But the Army's original plans for the Future Vertical Lift family of systems included a third acquisition program: the Advanced Unmanned Aircraft Systems (AUAS). Unlike the rapidly moving FLRAA and FARA programs, however, the Army has said little about the next steps for AUAS since completing a concept design phase in early 2019.

Meanwhile, GA-ASI's strategy is focused on proving the MQ-1C ER, also known as the Gray Eagle, as the Army's AUAS.

Since November, the Poway, California-based company has staged two demonstrations funded by internal research and development (IRAD) accounts of the MQ-1C ER. A third and final demonstration is planned in June.

"We took it upon ourselves on IRAD," says Chris Pehrson, vice president of strategic development.

GA-ASI designed the MQ-1C about 15 years ago to meet the Army's requirements for an extended-range/multi-purpose (ER/MP) UAS. The ER/MP profile called for the MQ-1C to operate as a standalone system, one capable of sensing targets at a short range in any weather—using either a Northrop Grumman StarLite synthetic aperture radar (SAR) and an electro-optical/infrared payload—and carrying up to four AGM-114 Hellfire missiles. The aircraft is controlled from a mobile, ground-control station contained in a shelter.

But the Army's requirements for a medium-altitude, Group 4 UAS are evolving. The AUAS requirements outlined in the concept design stage call for an aircraft that can sense dozens of kilometers beyond the limit of the current radar, as well as new payloads capable of identifying a more sophisticated military adversary. The Army also wants a UAS that can employ a more diverse set of effects than an AGM-114, including nonkinetic options and even recoverable systems.

In November, GA-ASI's first demonstration showed how the Army could in the future operate the MQ-1C from a laptop computer instead of a cumbersome, shelter-based ground control station. GA-ASI also integrated the Lynx Block 30A SAR with a ground-moving-target indicator mode, which is capable of detecting targets at up to 47 mi. (75 km). Such distances are well beyond the range of any onboard AGM-114 missiles, but the MQ-1C now could be used to cue the Army's surface-to-surface missile batteries, such as the Guided Multiple Launch Rocket System or Advanced Tactical Missile System.

The second demonstration in January added more capabilities, including the L3Harris Rio Nino lightweight communications-intelligence payload. The Rio's antennas are described as capable of detecting emitters such as a modern adversary's command-and-control links at ranges up to 155 mi., vastly extending the reach of the Army's medium-altitude UAS fleet.

The demonstration also hinted about future weapon stores. The aircraft carried two Area-I Altius-600s, which belong to an emerging class of UAS called Air-Launched Effects (ALE). These stores are designed to perform a range of functions. Some are launched only to gather intelligence. Other ALEs carry sensors and explosives, creating a new class of air-launched loitering munitions.

The MQ-1C will launch the ALEs for the first time during a third demonstration scheduled in June in Arizona, which so far has not been postponed due to the outbreak of the novel coronavirus and COVID-19.

"The threats the Army is thinking about with Gray Eagle are the more tactical-range [surface-to-air missile systems]," Pehrson says. "The Gray Eagle, even equipped for [the future], is not going to be a penetrating platform. What the Gray Eagle will survive on is standoff distance and awareness of threats."

KF-X Radar Prototype Nears Ground Testing

- ADD-HANHWA AND LIG NEX1 SENSORS BOTH USE GALLIUM NITRIDE
- ELTA HAS SUPPORTED WORK ON KF-X RADAR DEVELOPMENT

Kim Minseok Seoul and **Bradley Perrett** Beijing

Radar development for the Korea Aerospace Industries (KAI) KF-X fighter is moving toward production of a prototype, following evaluation of a technology demonstrator in Israel and South Korea. The program, led by the government's Agency for Defense Development (ADD), is planning to ground-test the production-representative prototype by the end of May, manufacturing subcontractor Hanwha says.

The company that Hanwha beat to the contract, LIG Nex1, this year is beginning a fourth phase in its effort to privately develop an advanced fighter radar, aiming at reducing the size of transmission and reception units.

Development of the KF-X radar is 50% complete, Hanwha researcher Hong Yoon-Sung told the *Chosun Ilbo* newspaper, adding that the prototype would be tested within months.

A prototype radar is due to be fitted in a KF-X for flight tests in 2023. Development is scheduled for completion in 2026, the year in which deliveries of the fighter are supposed to begin. Software for air-to-air and air-to-surface modes is due to be developed by October 2021.

The design includes an active, electronically scanned array (AESA) and, according to a government research institute statement in 2014, gallium-nitride components. In several countries, the latter are superseding gallium-arsenide technology—formerly the standard for AESAs. The demonstrator also uses gallium-nitride technology, according to the South Korean news outlet Today Defense.

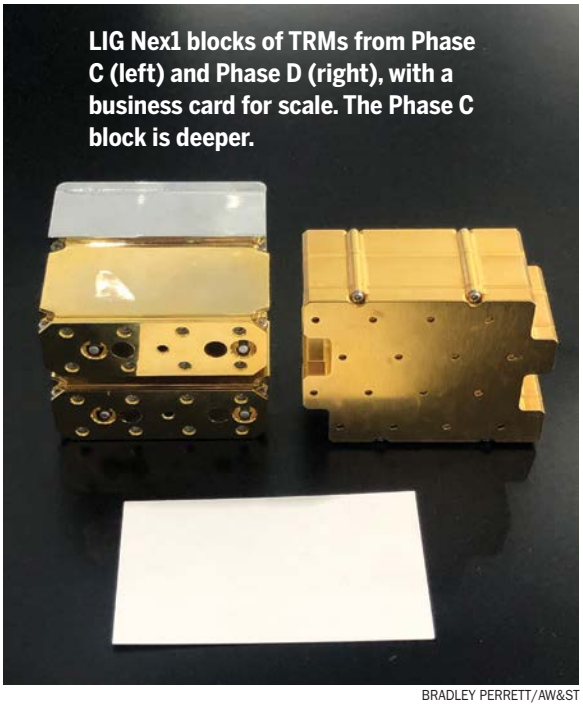
Cooling power provided to the demonstrator radar is 7.7 kW, Hanwha says. Analyzing the gallium-arsenide Northrop Grumman APG-83 radar, Hellenic Air Force researchers last year worked on the basis of 5.6 kW cooling and found an average antenna output of up to 1 kW. So the South Korean demonstrator should exceed that figure.

Hanwha said in November that evaluation of the demonstrator hardware had been completed. The demonstrator radar was installed in an Elta Systems-owned Boeing 737 testbed and flew 10 times in Israel and six times in South Korea, the ADD said in October. The demonstrator includes an antenna and software from the ADD and Hanwha and signal processors and software from Elta.

But South Korean officials and industry leaders have a strong tendency to play up the role of indigenous engineering work. It would not be surprising, therefore, if Elta helped in design or at least refinement of the demonstrator. Similarly, the Israeli company may be quietly helping, or standing by to help, with development of the production sensor.

In December, the ADD announced a contract with Hanwha to add the terrain-following function. Pictures and models of the KF-X have previously shown it with a navigation pod, like the U.S. AAQ-13, implying that the radar lacked terrain-following, which is used for low-altitude flight.

A video presentation made by Hanwha shows the demonstrator radar was tested in three air-to-air modes: all-aspect search and track, nose aspect search and track and air combat maneuvering. The tested air-to-surface modes were stationary and moving-target indication, synthetic aperture, ranging and air-to-sea.



LIG Nex1 blocks of TRMs from Phase C (left) and Phase D (right), with a business card for scale. The Phase C block is deeper.

BRADLEY PERRETT/AW&ST

As for the LIG Nex1 private effort, building of a complete radar and flight-testing it is planned for 2023, a source close to the program says. The transmission frequency is in the X band.

Saab has provided advice to LIG Nex1 on this program, especially in regard to testing, says the source. The South Korean company is designing all the hardware.

LIG Nex1 began work on AESA radars with what it calls Phase A in 2007-10. At that time and in Phase B, in 2011-13, it used gallium arsenide. For Phase C, in 2014-19, it moved to gallium nitride, which, the source says, provided 10 times as much power from each transmit-receive module (TRM). A Phase C radar was tested in the air, mounted on the cargo door of a Lockheed Martin C-130H Hercules.

The key objective of Phase D is reducing antenna depth. The array is composed of blocks that each contain 16 TRMs, which are externally visible as little holes. If the blocks can be shallower, the array they form will be farther from the nose. Since the radome tapers, the array can be larger.

The benefit of this is greater than it may seem. In a representative aircraft design, there will be space for a 750-mm-dia. (29.5-in.) Phase D antenna instead of the 700 mm possible for the Phase C array, says the source. Area and therefore power can be 15% greater, at least in principle.

In practice, LIG Nex1 expects to fit an antenna of about 1,100 Phase D TRMs in the larger space, compared with about 1,000 for Phase C, so the increase is 10%.

LIG Nex1 exhibited TRMs from all four phases at the Seoul Aerospace and Defense Exhibition held in October 2019. It also showed a mockup of a complete radar, but the exhibit provided little information.

Tempest Accelerates Toward End-of-Year Decision Milestone

> INDUSTRY REMAINS OPTIMISTIC ABOUT POTENTIAL JAPANESE PARTNERSHIP

> ITALY-SWEDEN JOINT STUDIES FEEDING INTO UK BUSINESS CASE

Tony Osborne London

BAE SYSTEMS CONCEPT. BACKGROUND: SHUTTERSTOCK

Toward year-end, British procurement officials will submit their first business case for pursuing development of a next-generation combat aircraft.

The process will be the first major milestone for the UK's accelerating Combat Air Strategy and the Team Tempest industry consortium supporting the UK's Future Combat Air System Technology Initiative (FCAS TI).

It has been almost two years since the UK formally announced it was embarking on FCAS TI, developing the processes, technology and experience necessary to take the lead on the development of a next-generation combat aircraft.

The government has invested close to £2 billion ($2.5 billion) for the FCAS TI, with industry—including BAE Systems, Leonardo, MBDA and Rolls-Royce—also making sizable but as yet undisclosed investments to support it through the Team Tempest consortium.

"The idea of bringing a system into service by 2035 is a challenging task," Andrew Kennedy, BAE's Tempest strategic campaigns director, tells Aviation Week. "If you look back at recent programs and the type of capabilities we are looking at, you are looking at a pretty racy program. . . . So what we need to do within the Tempest activity is give [ourselves] confidence and give the government confidence that we can deliver on those promises."

The promises are a challenge. They call for development of an advanced next-generation combat aircraft that is easily upgradable and programmable and that can be delivered in half the time it took to bring the Eurofighter Typhoon to the front line. Several elements of the work to support the Tempest have been disclosed in recent months. Leonardo revealed work on miniaturized radar warning receiver technology, while Rolls-Royce has been progressing in its work on embedded electrical starter generators.

Hurdles remain, however.

The UK may be busy battling the novel coronavirus that causes COVID-19, but it is also ploughing through an integrated review of its defense capabilities, with a particular focus on the UK's oft-criticized defense procurement process (*AW&ST* March 23-April 5, p. 46).

Nonetheless, the view from industry is that the Tempest will be viewed favorably as a wider national effort that could have spillover benefits for other sectors. The work has already created 1,000 full-time jobs across industry and government. This will grow to around 1,400 jobs by year-end and 2,500 in 2021. And exports could help underpin London's diplomatic efforts, particularly in the post-Brexit world.

"We need to talk about the value of the Combat Air as opposed to the cost of Combat Air," Kennedy says. "The Combat Air Strategy outlined very clearly at the time that Combat Air is a critical national asset."

That is not just a reference to the Royal Air Force (RAF), he suggests, but to the wider industrial enterprise that "underpins the ability for the RAF to have the kind of freedom of action [and] operational advantage that it requires."

The UK's Tempest technology and innovation work will expand during 2020 and 2021.

A key part of bringing the platform to the fore in 2035 will be international partnerships. The UK has already secured a 10-year memorandum of understanding from Sweden and a statement of intent agreement with Italy, signed in July and September, respectively. Both accords involve looking at how the nations can best collaborate and how the information obtained from ongoing studies will "inform the business case," Kennedy notes.

The aim of the studies is to align not only on military requirements but also on industrial expectations, timelines and cost. The countries are also discussing the industrial model for the Tempest. Kennedy says it is possible the model adopted could be completely different from that used by aerospace or defense in the past.

"What we are trying to do is find a model that is optimized for delivery. . . . I can't go into the details of what it is that we're looking at, but what we're focused on is the end-goal as opposed to anything else," he says.

Procurement officials are looking at the F-35 development model, with the UK as a "controlling mind." But some have suggested this may be too autocratic. Another option could be the so-called "best athlete" approach, whereby each nation brings its best capabilities to the table, such as Sweden's rapid-development capabilities or Italy's experience in electronic warfare.

Work to bring Japan onboard is also proceeding despite media reports suggesting Tokyo is instead looking at working with the U.S. on its JF-X program to replace the Mitsubishi F-2.

Kennedy says the Team Tempest partners "continue to work and support the UK government in discussions with the Japanese to consider more deeply how the two nations can collaborate on the combined combat air requirements."

The business case will decide whether the Tempest concepts will be mature enough to begin the traditional development cycle. If approved, the project will move from the current concept into an assessment phase, with a corresponding lofty increase in spending.

SIKORSKY

Raider-X's rigid coaxial rotors provide speed and agility.

Risk and Reward

- BELL 360 INVICTUS DRAWS ON COMMERCIAL MODEL 525
- SIKORSKY'S RAIDER-X DEVELOPED FROM S-97 PROTOTYPE

Graham Warwick and **Lee Hudson** Washington

The U.S. Army has bracketed its chances of successfully developing a new armed scout rotorcraft by selecting both conventional and unconventional designs for two competing prototypes of its Future Attack Reconnaissance Aircraft (FARA).

Bell and Lockheed Martin company Sikorsky have moved into Phase 2 of the FARA Competitive Prototype program, with the Army terminating "other transaction for prototype" agreements with AVX Aircraft, Boeing and Karem Aircraft, which lost.

The decision pits the most conventional option, the Bell 360 Invictus winged helicopter, against Sikorsky's unconventional Raider-X compound helicopter in a schedule-driven contest to replace Boeing AH-64Es used in the armed reconnaissance role. The first unit is to be equipped in fiscal 2030.

"We could not have asked for more," says Dan Bailey, FARA program manager. "All five of the vendors brought different configurations. And the beauty going forward is we have two different configurations continuing in the program."

Few mandatory requirements have been set for FARA, but they include a maximum cruise speed of at least 180 kt. and a rotor diameter of no more than 40 ft. to enable the aircraft to fly between buildings in urban combat.

The Raider-X has side-by-side seating, rigid coaxial rotors, tail-mounted propulsor and a single 3,000-shp General Electric T901 engine. Sikorsky's S-97 Raider demonstrator has reached 207 kt. in flight testing.

The Invictus has tandem seating, a single main rotor and a ducted, canted tail rotor. To meet the 180-kt. requirement, the Bell design has a wing to offload the rotor and a supplemental power unit to augment the single T901.

"Both performers we are taking into Phase 2 provide leap-ahead capabilities . . . in speed, range and endurance at range—that combination which gives us superior lethality and survivability over our current fleet," says Brig. Gen. Walter Rugen, director of the Future Vertical Lift (FVL) Cross-Functional Team.

The Bell and Sikorsky proposals were deemed "most advantageous overall," says Bailey. This was judged on three criteria: how well they met the mandatory attributes, maturity of their designs, and their ability not only to meet the Army's schedule and "execute the Competitive Prototype program, but move into a final integration qualification phase and into production."

AVX with L3Harris Technologies and Karem with Northrop Grumman and Raytheon had strong teams, but as small companies they were always outsiders. Boeing offered an all-new winged compound that likely was judged higher-risk. Bell drew on its 525 commercial helicopter and Sikorsky on its S-97 prototype.

Rugen calls out Bell's low-drag design and says the Raider "continues to impress" in flight tests. "It presents us with a great problem to have because we have two great competitors on a program that we must deliver for the Army. Our No. 1 gap is our future scout aircraft," he says.

The Army has set aside $750 million for each prototype, $15 million of which was spent on Phase 1 initial design, and manufacturers are contributing their own funds, says Bailey. The next major decision point is the final design review, planned for December, when the Army will again assess whether the competitors are meeting the requirement and if there is a "risk of not meeting our schedule," he says.

Ground-testing of the prototypes is planned to start in 2022, with first flights targeted for November 2022. In the fourth quarter of fiscal 2023, flight-testing will move from the contractors' sites to Redstone Arsenal in Alabama for a final flyoff evaluation using government-only crews.

The Army, meanwhile, will mature the FARA requirements through a series of gates leading to a weapon system preliminary design review and competitive downselect from two to one in late 2023, enabling a program of record to start in the first quarter of 2024.

BELL

The wing and second engine are key to Invictus' speed capability.

"This is the beauty and benefit of the prototyping design of this program," says Pat Mason, program executive officer for aviation. "We will get to see both vendors go to their final designs and build their prototype air vehicles as we simultaneously carry forward the integrated mission systems and other elements of the FVL ecosystem. That will give us a clear indication on the technology, maturity and the ability of the prototype aircraft to meet the requirements."

While configuration was not an explicit part of the evaluation, the downselect gives the Army disparate options. "We didn't even tell them if it was a side-by-side or a tandem cockpit. . . . So it really was a holistic look at the overall aircraft," Bailey says. "The beauty will be that, in the fiscal 2023 time frame, we will have two aircraft flying that bring different unique aspects to the solution and allow the warfighter to make the best decision."

Finishing Touch

> FIRST MISSION FOR U.S. SPACE FORCE

> LAUNCH TEAM EMBRACED SOCIAL DISTANCING

Lee Hudson Washington and **Irene Klotz** Cape Canaveral

While thousands of U.S. companies and agencies shut down to help stem the spread of the COVID-19 coronavirus, the 45th Space Wing at Cape Canaveral AFS, Florida, and United Launch Alliance launched the sixth and final member of a satellite constellation that is designed to provide secure, jam-proof communications services for President Donald Trump, U.S. armed forces and allies worldwide.

The Advanced Extremely High Frequency (AEHF) network follows the five-member Military Strategic and Tactical Relay (Milstar) Block II satellites, launched 1994-2003. Both networks provide national security leaders with assured, survivable communications services that are difficult for adversaries to detect or intercept.

With 10 times the throughput of the heritage Milstar system, the new network will, for example, be able to support recognizable voice communications, says Lt. Col. Paul La Tour, AEHF space segment material leader.

Imagine a post-nuclear environment in which the U.S. president could communicate but the voice would not be recognizable, La Tour said during a March 24 prelaunch press conference.

Milstar technology of the 1990s could support only low data rates, which distorted voice quality. AEHF incorporates Milstar's low and medium data rates—from 75-2,400 bps and 4.8 kbps-1.544 Mbps, respectively—and adds a new signal capable of supporting 8.192 Mbps. The data rates are slow by terrestrial standards but include the ability to resist jamming and continue operating even after a nuclear war.

The AEHF satellites are cross-linked so they can transmit signals around the world without sending data down to a ground station. They include gimbaled-dish antennas to reach mobile users, frequency-hopping radio technology and phased-array antennas that use software to adapt transmission patterns to block potential jamming signals.

The Air Force purchased the last two AEHF satellites, AEHF-5 and -6, under a firm, fixed-price contract for $2.15 billion for both spacecraft—more than 40% less than the predecessor AEHF satellites. The cost does not include launch services.

"The Pentagon was able to achieve more than 40% cost savings over previous AEHF contracts by purchasing AEHF-5 and -6 in a block buy," says Mike Cacheiro, AEHF program manager at Lockheed Martin, which built the satellites.

AEHF-6 was delivered into a geostationary transfer orbit by a United Launch Alliance (ULA) Atlas V rocket, which lifted off from Cape Canaveral AFS on March 26. The launch was the first payload for the newly created U.S. Space Force, though the base's official renaming was postponed due to work and travel restrictions stemming from the COVID-19 pandemic.

Once AEHF-6 reaches its operational orbit 22,000 mi. (35,400 km) above the equator and passes initial tests, it will join a constellation to support secure communications for the U.S. Army, Navy, Air Force and national security agencies as well as international partners Australia, Canada, the Netherlands and the UK. The constellation is designed to operate well into the 2030s.

The launch was the first of nine planned U.S. Space Force missions this year. The missions remain a top priority for the military amid base shutdowns, travel disruptions and mandatory telework orders implemented in March to minimize the spread of the novel coronavirus.

"We are continuing with the secretary of defense's priorities of taking care of our military members and their families; second, continuing the mission; and third, supporting the whole-of-government effort for the situation," said Brig. Gen. Douglas Schiess, commander of the 45th Space Wing and director of the Eastern Range at Patrick AFB, Florida.

For the AEHF-6 launch, the 45th Space Wing and ULA cut about 25% of their launch teams and implemented COVID-19 social-distancing protocol by spacing apart workers' consoles and isolating teams. "For example, the crew working the AEHF launch and the next crew working a different launch—we're keeping those two crews separated . . . so they're not in the same facility at the same time," Schiess says.

Schiess also barred trainees and observers from mission control centers and closed the base from public launch viewing.

The next National Security Space mission is a GPS-3 satellite, which is scheduled to launch onboard a SpaceX Falcon 9 rocket on April 29.

ULA

A United Launch Alliance Atlas V lifted off with the AEHF-6 satellite from Cape Canaveral on March 26.

20 TWENTIES

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Hydrogen In, Carbon Out

- EUROPEAN REPORT SEES ROLE FOR CLEAN HYDROGEN IN AVIATION
- SIGNIFICANT BARRIERS REMAIN

H2Fly's four-seat Hy4 is planned to fly using hydrogen fuel cells in 2020 under Europe's Mahepa project.

Graham Warwick Washington

ONE IN A SERIES

Periodically, hydrogen rises to the surface as a way to reduce aviation emissions only to sink under the weight of challenges in using the high-energy, but low-density, fuel in aircraft. Interest in hydrogen is enjoying a resurgence, though, as part of wider efforts to combat climate change.

That renewed interest is strongest in Europe, where on March 10 the European Commission announced plans to launch a Clean Hydrogen Alliance as the centerpiece of a new strategy to accelerate both the decarbonization and digitalization of the region's industries.

The alliance is intended to bring investors together with governmental, institutional and industrial partners to foster the use of clean hydrogen both as an energy carrier and directly to reduce emissions from industrial processes such as steel production.

While aviation was not specifically called out at the high-level launch of Europe's new industrial strategy, the promise of widely available clean hydrogen is turning the heat up under the resurgent interest in its use as a low-emission renewable fuel for aviation.

Alongside sustainable fuels and electric propulsion, hydrogen has a role in helping aviation address emissions challenges, and industry should allocate resources to exploring its potential, concludes a report by European consultancy Roland Berger.

While it promises benefits, hydrogen propulsion presents significant challenges, the report says, but with other transportation and industrial sectors making increasing use of the technology for power trains and energy storage, aerospace could benefit from a rapidly growing supply chain.

Roland Berger identifies sustainability options for aviation that range from "net-zero" to "true zero" emissions. Carbon offsetting and sustainable aviation fuels offer a path to net-zero carbon emissions, while hybrid-electric aircraft could reduce gross emissions by 10-50%.

Combustion of hydrogen instead of kerosene in jet engines could reduce gross carbon emissions by aircraft to zero but would still produce nitrogen oxides (NOx), which are indirect greenhouse gases. Electric propulsion using hydrogen fuel cells could reduce gross emissions to zero, including NOx.

Hydrogen propulsion—either by combustion or fuel cell—would emit water vapor, which is also a greenhouse gas. Water vapor additionally can create contrails and cirrus clouds, which can contribute to climate change through radiative forcing. But "its harmful effects can be minimized through careful operation," the report says.

Roland Berger identifies five key barriers to hydrogen in aviation, none of which will surprise aircraft and engine developers. Hydrogen stores a lot of energy but in a large volume. It has a gravimetric energy density of 33 kWh/kg, three times that of kerosene and more than 100 times that of the best lithium-ion batteries.

But liquid hydrogen has a volumetric energy density less than a quarter that of kerosene and must be stored at cryogenic temperatures in large and heavy insulated tanks. Aircraft-grade storage systems could reduce the stored hydrogen's energy density to 10-21 kWh/kg, Roland Berger says, adding: "Nevertheless, hydrogen remains superior to conventional fuel in terms of power density by unit weight."

Of the five barriers identified by the report, one is the need to redesign aircraft to provide additional volume to accommodate cryogenic hydrogen tanks. Roland Berger acknowledges this as the main drawback but argues liquid hydrogen still offers advantages over battery storage in energy density.

Because of hydrogen's low volumetric density, "the airplane becomes larger, heavier, with more drag so it needs more energy; so you could be increasing your carbon footprint, not dropping it," says Alan Epstein, Massachusetts Institute of Technology professor emeritus and former Pratt & Whitney vice president of research and environment.

"Because of the low density, the value of hydrogen is very dependent on aircraft speed. So it might make sense for a surveillance application where the aircraft just loiters, such as Boeing's Phantom Eye, or slow general-aviation aircraft, but it gets much harder as the

speed goes up," he says. "Indeed, it's unclear that the airplane design will even be close at airliner Mach numbers."

"You need 4-5 times the volume to store the same amount of energy as jet fuel. This means there is insufficient room to store the hydrogen in the wing, which increases the bending moment on the wing root and results in a heavier wing structure," acknowledges Robert Thomson, Roland Berger partner and one of the report's authors.

"Thus our view is [that] hydrogen is unlikely to be used for long-range aircraft where drag and weight are critical and cruising speed important," he says. "Hydrogen's most likely use will be in the narrowbody market, where aircraft don't spend that long at cruise, so a slightly lower speed doesn't have that much effect on trip duration, and drag is also less important."

A second barrier Roland Berger identified is the need to redesign the engine to burn hydrogen or the aircraft to take advantage of distributed propulsion architectures enabled by but not unique to fuel-cell power trains. The report cites two combustion concepts that reduce NOx production from burning hydrogen to levels at or below kerosene: lean direct injection and the micromix combustor.

The remaining three barriers identified by the report relate to the hydrogen supply chain: sustainable production, infrastructure and cost. Of the 70 million tons of hydrogen produced today, the report says, only 1 million tons are "green" hydrogen produced sustainably via electrolysis using renewable energy. But this is changing as the growth in renewable electricity drives the use of hydrogen for energy storage. As its name suggests, Europe's Clean Hydrogen Alliance can be expected to accelerate that trend.

Infrastructure barriers include hydrogen delivery to airports. Existing natural gas networks could be used to transport gaseous hydrogen, the report notes, but would require significant investment. And the hydrogen would have to be liquefied at the airport. This would require infrastructure, and hydrogen liquefaction is energy-intensive and therefore costly.

Cost is the final barrier identified by Roland Berger, which notes hydrogen is more expensive than kerosene on a kilowatt-hour basis. "Gray" hydrogen produced by steam methane reforming or coal gasification is on par with jet fuel at about $0.05/kWh, but green hydrogen produced by electrolysis is about three times as expensive, at $0.14/kWh. Energy projects are under development that promise green hydrogen costs as low as $0.07/kWh, the report notes.

Safety is not identified as a barrier by the report, despite hydrogen's Hindenburg reputation, an omission noted by Epstein. "I have yet to see an airliner design with liquid hydrogen in which the passengers have any chance of survival in an accident, both from contact with the liquid cryogen and the fact that the wide flammability range of hydrogen makes it very easy to ignite compared to Jet A," he says.

"Airbus studied safety as part of its research into the Cryoplane around 20 years ago and stated it is a 'psychological problem primarily,' pointing out that hydrogen doesn't form a carpet of fire and the proceeds of combustion are not toxic," Thomson responds. "But no one has certified a hydrogen aircraft yet, and the means to do so is not yet established," he acknowledges.

The European-funded Mahepa research project is developing a modular hybrid-electric propulsion architecture and will fly two four-seat test aircraft this year: one with a combustion engine and batteries and one with fuel cells. Slovenia's Pipistrel is studying scaling up the technology to a 19-seater.

Looking further ahead, NASA has funded the Center for Cryogenic High-Efficiency Electrical Technologies for Aircraft (Cheeta) at the University of Illinois, Urbana-Champaign to study a fully electric single-aisle airliner using hydrogen fuel cells and superconducting electrical systems.

"Our program was initiated as a way to study far-future aviation technologies that have a much longer developmental timescale associated with them, compared to nearer-term turbine/battery hybrid-electric configurations, for example," says Phillip Ansell, associate professor at the university's Grainger College of Engineering.

"We are seeing substantial promise in the idea of hydrogen-electric aircraft and have seen potential ways to address some fundamental challenges associated with use of hydrogen, but many solutions will require large investments—for example infrastructure—or substantial R&D efforts to complete," he says.

"There is a precedent for hydrogen-powered aircraft, either with internal combustion engines or fuel cells, so we know the idea is viable," Ansell says. "The bigger question is how to scale previous demonstrations up to single-aisle platforms, determine if the aircraft concept can be cost-competitive and devise a way to be able to sustain energy production and distribution across entire fleets of aircraft."

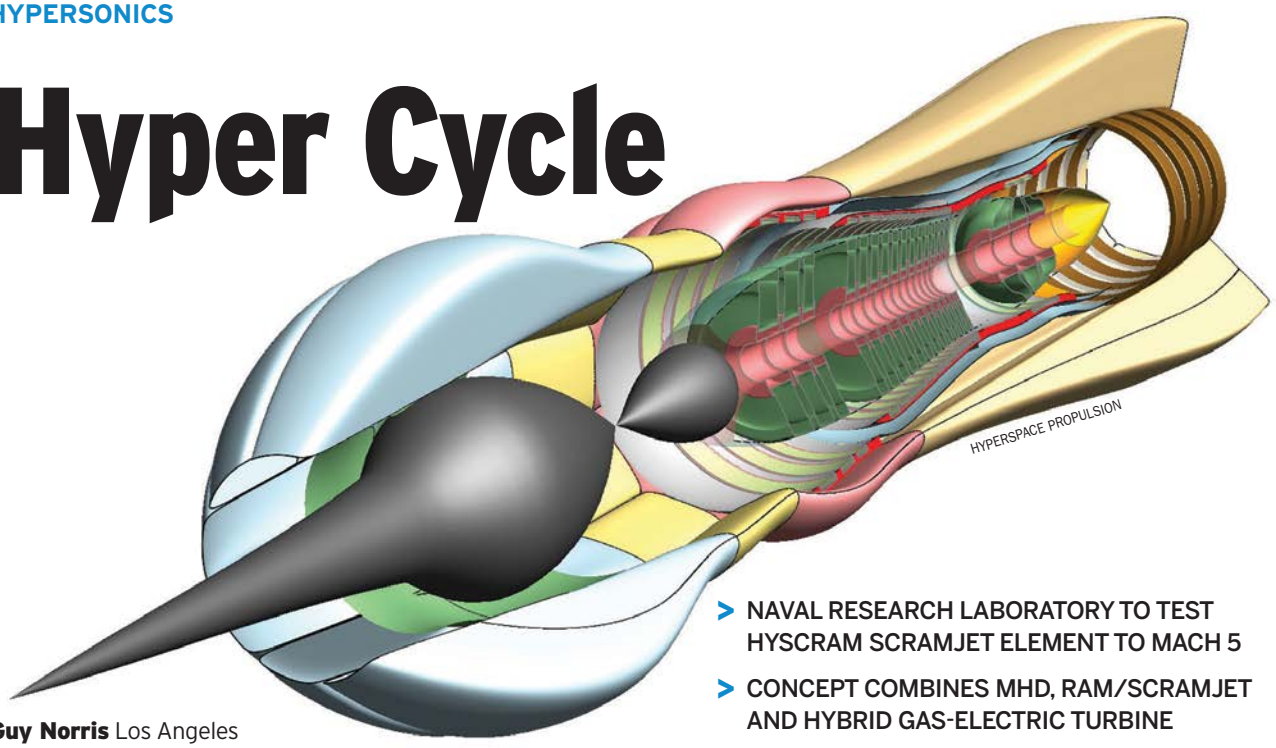
UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

The NASA-funded Cheeta center is studying technology for a full-size fuel-cell-powered airliner.

Roland Berger identifies several hydrogen aircraft projects. These include startups Alaka'i, developing the Skai electric vertical-takeoff-and-landing (eVTOL) air taxi, and ZeroAvia, which with UK government support is developing a power train for 10-20-seat aircraft. Both are using hydrogen fuel cells.

Singapore's HES Energy Systems has unveiled plans for a four-passenger regional aircraft, the Element One, while Germany's APUS is developing a four-passenger light aircraft, the i-2. They also are using fuel cells. Toyota is flight-testing a fuel-cell unmanned eVTOL at Mojave Air and Space Port in California.

Hyper Cycle



- NAVAL RESEARCH LABORATORY TO TEST HYSCRAM SCRAMJET ELEMENT TO MACH 5
- CONCEPT COMBINES MHD, RAM/SCRAMJET AND HYBRID GAS-ELECTRIC TURBINE

Guy Norris Los Angeles

The core is circumferentially enclosed by a cluster of nine dual-mode ramjet/scramjets arranged in load-carrying segmented ducts.

A novel hybrid hypersonic propulsion system combining superconducting electrical power, a gas turbine, ram/scramjet and magnetohydrodynamic (MHD) technology is being developed by California-based startup HyperSpace Propulsion.

The turbine-based combined-cycle (TBCC) engine is designed to power a hypersonic vehicle from a standing start to speeds of Mach 8-plus and could be adapted to commercial and military applications ranging from high-speed aircraft to missiles as well as, potentially, space launch systems, the developer says. The baseline concept is an outgrowth of a hybrid electric-gas turbine configuration unveiled in the 2010s by HyperSpace sister company HyperMach for a proposed Mach 5 business jet dubbed HyperStar.

Although development of the initial hybrid civil engine concept has taken longer than hoped, HyperSpace says the recent increase in interest in hypersonic technologies by the U.S. Defense Department has injected fresh impetus into the new TBCC derivative version. "We have the support and the focus now for our efforts," says HyperSpace CEO Richard Lugg. "If we are successful with an electric-hybrid scramjet, we have a product that could become a naval weapons program, and at the same time we can maintain our trajectory toward a commercial hypersonic program with the full TBCC Hyscram engine."

The company's commercial designs have most recently focused on a Mach 6.65 airliner concept sized for 200 passengers and a range of 10,600 nm. Provisionally targeted at entry into service in the early 2030s, the design is configured with four 190,000-lb.-thrust commercial-derivative Hyscram hybrid turbofan ram/scramjet MHD engines, which share some of the same fundamental design features of the military TBCC concept.

The core of the Hyscram (hypersonic hybrid superconducting combustion ram accelerated magnetohydrodynamic) engine is a turbofan configured with a magnetically levitated fan and compressor and turbine stages, along with a series of axially mounted superconducting power generators. As each rotating stage is held in place with active permanent-magnet air bearings, the design requires no mechanical support shaft, oil system or gearing. A plasma combustor generates an ionized flow that, along with exhaust gas, is accelerated by a four-ring MHD electromagnetic augmenter device at the back of the engine.

Circumferentially enclosing the core is an array of nine dual-mode ramjet/scramjets arranged in segmented ducts. Air is admitted to the ram/scramjets by a translating inlet spike or cone. This resembles the design used in the Mach 3.3-capable Lockheed SR-71, which moved fore and aft depending on flight condition. When the electrically actuated spike is fully forward, the airflow is directed to the ramjet/scramjets, and when retracted the bulk of the flow is diverted into the power-generation turbine core. The "three engine cycles—turbine core, ram/scramjet and MHD thrust" are therefore never fully disconnected, Lugg says.

HyperSpace claims several advantages for the superconducting electric hybrid TBCC versus a conventional turbine-based design because the turbine core is completely integrated and embedded inside the ramjet/scramjet engines with a common central flow path. The design has the theoretical capability of operating to a much higher takeover Mach number before transitioning from turbine to ram/scramjet mode.

The company estimates the turbine will run up to Mach 5-6 before transitioning to scramjet power, which will be used to operate to Mach 8-plus. "Our turbine is operable at very high

Mach numbers because it is shaftless-electric, and all the loads of the rotating machinery are carried in the exoskeleton of the engine structure," Lugg says. "We are operating at rpms and loads that were previously impossible until we came along with this concept."

The outer casing for the turbine engine also forms the inner casing of the double-walled ram/scramjet ducting. The space between the double walls is used to hold the JP7/8 subsystem for fueling and cooling as well as to provide space for the electromagnetic power systems and controls. The company says the common airflow path through the center of the powerplant eliminates the need for completely separate turbine and ramjet/scramjet engines. "Ours is all one mass flow, so we are saving volume, weight and complexity. Plus, we don't have the issue of cocooning a hot turbine," he adds.

The engine is configured with a three-stage fan, a 13-stage compressor (all electrically driven), and a low-speed, subsonic combustor. Flow exits the combustor through a three-stage power turbine that generates both thrust and electricity. "We want to be able to generate a large amount of electricity across the entire flight envelope, so we keep the turbine core operating above Mach 5 to produce electricity, and above Mach 6 it is producing less thrust and more electricity due to the ramjet/scramjet engines taking over," Lugg says.

"We use electrical power to run the MHD, and in our scenario, we are using it to augment thrust as well as manage shockwaves," he says. The MHD is also designed to provide a constant ignition source for the plasma combustor in the ram/scramjet. "With the engine-vehicle design planned to be highly maneuverable, there is a high chance of incurring an 'unstart,' " Lugg says. An unstart is an instability that occurs when a strong shock initiated from a disturbance in the flow through the engine propagates upstream and spills out of the inlet. "So we are attempting to use MHD to electrically power combustion and stabilize it in all flight conditions in the ram/scramjet via a strut-jet ignition system across Mach 5-8," he adds.

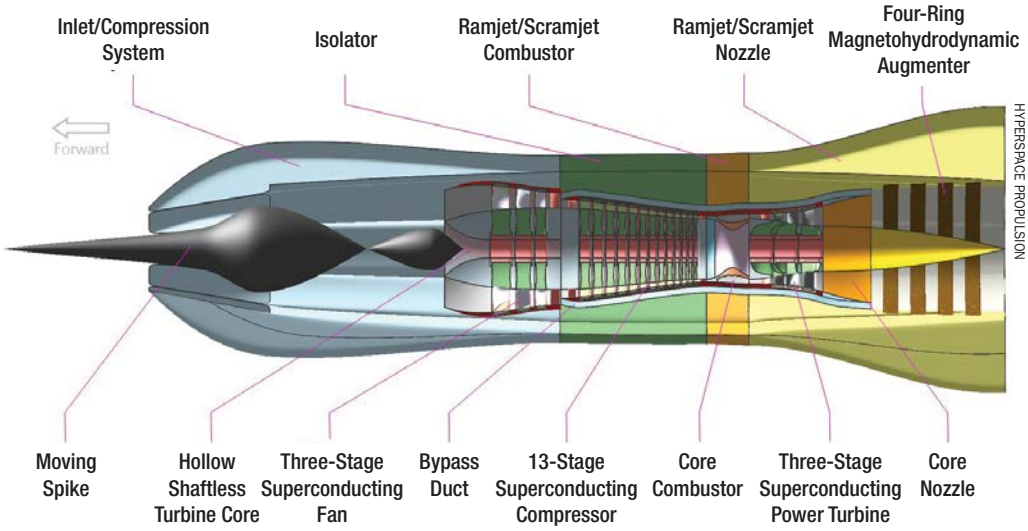
The hollow core of the engine is used to transfer electrical power generated by the turbine to the compressor and fan. "The beauty is you can turn this off or on like a switch on the wall," Lugg says. "Say, if you don't need the first three stages of the compressor as much because you are transitioning to supersonic compression in ramjet mode, then you can turn them off. At around Mach 5.5, when we transition to scramjet mode and you need hardly any mechanical compression, then we may need only three or so high-pressure compressor stages and shut the others off electrically."

In a typical application, the turbine core would be started using ground-supplied electrical power. "You have electrical input to start the induction motor, and at the same time, the turbine blisks will rotate so that will begin [ingesting and] compressing air and achieving combustion for start-up," Lugg says. "Once you have start-up, you have electric power for thrust to power the fan for low-speed operation and taxiing to the runway. At takeoff, you will be at 90-100% power and then running on turbine core power and burning jet fuel."

Initial testing of a single representative hybrid ramjet/scramjet duct will occur under a Cooperative Research and Development Agreement with the U.S. Naval Research Laboratory (NRL). Testing will be conducted in the NRL Hypersonic Wind Tunnel, scheduled to become operational this fall. The test program is divided into three main phases, with the initial study focused on wind-tunnel testing of a subscale hybrid ramjet/scramjet duct, followed by demonstrations of the cycle in a flight-test vehicle in "2023," Lugg says. Follow-on phases, if sanctioned, "would test more integrated versions and a full engine build of this highly innovative TBCC Hyscram engine," he adds.

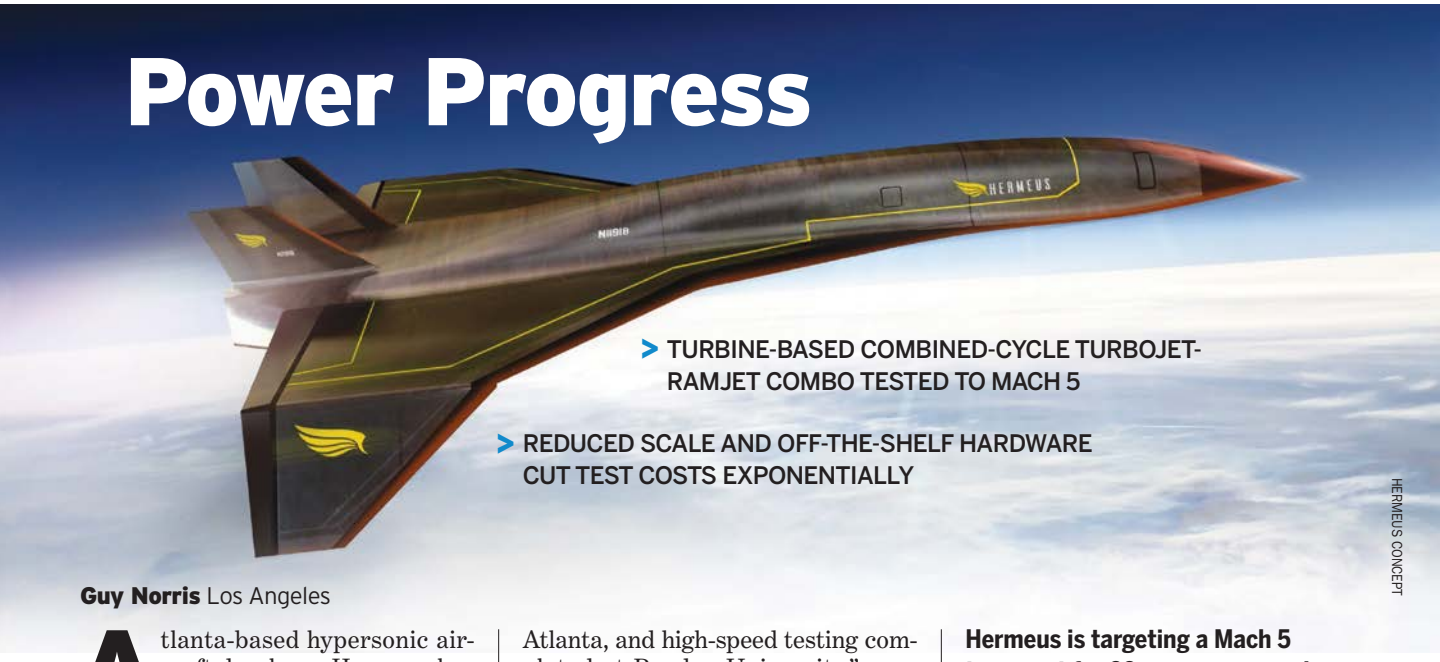
The new research test facility, located at the NRL's High-Speed Aerodynamics Laboratory at the Naval Center for Space Technology in Washington, is a long-duration aerodynamics test site capable of real-time altitude and speed variation. The facility, which relies on a pressurized air source and a convergent-divergent nozzle to achieve test points, is designed to recreate flight conditions from sea level to altitudes over 30 km (19 mi.), and speeds from Mach 1.3 to more than Mach 6.

Hypersonic Hybrid Superconducting Combustion Ram-Accelerated Magnetohydrodynamic (Hyscram) Engine



A translating spike is designed to control inlet air flow to the core turbine and divert air to the ramjet/scramjet for hypersonic flight.

Power Progress



> TURBINE-BASED COMBINED-CYCLE TURBOJET-RAMJET COMBO TESTED TO MACH 5

> REDUCED SCALE AND OFF-THE-SHELF HARDWARE CUT TEST COSTS EXPONENTIALLY

HERMEUS CONCEPT

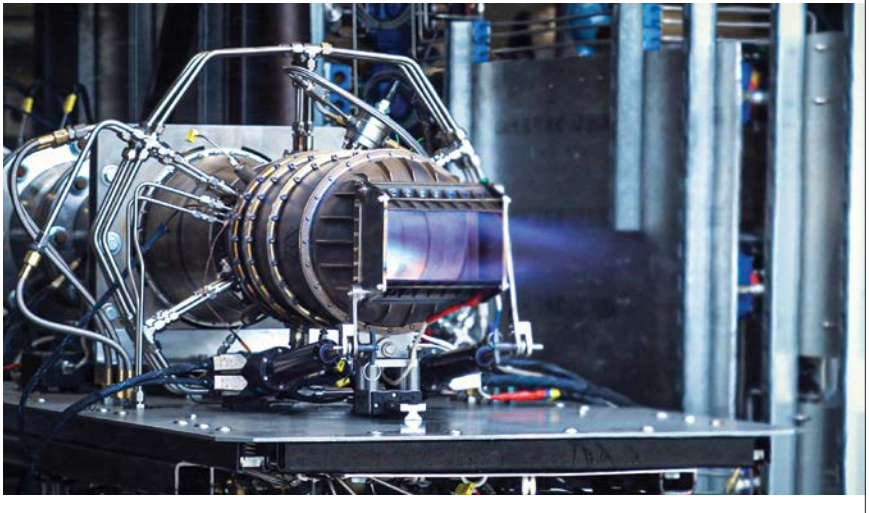
Guy Norris Los Angeles

Atlanta-based hypersonic aircraft developer Hermeus has completed scaled static and wind-tunnel tests of a turbine-based combined-cycle engine prototype up to Mach 5 and is working on near-term plans to test transition between engine modes.

The company is focusing on propulsion development as the first priority in its ambitious initiative to develop a high-speed transport for entry into service by the end of this decade. Provisionally sized to carry around 20 passengers over transatlantic ranges at speeds of up to Mach 5, the vehicle is designed around existing and near-term airframe, materials, systems and propulsion technologies.

"Sea-level static testing has been completed at our in-house facility in Atlanta, and high-speed testing completed at Purdue University," says Hermeus cofounder and CEO AJ Piplica. The turbine-based combined-cycle (TBCC) engine consists of an off-the-shelf turbojet, an in-house-developed precooler and a ramjet. The turbojet is designed to operate from a standing start to Mach 3.3, while the ramjet operates over the transition range from Mach 2.8 to above Mach 3 and then onward up to Mach 5.

HERMEUS PHOTOS



A scaled version of the Hermeus combined-cycle engine has run to Mach 5-like conditions in direct connect tests.

"We have moved very quickly and efficiently to buy down technical risk," Piplica says. The company has gone from "nothing to a tested engine at Mach 5 in nine months for almost two orders of magnitude less cost than AFRE," he says, referring to DARPA's Advanced Full-Range Engine (AFRE) program. AFRE aims to demonstrate a powerplant that can propel a reusable aircraft from takeoff to Mach 5 and back, using a combination of an off-the-shelf turbine engine and a dual-mode ramjet-scramjet.

Hermeus is targeting a Mach 5 transport for 20 passengers and a range of 4,000 nm.

"It is super-critical to reduce as many of the risks as possible, and there are good test facilities around the country, many of them at universities at this scale at least, that allow us to do this at much lower cost than the probably tens or hundreds of millions of dollars if you're doing it at full scale. Of course, you're not solving everything, but you're starting to knock down the biggest challenges. You have to start somewhere," Piplica says, noting that extensive use of additive manufacturing has also contributed to savings in cost and time.

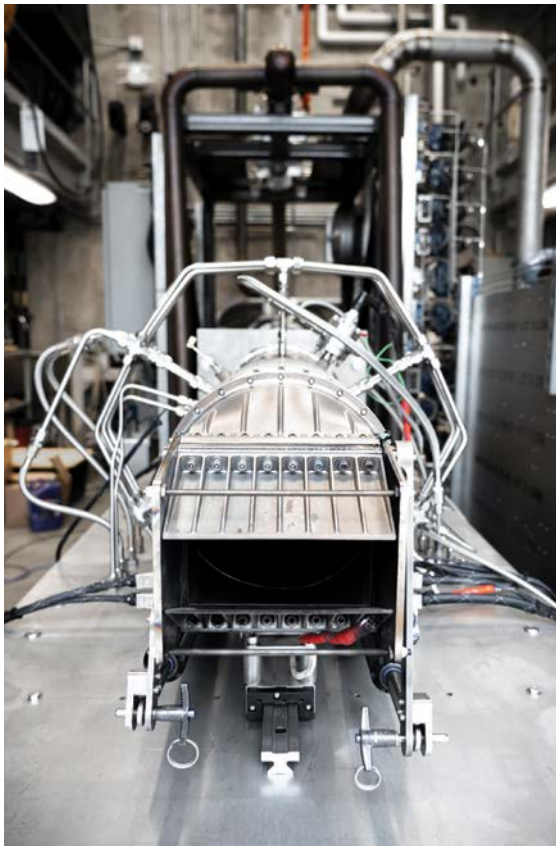
Tests of the engine, which incorporates a common inlet and nozzle for the two flow paths, have so far focused on "operability of individual operating modes and demonstrating overlap between them," he adds. "Mode transition is on the near-term road map though."

For the moment, Hermeus declines to provide details of the precooler system or the off-the-shelf turbojet. Piplica says, however, that "the engine is pretty small and nothing we'd put in a flight vehicle, but it is bigger than a JetCat [a high-end hobby turbine provider] and smaller than a Williams." Hermeus has "built everything else," he adds. "In June, we had an open field and grass at DeKalb-Peachtree

Airport in [Chamblee,] Georgia. Six months later, we had a test facility in a modified shipping container and an engine test campaign completed with over 100 tests. It was a busy second half of last year."

Tests at Purdue's Zucrow Labs in West Lafayette, Indiana, and in Georgia have evaluated the TBCC with a direct connect inlet. "The hardest part of the whole thing is really the inlet, and we haven't bitten off that part yet," Piplica says. "We will be getting into inlet testing at a different facility later this year." Beyond this, Hermeus plans to scale to a Mach 5 flight vehicle "over the next few years," he adds.

In the near term, the company's other key challenge is growing the development team. "We were at eight people in January, and we have to get up to 25 or 30 by the end of the year. That's an extra 20 hires of really just the best. The exact engineer that we need doesn't exist because there haven't been too many people working on these types of systems in the past; so we have to pull people from different parts of the industry. That's the big thing," he says.



Exhaust from the turbojet and ramjet passes through the same integrated nozzle.

So far this year, the company has put out calls to recruit an aerodynamics engineer—responsible for aerodynamic and system-level design, analysis, integration and testing—and an airframe mechanical engineer for the design, analysis, manufacture, test and certification of the airframe assemblies. Hermeus seeks to fill other positions ranging from lead avionics engineer to flight software engineer and mechanical engineer for propulsion.

Fly by Wire for All

> HIGH-RELIABILITY FBW DESIGNED TO BE AIRCRAFT-AGNOSTIC

> R44 LIGHT HELICOPTER BEING USED FOR DEVELOPMENT

Graham Warwick Washington

Fly by wire has improved the safety and capability of military and commercial aircraft but has yet to penetrate general aviation because of its cost and complexity. Now a U.S. startup is targeting the safety record of light aircraft and helicopters by developing a high-reliability fly-by-wire system for retrofit across a wide range of aircraft to provide simplified flight control with full envelope protection.

Skyryse has already installed its FlightOS automation system on three different types of helicopter, including the Robinson R44, and anticipates FAA supplemental type certification (STC) of its first retrofit in "months," CEO Mark Groden says.

Skyryse is using the Robinson R44 light helicopter as the development platform for its flight automation system.

FlightOS is based on a triple-redundant fly-by-wire (FBW) architecture engineered to the same DAL A design assurance level as commercial aircraft systems, with a probability of catastrophic failure of 10^{-9}/hr. This provides envelope protection, automates emergency management and integrates hazard avoidance.

"What we have built is an ability to abstract a lot of the dynamic flight control so as to allow the pilot to be more focused on mission decision-making," Groden says. "This technology is capable of reducing the cognitive load on pilots and helping unlock their ability to think many steps ahead of the aircraft."

Skyryse's goal is to bring FBW to general aviation (GA) to improve safety by developing a system that is agnostic to the aircraft type on which it is installed, thus reducing cost by increasing production volume.

"If you architect one of these systems for one aircraft platform, you would have a problem, because the volumes in general aviation don't support the design, engineering and manufacturing of a fly-by-wire system," he says. "But if your system is designed to be aircraft-agnostic across platform types, and you build that architecture so it truly can be put into all GA aircraft around the world—retrofit and future vehicles—now you've achieved economies of scale."

SKYRISE

FlightOS uses triple-redundant, jam-proof electromechanical actuators that can replace an aircraft's mechanical flight controls or piggyback on them to enable mechanical linkages to be retained as a backup. Triplex localization sensors are included, and FlightOS can interface with terrain maps and sense-and-avoid systems to understand its environment and detect dynamically moving obstacles.

"The software is something that is pretty unique to us. What we are making possible is the first set of aircraft to be software-defined in the way Tesla created software-defined cars," he says. "Once the system is installed in an aircraft, we have the capability of accessing all of the primary flight-control functions with software updates that make the aircraft increasingly capable over time."

FlightOS has been architected by Skyryse Chief Technology Officer Gonzalo Rey, who was previously CTO at Moog, where he was involved in the certification of fly-by-wire systems on multiple aircraft, Groden says. "The backbone is a DAL A system that can be STC-ed into an existing aircraft and, on the back of that, software updates will make it increasingly automated to make the aircraft safer and more capable."

Skyryse has been flight-testing FlightOS since January 2017. "We've architected the system to be entirely aircraft agnostic across anything with a pilot. We are already working on the R44, which arguably is the hardest platform to do in general aviation because you don't have much volume or available power. And by the way, it's super unstable because it's a light helicopter," he says.

The hardware is essentially identical, whatever the application. "So we can integrate into fixed-wing aircraft or bigger rotorcraft. And those are much easier platforms for us to integrate into because there is power, weight and cooling capacity, and of course those aircraft are inherently more stable," Groden says.

The data required to develop FBW systems for GA aircraft generally does not exist, so Skyryse performs extensive system-identification flight tests

to characterize the vehicle's flight envelope and control responses. "That process we have done three times already, with three different helicopters," he says. "And helicopters are much more difficult to characterize than fixed-wing."

Skyryse's strategy to improve safety is to automate and simplify flight operations. "We know that in general aviation today, the level of safety is not where it needs to be. Even for the best pilots with thousands of hours flying a helicopter, it's a lot to handle," Groden says. "We want to take the 6,000-hr. or 8,000-hr. pilot and make them as good as they've ever been on their best day. And we want to take pilots with a couple of hundred hours and elevate them to the same level, so it is like a rising tide."

To achieve this goal, FlightOS must be highly reliable and available. "This isn't like an autopilot, where we expect the aircraft to be dumped back on the pilot when it fails. It's our intent for the system to be online and in control and capable of handling all situations the aircraft can encounter," he says.

"We know complex systems fail in complex ways, and that is the worst time to dump a system on the pilot and say, 'It's your bird; figure out what's going on, and then try to make the best decision as quickly as possible.' A computer is much more capable than the human in managing those types of situations," Groden adds.

Ultimately, Skyryse wants to make it easier to learn to fly any aircraft, fixed- or rotary-wing. "It's our vision that it will be as easy to get into any aircraft as it is in today's automobiles, where your user interfaces are identical—steering wheel, gas pedal, brake pedal. It doesn't matter what make or model car; whenever you get into the vehicle, in a matter of seconds you're driving out of the parking lot," Groden says.

The training framework already exists to gain a private pilot's license in 40 hr., or a sport pilot's license in 20 hr., but "it's just not supporting the proficiency of those highly perishable skills," he says. "So we can empower those people [who] already know how to fly to fly a heck of a lot safer and in flying conditions that they otherwise wouldn't be capable of doing."

Skyryse is still experimenting with "intuitive" interfaces for FlightOS. "I'd like to get away from conventional flight controls because they utilize the human body fully if you're flying the aircraft in bare metal," he says. "You've got a hand or a foot on something that doesn't enable you to grab a checklist or push another button or flip a switch or change your radio frequency. It's very cumbersome.

"There's a wide body of possibility, and obviously doing this in a way that has the redundancy and the reliability needed is most important because this is where the human ultimately plugs into the technology," Groden adds. "But it definitely shouldn't be happening through the World War II-like controls that exist in every aircraft right now."

Skyryse has a "clear path" to certification defined with the FAA but is not disclosing a specific timeline. "What I can say is Gonzalo [Rey] has been through this about a dozen times on other projects during his tenure at Moog, so we are confident in our process with the FAA," he says.

Although Skyryse has focused on the light-utility R44 as the platform for development, its initial target market for FlightOS retrofits will be higher-value special mission helicopters. "We're engineering the system to be capable of operating the hardest vehicle type, which is the light helicopter, while simultaneously saying, 'Where is the market demand the strongest?'" Groden adds.

He cites firefighting, search-and-rescue and offshore oil, "where missions are difficult to fly and the platforms are generally more expensive," he says. But Skyryse's ultimate goal is to apply FlightOS across as many current and future aircraft types as possible to drive volume up and cost down.

"Think of us as Microsoft," he says. "We want to be the platform technology stack, the software that powers all your existing transportation today in general aviation and then future transportation for the air taxi market."

CARGO CONNECTIONS

Military interest in the potential of eVTOLs follows an evaluation of Joby's tiltprop air taxi.

JOBY AVIATION

> USMC ASSESSES eVTOL POTENTIAL IN UNMANNED AIR LOGISTICS

> MILITARY UNMANNED LOGISTICS USE EYED FOR URBAN AIR TAXIS

Graham Warwick Washington

ONE IN A SERIES

The pace of development in the urban air mobility market is adding energy and opportunity to the U.S. military's long flirtation with unmanned logistics. Encouraged and intrigued by the vehicles it sees being developed, the U.S. Marine Corps has joined the U.S. Air Force's Agility Prime program to accelerate commercial development of electric vertical-take-off-and-landing (eVTOL) aircraft.

The Air Force unveiled Agility Prime in February with the goal of helping commercial manufacturers obtain FAA certification for their vehicles by providing access to government test resources. The service also aims to foster potential government markets for early adoption of commercial eVTOLs for missions such as distributed logistics, medevac, firefighting, search and rescue, disaster relief and base security.

The Marine Corps is interested in three classes of VTOL cargo aircraft, or Unmanned Logistics Systems-Air (ULS-A). The small platform would deliver 60-150 lb. over a 5-10-nm radius for squad resupply. The medium platform would carry 300-500 lb. over a 15-110-nm radius for platoon resupply and cargo flights between expeditionary bases.

The large ULS-A, where eVTOLs could find a niche, would fly a 1,000-3,000-lb. payload over a 150-300-nm radius, from ships to small, austere landing zones on shore and from distribution sites to expeditionary bases. In addition to cargo, the autonomous vehicles could carry passengers.

ULS-As of various sizes would take resupply convoys off risky roads and free up manned helicopters for combat missions, says Carmine Borrelli, deputy of the Logistics Innovation Office at the Marine Corps Warfighting Laboratory (MCWL).

The small platform "would be simple enough that you hit the button and plan the mission," he says. "It takes off, lands or drops the cargo, and is able to simply return to base or continue its mission. The small [ULS-A] effort is funded toward midtier acquisition for five years. That effort is moving along. We just completed a prize competition out of Naval Air Systems Command."

The Tactical Resupply Unmanned Aircraft System (TRUAS) competitive flyoff was conducted at Yuma Proving Ground, Arizona, on Jan. 27-31 to evaluate the autonomous aerial delivery capability of existing small UAS. Six companies competed.

Survice Engineering won the $100,000 first prize with the TRV-150, a multirotor cargo UAS developed with the UK's Malloy Aeronautics. Capable of lifting up to 150 lb., the TRV-150 can carry a 50-lb. payload 50 km (27 nm). Chartis Federal took second place with Periscope Aviation's Mk. 4 heavy-lift UAS. Autonodyne took third place.

"We'll go on to develop prototypes of the top two or three, and those prototypes will be put into the fleet in a little different way from what our acquisition system has done in the past," says Borrelli. The Marine Corps could begin field-user evaluation of the prototypes as early as fiscal 2021. This could lead to a procurement program, he says. The Marine Corps is aiming for early operational capability by 2023 and full operational capability by 2026.

Development of the medium platform is being pursued with the U.S. Army through the three-year ULS-A joint capability technology demonstration (JCTD) funded by the Office of the Secretary of Defense and running to 2021. This is looking at autonomous logistics and, potentially, limited casualty evacuation and emergency extraction. The Marine Corps is aiming for early operational capability with the medium ULS-A by 2025 and full operational capability by 2030.

There is approximately $120 million in the budget beginning in fiscal 2019 for the small platform and to begin preparations for a medium ULS-A program once the JCTD is complete, says Borrelli. There is also approximately another $30 million from stakeholders in 2019-21 for the

JCTD. Early operational capability of the medium ULS-A is planned by 2023 and full operational capability by 2030.

The Marines used two unmanned Kaman K-Max external-lift helicopters operationally in Afghanistan in 2011-13. Able to lift up to 6,000 lb., these aircraft were retired after returning from Afghanistan. The K-Maxs have now been reactivated, and Congress added $18.5 million to the 2020 budget to use them to advance autonomy and beyond-line-of-sight capabilities for the large ULS-A.

In the large category, Borrelli says, the Marine Corps is interested in the potential of the eVTOL industry to provide a platform that is lower-cost and simpler to operate. "We are heavily partnered with the Army on the medium. Now the Marine Corps Warfighting Lab will be partnering with Agility Prime," he says. The MCWL will provide funding and help in developing use cases for eVTOLs based on its analysis work.

"We've had a lot of experience with use cases, [and determining] what and how we want to deliver. We look forward to the next year in partnering with Agility Prime so we can develop some use cases and begin to fly some things on some of the larger platforms," he says.

The MCWL's Logistics Innovation Office has been interested in eVTOLs for a couple of years, since the Pentagon's Defense Innovation Unit funded Joby Aviation and Kitty Hawk to explore the military utility of the vehicles. The idea was hard to sell to the user community, but that is changing with the growing momentum in the air-taxi sector, Borrelli says.

The large ULS-A requirement was originally to carry up to the 6,000-lb. capacity of the K-Max. But seeing the potential to use commercial urban air mobility vehicles to move not only cargo but also people, the Marine Corps has adjusted its requirement to look at the 1,000-2,000-lb. capacity of most eVTOLs.

"If the market is moving toward the 1,000-lb. cargo platform that's a flying car, and many of them are going to be out there and the cost is going to come down considerably, then it would be in our best interests to figure out how best we use that platform," says Borrelli. "So in the 1,000-lb. [category], we look to ride on the coattails of the industry."

The Marine Corps is still looking at heavier cargo. "We also want to get our requirement out there in the 2,000-3,000-lb. [range] and beyond that to 6,000 lb., where we still have things we need to move. It would be important to get out there and see what the [eVTOL] market could bring without making these very expensive aviation platforms," he says.

In February, the Air Force's Agility Prime program office published an "innovative capabilities opening" (ICO), establishing a contracting framework for prototyping projects designed to show whether, as their developers assert, eVTOL vehicles can revolutionize mobility, particularly logistics.

Under the ICO framework, which will remain open until Feb. 28, 2025, the service plans to release a series of solicitations for different "areas of interest" (AOI). The first of these—the "Air Race to Certification"—was released on Feb. 25. Other AOIs could range from autonomy to manufacturing.

Under the first AOI, the Air Force office plans to issue contracts to produce test reports that will substantiate company claims for their vehicles. Based on a test report, the service could proceed to the next step, potentially an early procurement, according to Nathan Diller, Agility Prime integrated product team lead.

"They can leverage that test report to get military certification that would allow near-term government use cases that would accelerate commercial certification, potentially providing revenue and data that accelerates the broader adoption of the technology," Diller says. The Air Force is aiming for an initial operational capability in 2023 with a "handful-plus" of vehicles.

Survice Engineering won the U.S. Navy's TRUAS flyoff with the Malloy-designed TRV-150.

MALLOY AERONAUTICAL

Cargo Operators Work Together for Sustainability Gains

> COVID-19 CRISIS WILL DELAY BUT NOT HALT AIR CARGO'S SUSTAINABILITY DRIVE

> EMBRACING DIGITIZATION WOULD ALSO HELP SUSTAINABILITY, SAYS HACTL CEO

JOEPRIESAVIATION.NET

Optimizing flight routes is part of Lufthansa Cargo's sustainability effort.

Helen Massy-Beresford Paris

ONE IN A SERIES

While the world reels from the spiraling impact of the COVID-19 pandemic, air cargo is one of the sectors keeping the economy moving by delivering goods and vital medical supplies around the world.

But once the immediate coronavirus crisis is under control, will cargo operators resume their focus on what they see as vital efforts to make their businesses more sustainable?

The International Air Cargo Association (TIACA) has set up a program aimed at driving sustainability goals throughout the industry by raising awareness, sharing best practices, encouraging innovation and partnerships, and supporting cargo operators, especially the smaller players that make up a large part of the industry.

Above all, TIACA Chairman Steven Polmans says, more cooperation is needed to improve the sector's sustainability record. "We do believe that as an industry, we urgently need to work on sustainability," he says, noting that the entire industry needs to take action, not just aircraft or engine manufacturers or airlines.

"The flying part is a very small portion of what the air cargo industry is all about, even if it's a very prominent one," Polmans says. "We're afraid that too much attention is going to that part. And we do not want that to be an excuse for other players in the industry to say, 'That's the problem part of the industry—we can ignore it.'"

Wilson Kwong, chief executive of Hong Kong air cargo terminal operator Hactl, a major player in what he describes as the "often-forgotten cargo-handling area," sees potential for improving sustainability in parallel with industry's efforts to increase digitization to make operations more efficient, reliable and transparent. "As an industry, we need to stop resisting digitization—that would take thousands of tons of waste paper out of the business, save many trees as well as [provide] greater efficiency and visibility."

Kwong adds: "Something we learned long ago is that steps that make good eco sense also often make good business sense."

Lufthansa Cargo, which operates a fleet of MD-11F and Boeing 777Fs and makes use of the belly capacity of Lufthansa passenger aircraft, is aiming to reduce its specific CO_2 emissions by 25% from its 2005 level by 2020.

To do this, Lufthansa Cargo is reducing CO_2 emissions by implementing fleet and engine modernization, using lighter containers, improving energy and resources consumption at ground operations, improving operations such as boosting load factor and optimizing flight routings, investing in innovation projects and working with customers on environmental issues.

Although new technologies provide opportunities for sustainability, such as modernizing cargo fleets, introducing biofuels or using lightweight materials to reduce the weight of containers, many established technologies are still not being fully exploited, Kwong says. He notes that Hactl, which holds a Green Week to improve ecological awareness among staff, has recently banned single-use plastics from its terminal—replacing them with cotton bags, reusable staff lunch boxes, refillable water bottles and 80 water fountains—and has made use of abandoned wooden pallets to make furniture. "We hold a Green Week to make our staff think about how they can contribute to a more sustainable planet," he says.

"We have upgraded our extensive chiller facilities to run on less harmful gases, installed air curtains to preserve temperatures and reduce power consumption, and more carefully regulated air conditioning to reduce power use," Kwong says.

The company is also using mobile computing to shake up its ramp operations, reducing tug distances, cutting fuel consumption and emissions as well as replacing some diesel vehicles with electric ones.

As a big player—it can handle up to 3.5 million tons per year—Hactl has an advantage over smaller counterparts.

"Any change we make tends to have a very visible impact," Kwong adds. "But there are opportunities for the industry as a whole, even at small sites, such as solar power [and] switching from diesel to electric power."

To encourage cooperation, bring together disparate players within the air cargo supply chain and bring smaller companies on board, TIACA has set up a sustainability working group, with short-term goals such as helping companies measure their sustainability performance through self-assessment and providing advice and training.

TIACA

TIACA Chairman Steven Polmans wants more coordination to improve air cargo sustainability.

"My dream as TIACA chairman is to eventually have in place an official logistics sustainability index, with certificates for companies showing how sustainable they are based on TIACA's sustainability vision," Polmans says.

Of course, the association's short-term activities are being disrupted by the COVID-19 crisis, which is threatening the very survival of some operators in the broader air transport sector, which was already under pressure before the pandemic hit: 2019 was the worst year for air cargo in a decade, thanks to weak growth in global trade and tariff wars.

But is there a danger that even once the coronavirus outbreak subsides, recovery efforts within the industry will push sustainability initiatives far down the agenda? Polmans thinks not. "If this had happened two years ago, that would have been a danger. At that time, sustainability was too much of a fashion. But I think it has now become important enough for everybody not to be forgotten."

Polmans also notes that improving sustainability means not only cutting emissions—the cargo sector has a role to play in humanitarian crises as well as in safeguarding wildlife, for example. "Too often when we talk about sustainability, people do not look further than the environment, and sustainability is so much more than that."

TIACA has launched an annual sustainability award and, in November 2019, recognized Wings for Aid, which is developing a remotely piloted aircraft system to deliver humanitarian goods to people isolated by natural disasters and human-made crises.

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Aerospace Calendar

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~~**March 30-April 2** **Now Oct 31-Nov. 3**~~—36th Space Symposium. Broadmoor Hotel. Colorado Springs. See spacesymposium.org

~~**April 1-4** **Now July 20-21**~~—DoD Hypersonic Capabilities Symposium. Mary M. Gates Learning Center. Alexandria, Virginia. See hypersonics.dsigroup.org

~~**April 6-8** **Canceled**~~—Sea-Air-Space 2020. Gaylord National Resort & Convention Center. National Harbor, Maryland. See seaairspace.org

~~**March 31-April 1** **Now April 13-15**~~—Passenger Terminal Expo 2020. Venue TBD. Amsterdam. See passengerterminal-expo.com/en

~~**April 1-4** **Now April 14-17**~~—Aero Friedrichshafen. Messe Friedrichshafen. Friedrichshafen, Germany. See aero-expo.com/aero-en

~~**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

~~**May 5-7** **Now Aug. 10-12**~~—Association for Unmanned Vehicle Systems International (AUVSI) XPONENTIAL 2020. Boston Convention Center. Boston. See xponential.org/xponential2020

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~~**April 1-2** **Now Oct. 26-27**~~—CAPA Airline Leader Summit: Making Money 2020. Dublin.

~~**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** **Postponed/TBD**~~—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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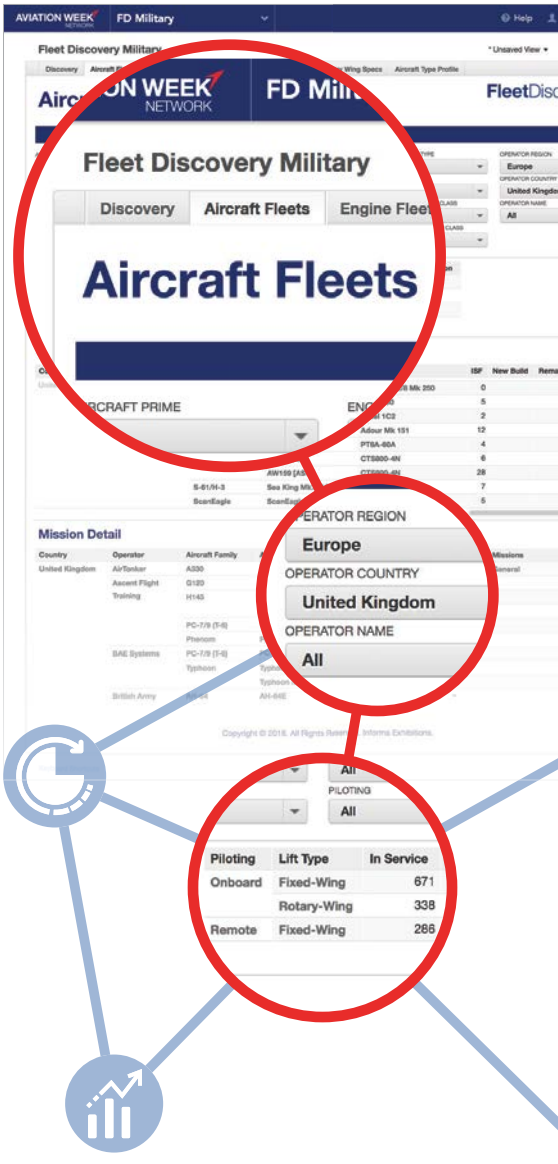

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AVIATION WEEK NETWORK

A Code of Conduct for Aviation

Desperate times call for bold measures, and the $2.2 trillion coronavirus economic rescue package passed by the U.S. Congress and signed into law by President Donald Trump certainly passes that test. Tucked into the gargantuan measure was $58 billion for airlines and cargo carriers, including $29 billion in grants to keep workers paid for the next six months, even if they are staffing empty flights. Boeing did not get the $60 billion directly that it had sought for aerospace manufacturers, but the aircraft giant and its suppliers still qualify for hefty rescue loans or guarantees.

The secretary general of the United Nations has called COVID-19 the worst crisis the world has seen since World War II, and governments have a duty to ensure that this unprecedented pandemic does not wipe out vital industries. But the torrent of rescue money could have negative side effects, and it is imperative that governments step back when the crisis subsides.

The market distortions of state aid already are apparent in the airline industry, where a lack of coordination among governments—even those within the EU—has tilted the playing field (see page 13). And what if Boeing receives government backstops that Airbus has said it does not need?

It is increasingly likely that when the pandemic subsides, the aviation industry will be facing a long uphill march to recovery, rather than the quick bounce-back that had been hoped for. As such, we urge the industry's stakeholders to start looking ahead and taking steps that will position them to recover as quickly as possible. Consider this Code of Conduct:

Take care of your employees. You will need them to excel and work as a team when you recover. Do whatever possible to keep them healthy and well-informed. In the near term, furloughs, wage freezes and hiring freezes may be unavoidable to control costs. But prioritizing shareholders or senior executives over workers would create labor issues that could slow any recovery.

Take care of your customers. You will only recover if they recover, so be flexible in responding to their issues during the crisis. Relationships cemented during hard times will pay off, while fractured relationships could cause long-term damage.

Take care of your suppliers. Aviation manufacturers have spent decades pushing risk down to suppliers while trying to limit their rewards to reduce costs. If your suppliers do not survive or take too long to recover, all those risks will rebound onto you.

Take care of your industrial base. The Pentagon wields an enormous amount of buying power at the taxpayers' expense. That should be deployed to keep its supply base healthy in the near term, even if it is at the expense of delaying long-term capabilities.

Take care of your business. You need to come back more agile and flexible than ever to adjust to the immediate challenges of a recovery and to tackle future challenges unrelated to the coronavirus, such as climate change.

And what about taking care of shareholders? Consider that in one recent year Boeing returned nearly six times as much money to shareholders through stock buybacks and dividends as it invested in R&D. Or consider that U.S. airlines sent 96% of their free cash flow to shareholders over the last five years. Now that hard times have hit, taxpayers are being asked to step in and foot the bill to save the industry. Shareholders need healthy airlines and healthy manufacturers. They can wait their turn.

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