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AVIATIONWEEK
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August 31-September 13, 2020 · Volume 182 · Number 17

JESSE H. NEAL AWARDS Est. 1955 66 WINNER
2020 Winner

Dynetics has flown a second Kratos-built X-61 Gremlins air-launched and air-recovered unmanned aircraft and demonstrated close-formation flight with a Lockheed Martin C-130. The flight, in July at Dugway Proving Ground in Utah, moved the DARPA program closer to an aerial recovery test later this year.

DEPARTMENTS

FEATURES

ON THE COVER

As two key future-rotorcraft competitions accelerate, the Sikorsky S-97 Raider (left) joined the Sikorsky-Boeing SB-1 Defiant for the first time when the high-speed rotorcraft flew in formation over the Florida test center in a demonstration for the U.S. Army. Lockheed Martin photo.

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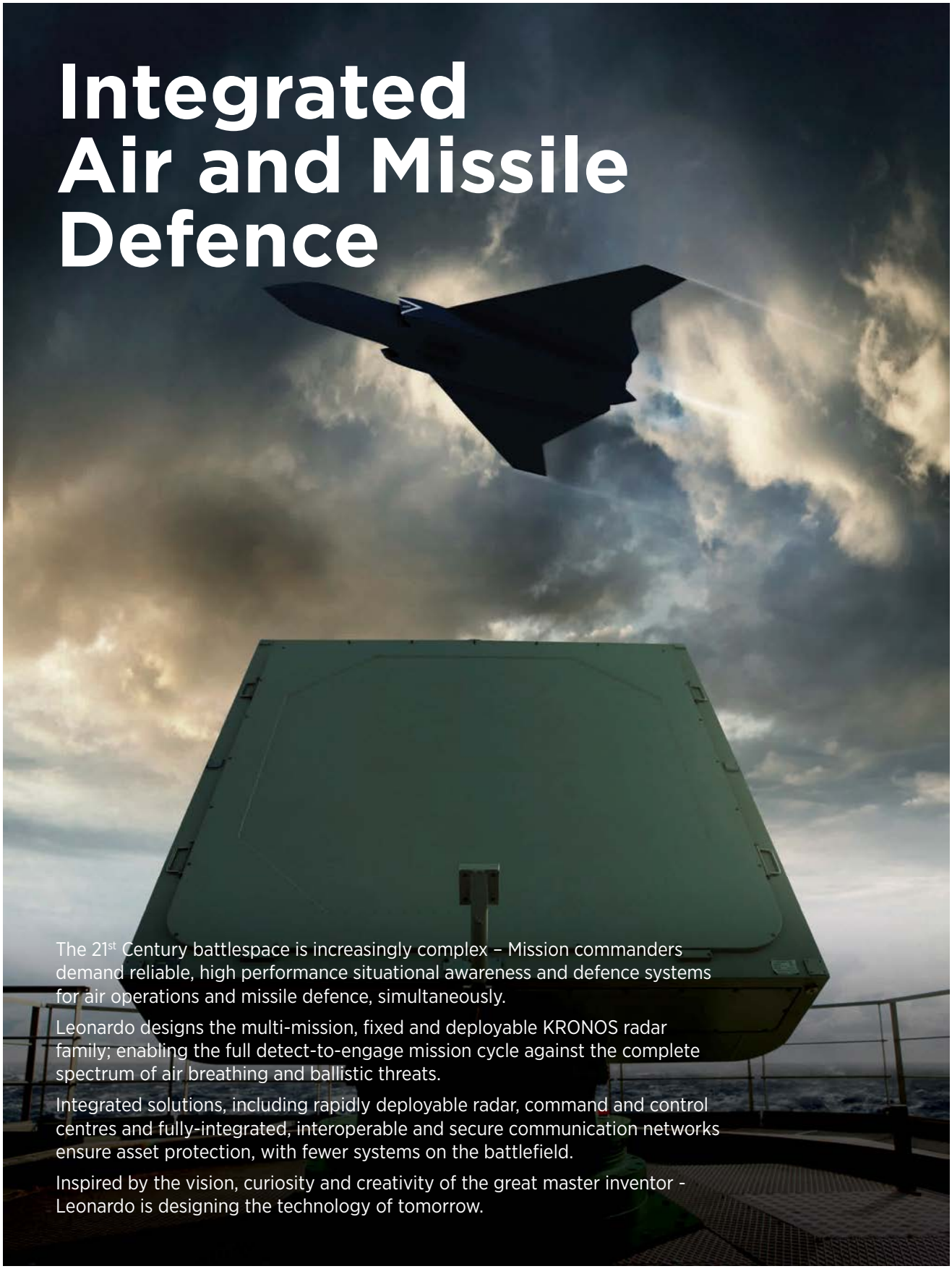

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FEEDBACK

NASA

SUBORBITAL SUSTAINMENT

Irene Klotz's column, "The Launchpad," is a favorite of mine. But I must disagree on one point in her recent column on suborbital spaceflight's hiatus beginning with the second Mercury launch *(July 13-26, p. 16)*. Well after the Mercury program, the X-15 was operating in near space. In 1963, Joe Walker reached an apex of the program, at 67 mi. Flights above 200,000 ft. were fairly common late in the program, and on Aug. 21, 1968, Bill Dana got his astronaut wings in the No. 3 ship. The last launch, on Oct. 24, 1968, topped out just shy of 50 mi.

I grew up with the X-1, the Skyrocket, the X-2 and X-15, and they were iconic. I probably found the X-15 more interesting than the Mercury.

Yes, some of the X-15 pilots were military, and the civilians were not recognized as NASA astronauts until much later; but I doubt that quibble was what your distinguished columnist had in mind.

Bernard Biales, Jamaica Plain, Massachusetts

FEEDING DOUBT

In his recent viewpoint, Collins Aerospace President Stephen Timm correctly points out that an interagency/interassociation approach is required in conjunction with government to create a safe and reliable "curb-to-curb" experience for passengers *(July 27-Aug. 14, p. 66)*. The flying public must be able to trust their health and well-being to both airlines and airports every time they fly. At present, they do not.

Current responses to COVID-19 in the industry are mostly a random and inconsistently applied assortment of ideas based on minimal deviations from business as usual. The absence of a standard, comprehensive approach among airports and airlines feeds doubt about safety among potential travelers. Until the traveling public replaces this doubt with trust, the industry will not rebound.

Our recommendation is for a national working group to be established under the auspices of Vice President Mike Pence. The group would achieve the goal of identifying a comprehensive, uniform industry approach to make the flying experience the safest and most consistent possible. Participants would include organizations such as the FAA, TSA and Centers for Disease Control, major airlines and airport authorities and labor leaders. The recommendations of this working group would not be optional; outcomes must become administration policy. Industry participants will be expected to play a role, even if it means subordinating their own interests to a degree.

Unless a focused national approach is adopted to regain public trust in aviation, the recovery of the industry and its component parts will remain stalled. It is time for a new approach, powered by a breakthrough in thinking, and it must be led by the very highest authorities.

Mike Higgins and the Stonebriar Strategy Group Thought Leadership Initiative, Dallas

MAX FLIGHT-TESTING

While the five strategic recommendations advanced by Kevin Michaels in "Rebooting Boeing" *(July 27-Aug. 14, p. 10)* may refocus Boeing on the share price chase, they would not help reestablish confidence in the reliability and safety of the metal and software bits that make up its products.

Boeing needs to show the traveling public and all its stakeholders that its leaders know what they are doing, and the best way to prove that is by demonstrating Boeing products, especially what is considered its most "defective" product, the 737 MAX.

Boeing should pull six unmodified MAX airplanes off the hardstands (in the same configuration as the accident airframes), place an experimental placard over the main doorway, and fly these six airplanes every day with Boeing personnel on board—the board of directors would be a nice touch. Then take six "modified" airplanes and do the same thing. Keep flying them. News media and civil aviation regulators should be on board as well.

This is what would have been done in the early days of commercial aviation to demonstrate reliability and safety to the traveling public.

Eric Hiner, Plantation, Florida

'DIRECT LAW'

The criticism of engineers' "1g environment" in the article "Checklist Challenges" *(July 27-Aug. 14, p. 18)* was on target, although, based on my more than 42 years in the industry, I believe the situation is a little more complex.

Engineers, by nature, are problem-solvers. Most of them are specialists, however, so when they make well-intentioned decisions, they often don't understand the broader implications.

They tend to approach a problem with the tools with which they are most familiar. They also tend to be craftspeople, so as they gain more experience, their designs become more complex. Combine this with the fact that program pilots are extremely knowledgeable and take pride in understanding complex systems that a line pilot would have to struggle to stay current on.

Program managers are judged on schedule and budget, and senior management is watching the stock market. The end result is that there are not enough people with a broad enough view to recognize when a design decision is going to cause a problem.

We on the design side of the industry have a responsibility to pilots and passengers to keep things simple. If it were up to me, every commercial airliner would be equipped with a single button labeled "DIRECT LAW." Pushing it would bypass all the computer software and give the pilots direct, analog control over the control surfaces so they could keep the dirty side down until they are able to figure out what is going on.

Vaughan Askue, Stratford, Connecticut

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

WHO'S WHERE

Hal Chrisman has been hired as president of *Raisbeck Engineering*. He was chief strategy officer with Acorn Growth and before that worked at ICF Aerospace and MRO, AeroStrategy and Pemco Aviation Group.

CACI International has hired **Todd Probert** as president of CACI's National Security and Innovative Solutions sector. Probert was vice president of Raytheon's command and control, space and intelligence business and before that was Honeywell Technology vice president of strategy and business development.

Boeing has revamped its corporate communications function under these newly appointed vice presidents: **Brian Moran**, global brand and corporate communications; **Gordon Johndroe**, global media and public affairs; **Georgina Goode**, global channel and content marketing; **Conrad Chun**, global communications for Boeing Commercial Airplanes; **Walt Rice**, global communications for Boeing Defense, Space and Security (interim); and **Allison Bone**, global communications for Boeing Global Services.

Aircraft Accessories and Components Co. has named **Mazen Johar** as CEO. Johar was deputy minister for industrial services at the ministry of industry and mineral resources and held executive roles at Nova Water, Saudia Cargo and Basic. He succeeds Mansour Bineid.

Wencor has promoted **Shawn Trogdon** to CEO from chief financial officer. Trogdon succeeds Chris Curtis, who has retired.

Duncan Aviation has promoted **Jeff Lake** to president from chief operating officer of its Lincoln, Nebraska, facility. He succeeds semiretired Aaron Hilkemann, who is now part-time board CEO and chairman. **Mike Minchow** succeeds Lake as the Lincoln chief operating officer; he was vice president of modifications and engineering. **Chad Doehring** steps up to chief operating officer of the Provo, Utah, facility from vice president of operations; he succeeds Bill Prochazka, who has retired. And **Ryan Huss** has been promoted to the new position of director of sales from airframe and engine sales manager.

SR Technics has promoted **Caroline Vandedrinck** to senior vice president of sales from vice president for the Americas.

Panasonic Avionics Corp. has hired **Joe Bentley** as chief technology officer. Bentley was senior vice president of engineering at Hulu.

Volocopter has promoted **Arnaud Coville** to chief technical officer from head of VoloCity development. He succeeds Jan-Hendrik Boelens, who has left the company.

Al Potter has been hired as *Leidos UK* managing director for national security and defense. Potter was a managing director and board member at Boeing Defence UK and before that was with Lockheed Martin Global.

BridgeComm has appointed **Paul Searcy** chief scientist and **Mike Mabry** technical program director of the optical wireless communications entity. Searcy was Meadowlark Optics vice president of research and development, and Mabry was Lockheed Martin principal R&D investigator.

AAR Corp. has elected **Robert F. Leduc** to its board. Leduc, who retired as president of Pratt & Whitney, also held senior executive roles at United Technologies Corp. and Sikorsky Aircraft among others.

CDB Aviation, a subsidiary of China Development Bank, has hired **Brendan O'Neill** as chief financial officer. He was senior vice president of financial reporting, planning and analysis at DAE Capital.

Robert Knox has been promoted to *AvAir* chief accounting officer from senior vice president of finance.

Avineon Inc. has hired **David McGill** as vice president of growth operations. McGill served on the Professional Services Council and as co-chair of the Northern Virginia Technology Council's Cybersecurity and Privacy Committee before joining Avineon.

Stertil-Koni has promoted **Carl Boyer** to Midwest regional sales manager from shop equipment specialist for product sourcing, sales, new business and customer relationships.

Aviation software digital records provider *Bluetail* has hired **D. Darwin Stout** as vice president of sales. Stout previously worked at Gulfstream, Embraer Executive Jets and Bombardier Learjet.

Components manufacturer *Essex Industries* has hired **Mathew Johnston** as vice president of business development. Johnston was business development vice president at Espey Manufacturing and Electronics and at Leonardo/DRS.

U.S. Army Gen. (ret.) **Vincent K. Brooks** has been elected to the *Jacobs Engineering Group* board. Brooks, the eighth African American to be promoted to four-star general, also is on the boards of Diamondback Energy, the Gary Sinise Foundation and the Korea Defense Veterans Association. He is a WestExec Advisors principal and a member of the Council on Foreign Relations.

H+S Aviation, a Signature Aviation Global Engine Services company, has hired **Jim Payton** as global strategic account executive for the company's newly acquired CTS800 engine product line. He had been with Rolls-Royce.

Katrina McFarland has been named to the *Exyn Technologies* board. She was assistant secretary of defense for acquisitions and acting assistant secretary of the Army. She is also a materials, mechanical, civil and electronics engineer.

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

FIRST TAKE

For the latest, go to
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RELIABLE ROBOTICS

COMMERCIAL

U.S. startups Reliable Robotics and Xwing are independently flight-testing Cessna Caravans modified for autonomous flight. Both plan regional cargo operations with unmanned Caravans (page 34).

The FAA is seeking information from industry on counter-unmanned aircraft systems for deployment at civil airports and for testing to determine the risk to a large turbofan engine from ingesting a small drone (page 30).

The NTSB has confirmed three mid-air collisions of drones with manned aircraft in the U.S. since 2017, and the board rates three other incidents as suspected drone collisions.

Energy company Phillips 66, renewable-fuels producer Gevo and fuel distributor Air BP, working with Finland's Neste, have all announced deals to make additional sustainable aviation fuel available.

Administrators for Virgin Australia are recommending creditors vote on Sept. 4 to accept Bain Capital's proposed A$3.5 billion ($2.5 billion) takeover of the airline.

AirBaltic and Airbus have agreed to delay delivery of the remaining 28 A220-300s the carrier has on order, with a new plan to complete delivery of all 50 of the type by early 2024.

Boeing has garnered its first new sale for the grounded 737 MAX this year, with Polish charter airline Enter Air placing a firm order for two 737-8s and options for two more.

SPACE

An independent panel commissioned by the U.S. Commerce Department has concluded its Office of Space Commerce is the best-suited federal agency to oversee future space traffic management.

KBR, once a high-profile energy and military logistics company, will acquire Centauri, a space, defense and intelligence company, in an $800 million deal that KBR calls "transformative" to its business.

The ninth and final Japan Aerospace Exploration Agency HTV cargo vehicle departed the International Space Station on Aug. 18, filled with trash for a destructive reentry into the Earth's atmosphere.

DEFENSE

Argentina is to loan Cordoba-based FADEA $2.5 million to build a second prototype of the IA-100 piston-powered trainer, which has been on hiatus since the first prototype flew in 2015.

Japan has issued what appears to be a request for proposals from UK and U.S. companies seeking to act as partners for the planned F-X fighter program.

Belgium and the UK plan to study areas of potential cooperation on unmanned aircraft systems. Both are gearing up to begin operations with the General Atomics MQ-9B SkyGuardian.

The U.S. Army is inching closer to its vision for equipping the Future Attack Reconnaissance Aircraft with air-launched effects by awarding $29.75 million in contracts for 10 projects.

The Israel-United Arab Emirates (UAE) peace agreement should open the door for the U.S. to approve Abu Dhabi's six-year-old request to acquire Lockheed Martin F-35s, the UAE's top diplomat said (see box at left).

By the end of September, the Pentagon will have cleared five companies—Altavian, Parrot, Skydio, Teal and Vantage Robotics—to sell small unmanned aircraft systems to the U.S. government.

A Boeing F/A-18E/F has started a "ski-jump" takeoff demonstration that is critical to the fighter's chances in an Indian Navy competition.

TECHNOLOGY

UK startup Vertical Aerospace has revealed its VA-1X tiltprop/multirotor

VIEW FROM WASHINGTON

Faster Weapons Sales to U.S. Allies?

The sale of Lockheed Martin F-35s to Poland paves the way for future Joint Strike Fighter deals to close within six months of the initial agreement, says the Pentagon's acquisition chief.

Defense trade modernization is a "key initiative" for Defense Secretary Mark Esper because the U.S. wants to support its partners and allies by supplying equipment, says Ellen Lord, undersecretary for acquisition and sustainment. It is helpful for U.S. partners and allies to have interoperable equipment while also blocking Russia from selling its platforms, she says.

Poland announced last summer it intended to purchase F-35As, and the NATO ally signed a contract for 32 aircraft in January. "I think the Poland effort really shows what happens when all the [Defense Department] agencies . . . work very closely with the State Department," Lord says.

The New York Times reported Aug. 19 that the Air Force provided a classified briefing on the F-35 to the United Arab Emirates (UAE). Asked if selling F-35s to the UAE is on the table, Lord deferred to the State Department.

VERTICAL AEROSPACE

electrical vertical-takeoff-and-landing (eVTOL) aircraft. The company plans to fly a prototype later in 2021 and bring the design to market in 2024.

Another UK startup, Hill Helicopters, has revealed plans to develop a five-seat, single-turbine helicopter for the private aviation market. Production is expected to begin in 2023.

Israel's Urban Aeronautics has signed an agreement with U.S.-based emergency air transport provider Hatzolah Air to develop a version of Urban's City-Hawk air taxi for emergency medical service applications.

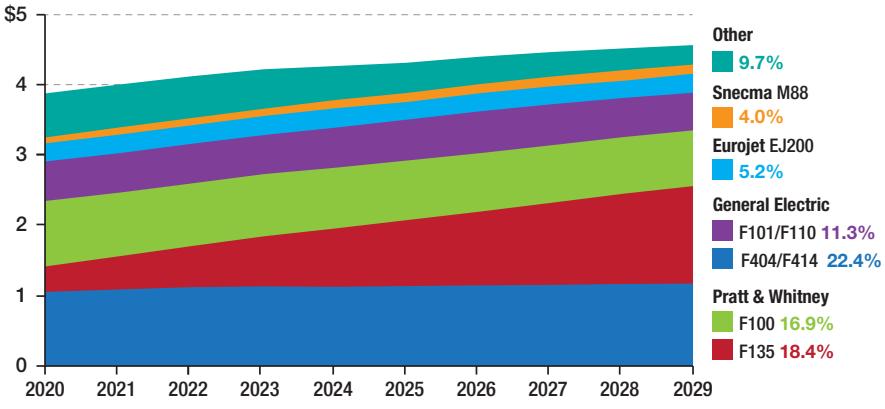
China's EHang is to launch an urban air mobility trial in Linz, Austria, the first operation of its kind in Europe. The initial phase of the trial will involve the EHang 216 autonomous eVTOL air vehicle.

Florida's aerospace and spaceport development authority, Space Florida, is to invest in Aerion Supersonic to support development of the manufacturer's new production site in Melbourne.

An additively manufactured bearing housing developed by Honeywell for the ATF3-6 turbofan has become the first 3D-printed flight-critical part certified for service on an operational engine.

Growing Military Engine Repair, 2020-29

(U.S. $ trillions)



Source: Michael Tint/Aviation Week Intelligence Network

Jet engines powering Western-designed fighters and training aircraft will generate $50.5 billion in maintenance, repair and overhaul demand over the next decade—rising from $4.5 billion in 2020 to $5.6 billion in 2029, for a compound annual growth rate of 2.45%. Most of the growth will come from Pratt & Whitney's F135, the engine on Lockheed Martin's F-35.

For more information about Aviation Week Intelligence Network data, go to **awin.aviationweek.com**

30 YEARS AGO IN AVIATION WEEK

The Lockheed F-117A made its first overseas deployment in August 1990 as 20 of the stealth attack aircraft were sent to Saudi Arabia in response to Iraqi strongman Saddam Hussein's occupation of Kuwait. Aviation Week Engineering Editor Michael A. Dornheim flew aboard a Boeing KC-135Q tanker that refueled the F-117As on the first leg of the trip from their base in Tonopah, Nevada, and took the photo that appeared on our Aug. 27 cover. The Lockheed-built aircraft had been operating since 1983 but had only recently come out of the shadows. Dornheim wrote that most of the crewmen onboard the KC-135 had never seen one. The F-117A's ability to precision-bomb while avoiding radar played a key role in defeating Iraqi forces and liberating Kuwait in early 1991, not to mention establishing a new generation of U.S. air dominance. The stealthy bomber was retired in 2008 after 25 years of service.

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

UP FRONT

P. BARRY BUTLER

Age of Automation

Training new pilots **to interface with machines**

TWENTY YEARS AGO, AERONAUTICAL science students did not arrive at Embry-Riddle Aeronautical University with hundreds of hours of flight time on a PC-based simulator. Nor did they own unmanned aerial vehicles equipped with remotely operated cameras and autoland control capability. Today's "internet of wings" continues to advance, bringing new capabilities as well as vulnerabilities to all types of aircraft and, equally importantly, their operators.

As aircraft, computers and automation merge at a rapid pace, my workday priorities remain constant: to help make our students as successful as possible and to provide the aviation industry with critical research and a workforce prepared to innovate and adapt to technological advances in aviation. While COVID-19 has temporarily slowed our industry, we cannot stop preparing for the future of aviation.

In today's environment, preparing students to become pilots and industry leaders goes beyond stick-and-rudder training. The future will be full of "flying computers." As commercial airliners and airports become increasingly automated, aviation leaders must keep expanding their awareness of how current human-in-the-loop research will revolutionize "business as usual" tomorrow.

DAVID MASSEY/EMBRY-RIDDLE

Embry-Riddle has always prioritized safety, which has made us early adopters of simulation and virtual and augmented reality—critical tools in advancing our knowledge of human-machine interfaces. Our philosophy is that we do not train pilots; we prepare decision-makers. Our flight-training programs strive to incorporate an understanding of human factors to ensure that pilots of highly automated aircraft can respond swiftly in a crisis. Through our research programs, we continue to explore how aircraft systems can benefit from artificial intelligence and automation without causing a concomitant degradation of pilots' stick-and-rudder skills. For example, we have ongoing research into whether onboard, real-time diagnostics help pilots maintain situational awareness despite increased automation on the flight deck.

The convergence in technology drives a convergence of disciplines. As educators, we must integrate expertise from multiple disciplines. A traditional silo mentality restricts our field of view. To get the highest performance from humans and their flying machines requires cross-disciplinary research and education.

In response to the merging of highly automated aircraft and their human operators, we have challenged our five colleges to create more cross-disciplinary initiatives and shared research, informed by industry advisory boards. We have convened aviation experts focused on flight, design, manufacturing and human factors to advise us in developing robust cyber- and big-data education, for example. We are also undertaking collaborative research with multiple airframe manufacturers—companies with different philosophies on the "allocation of control authority" between pilots and aircraft.

Our goal is to infuse all of our educational programs with a comprehensive perspective on human and machine performance in aviation. That requires competencies that will transform the industry, such as data analytics, cyber-resilience and advanced manufacturing. We also want graduates of our technical programs to have a solid business foundation so they will recognize how to monetize new opportunities.

This broadening of old boundaries is critical to aviation safety, efficiency and the economy. Designers need to understand pilots so their designs reflect human manual and cognitive skills. Pilots need to understand the aircraft's architecture and logic so they do not sacrifice situational awareness and become complacent or overly reliant on automation. Scientists need to understand entrepreneurship to speed the evolution of ideas into products.

Driving technological innovation and research in higher education is vital to the future success of our industry. Discovery-driven education is equally important. Providing real-world, applied research opportunities for students will ease their entry into tomorrow's aerospace workforce and elevate their value to employers.

Figuring out how best to keep "humans in the loop" as we develop more autonomous and intelligent systems is a defining challenge too complex for any single discipline or institution to address alone. Figuring out how best to keep "students in the loop" so they graduate with a strong foundation backed by a varied skill set is a defining challenge for aviation education.

P. Barry Butler is president of Embry-Riddle Aeronautical University.

GOING CONCERNS
MICHAEL BRUNO

BEFORE THE COVID-19 OUTBREAK this spring, flight simulators and pilot training were some of the hottest side hustles that legacy aerospace manufacturers could play as they rode the historic updraft in airliner traffic. Business was expected to be so good that even with the grounding of the Boeing 737 MAX, leading simulator and training provider CAE was building "white tail" simulators without assigned customers.

That was then, and this is now. According to a new analysis by Oliver Wyman advisors, if Congress and the Trump administration fail to provide another bailout for the airlines by Oct. 1, the U.S. could see as many as 225,000 additional airline workers lose their jobs starting this fall, or 30% of the total U.S. airline workforce. That is on top of cuts already made through voluntary departures.

U.S. majors spent the summer warning that thousands of pilots could be let go. LinkedIn is filling up with essays about how pilots can change careers and why other industries should consider hiring professional pilots due to their skill sets and temperaments. But since global commercial air travel is not expected to return to 2019 levels until 2024, according to the International Air Transport Association and S&P Global Ratings, a casual observer could expect the simulator and training business to go cold fast.

There is a chill, for sure. In June, Textron announced it ceased manufacturing at its TRU Simulation + Training facility in Montreal, essentially exiting the marketplace. "We've seen a substantial decline in demand and [an increase in] order cancellations for flight simulators in light of the expected long-term impact of the pandemic on the commercial air transport business," Chairman, CEO and President Scott Donnelly told financial analysts on July 30.

The commercial simulator business accounted for roughly $100 million of Textron's annual revenue, just 1% of sales—not a big loss for the multi-industry giant. Still, exiting a business is a long-term gamble, and rivals L3Harris Technologies and leader CAE have not gone that far.

Certainly, L3Harris and CAE see less activity, and they are going through restructuring of their own. L3Harris, which recorded about $800 million in related revenue last year, anticipates simulator sales will be down 40% for 2020. As of the second quarter, its training business was off 40-45% from plan, with no new full-flight simulators sold after the first quarter—and no expectations of any for the rest of this year.

CAE also experienced dramatic cuts in activity. With more than half of its global training operations either closed or temporarily reduced, utilization reached a low point around the 20% range during the recent quarter, CEO and President Marc Parent said on Aug. 12. Since then, the Canadian company has seen average training center utilization rise to 40% as some flight crews resumed some of their critical training activities. What is more, the company managed to sell two full-flight simulators to airline customers during the quarter, a period that analysts broadly expect to be the nadir of the pandemic.

Looking To Climb

Simulator and pilot-training providers see **blue skies**

CAE

Indeed, the irony of the situation is that despite the rapid, sudden contraction of the marketplace, the pilot-training and simulation business still should be a growth industry. According to an August report by Global Industry Analysts, a big-data market intelligence firm, worldwide commercial and military flight simulation is projected to reach $6.1 billion by 2025, with a compound annual growth rate of 3.9%. Driving this growth will be the need to curb rising costs of pilot training by replacing traditional techniques with low-cost virtual training methods, the launch of new-generation aircraft and the parallel need to retrain pilots. On top of all that, if airliner travel does return to 2019 levels and continues growing, there could once again be a pilot shortage.

CAE and L3Harris see it, according to their leaders. "As the global fleet eventually resumes service, we expect to continue building on our previously positive momentum, increasing market share and securing new customer partnerships with our innovative training and operational solutions," Parent says. "We're currently in advanced discussions with a number of airline customers to potentially do more for them. I believe the current context will lead to more airline training outsourcing opportunities as the industry looks for ways to gain greater agility and resiliency in the post-COVID-19 era."

L3Harris Chief Operating Officer and President Christopher Kubasik expressed similar sentiments in June to Aviation Week. "It'll be interesting to see how the airlines [respond]," he said. "Are they going to still deploy capital to buy simulators, or are they going to send them to our schoolhouses, where we've already invested in the sims?"

Before the pandemic, L3Harris increasingly sensed that airlines wanted to outsource training and simulation, so they can keep all of their own pilots dedicated to revenue-producing flights. But even if they do not, L3Harris is positioned to respond. "We're kind of on both sides of that equation," Kubasik stressed.

INSIDE BUSINESS AVIATION
WILLIAM GARVEY

THE COLLIER TROPHY GOES TO "the greatest achievement in aeronautics or astronautics in America" during the preceding year. One year it went to Chance-Vought's F8U Crusader, a just-launched U.S. Navy fighter. Fine choice, but the right one?

After all, there was another aircraft that also first flew in 1955, Cessna's Model 172 Skyhawk, a Mach 0.17 (125 mph) performer versus Crusader's Mach 1.2. And yet that and its other modest numbers, including a base price of $8,750, made Cessna's new low-tech model an instant hit. Why?

TEXTRON AVIATION

An iteration of the four-seat, high-wing Model 170, the 172's principal difference was its landing gear. The 170 was fitted with two main fixed gear forward and a tailwheel, a so-called "conventional" configuration, whereas the 172 substituted a nosewheel for the tailwheel—a "tricycle gear" setup. To the unfamiliar, that may seem inconsequential, but most pilots prefer the latter by far.

A tailwheel plane's nose points skyward while on the ground, and the angle can be so pronounced as to block the view of the pavement ahead. Consequently, the pilot must sashay while taxiing. And when landing, the runway can disappear again just before touchdown, making rollout an act of faith. Additionally, crosswinds require serious rudder and aileron work when taking off, touching down and on the ground since the forward placement of the main gear results in an aft center of gravity (CG), which, combined with a castoring tailwheel, can cause the aircraft to "weather-vane" into the wind.

By contrast, tri-gear aircraft sit level, providing a clear view forward when on the ground. And most nosewheels do not swivel, which, along with a forward CG, helps stabilize the aircraft from crosswind forces while on the ground.

The seemingly simple switch resonated with buyers, and Cessna delivered a remarkable 1,400 172s in 1956, the first full year of production. Thanks to that nosewheel and the aircraft's stellar operating record, they have been buying ever since.

Martha King, a co-founder with her husband, John, of the well-known King Schools pilot instruction company, recently described the 172 thusly: "It's dependable, predictable, well-mannered and maintainable by almost anybody." To which John added: "And trustworthy, reliable and capable."

In addition to their Dassault Falcon 10, the Kings have owned several 172s, purchasing their current one last year. Long a staple among flight schools globally, the Skyhawk, according to the Kings, is "part of the foundation of civil aviation." Indeed, it seems most pilots, including many military aviators, have logged time in a 172.

And Mark Baker, president and CEO of the Aircraft Owners and Pilots Association, opines that the 172 is "about the most versatile and forgiving airplane out there, and a great choice for those both learning to fly and looking for their first airplane." Baker has owned four of the type in his life, including one for his son's and nephew's flight training.

Cessna has updated the model regularly with more powerful engines and improved avionics—the current 172S features a 180-hp Lycoming engine and a Garmin G1000 cockpit—but save for the swept fin and rear windows added in the 1960s, its configuration is close to the original. Operators seem to approve.

The 172 Skyhawk has been in manufacture, with a notable interruption, since the outset. Cessna reportedly turned out more than 4,000 during the model's first five years, but between 1986 and 1996 it suspended all lightplane production while the industry campaigned, ultimately successfully, to resolve product liability issues. Since then, annual Skyhawk output has ranged from 490 in 2000 down to 85 in 2010. Last year it delivered 126 and another 48 in the first quarter of 2020.

In total, more than 45,000 Skyhawks have been delivered, making it by far the most populous airplane ever produced, with more being added every month.

And while the retail price of a new 172 is now $400,000, the Aircraft Bluebook notes that prices for 10- and 20-year-old models average $280,000 and $135,000, respectively—reasonable in a market where the age of a single-engine piston aircraft averages 46 years. As for an original 1955 Skyhawk: yours for $25,000.

All in all, these are impressive numbers for a Medicare-qualified flying machine, one that continues in both widespread service and production. It seems award-worthy to me. Meanwhile, of the 1,261 Crusaders built, the Navy retired its last 33 years ago.

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

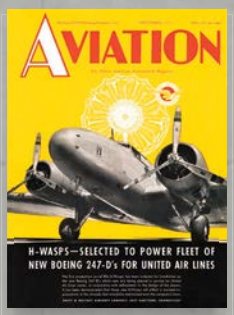
1918

1959

1982

104 YEARS
COUNTLESS MILESTONES

1934



1967

1995

2019

1944

1968

2007

2020

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Time To Face Reality

Getting back to 2019 is **the wrong target** for aircraft OEMs

SINCE THE COVID-19 PANDEMIC waylaid commercial aviation in March, there has been much talk about when aircraft production volumes will return to "normal." Across the industry, leading CEOs have defined "normal" as 2019. But a closer look at earlier market forecasts and planned production rates shows that 2019 is the wrong benchmark.

Although conventional wisdom last year was that Airbus and Boeing would raise output ever higher, the two aircraft manufacturers already were producing more airplanes than the market could absorb and were planning to build significantly more in the future. Let's do the math.

In 2019, Airbus projected demand for 39,000 aircraft of 100 seats or more over the next 20 years—an average of 1,970 annually and a figure roughly in line with Boeing's forecast. If the two companies split the market 50-50, each would have demand for 985 aircraft a year. But that number already is too high because it does not take into account sales by Brazil's Embraer, China's Comac or Russia's United Aircraft Corp. It is also possible that another company, perhaps a market disruptor, could build the first hybrid-electric 100-seater in the next couple of decades.

AIRBUS

Airbus delivered 863 aircraft in 2019, reasonably close to its allocation of the forecast 20-year average; Boeing planned to build and hand over about 860 jets last year, for a combined total of approximately 1,840 aircraft. Boeing ultimately delivered just 380 units because of the 737 MAX grounding, but the point is that both companies were planning to build nearly as many aircraft as their average forecast for the next 20 years. In other words, even before the biggest downturn in aviation history, no room for any production growth existed. Take the other aircraft manufacturers into account, and you could surmise there already was significant overproduction, particularly in the narrowbody segment.

Of course, the fallout from the novel coronavirus pandemic has made all these studies and production plans irrelevant. But industry needs to realize its pre-COVID-19 plans were already unrealistic. One way or another, it had to go wrong, maybe not as dramatically as it turned out, but there was no way the dreams could have become reality.

To no one's surprise, the signs of overproduction have been visible during the crisis. Airbus cut output by only one-third, aiming to keep as high a level as possible. Boeing wants to hand over the undelivered stored MAXs and ramp up production of new ones at the same time. Essentially, airlines may be forced to accept aircraft they clearly do not want and cannot afford. Airbus is already producing a significant number of white tails, something it had promised to avoid.

Keeping production high now is shortsighted. It weakens airline customers further during a time of huge financial pressure. It is also bad for future pricing once airlines are ready to take more aircraft. There will be ample capacity from lessors or cheap, almost brand-new aircraft that operators want to dispose of.

Arguably, steep cuts in production could ruin the supply chain. But the bitter truth is that although some parts of the supply chain were struggling to keep up with the tempo before the crisis, there is now far too much capacity. And clearly, an excess of capacity will continue for years.

Management understandably wants to minimize the damage and needs time to digest the avalanche of bad news over the past few months. The financial and market pressures are also obvious: the fewer deliveries, the less revenue and the smaller the market share. Boeing, already badly damaged by the MAX production interruption and that aircraft's disappointing reception by customers, has every incentive to contain any further loss of market share.

Nonetheless, more tough decisions loom. On the Boeing side, a slower reintroduction of the MAX is inevitable, as is a very slow service-entry process for the 777X. Airbus will have to cut narrowbody output further. If long-haul travel does not return quickly—and no indications suggest it will—Airbus will also have to take another hard look at A350 and A330neo rates, as painful as that may be.

Remembering that earlier plans were unrealistic will be particularly important once demand recovers. A more measured approach is needed this time despite competitive incentives to do the opposite.

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71st International Astronautical Congress
– The CyberSpace Edition
12-14 October 2020

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'The Golden Age Is Over'

- > PANDEMIC CAUSES UNHEARD-OF FALL IN DEMAND
- > SLATTERY SUCCEEDS JOYCE AS CEO OF GE AVIATION
- > GE AVIATION TO REDEFINE TECHNOLOGY ROAD MAP

Jens Flottau Frankfurt

Years from now, historians will look back and describe 2020 as a catalyst for fundamental change across the aviation sector. The novel coronavirus pandemic has had multiple, multifaceted effects across the aviation industry, some of which are still to unfold.

The engine sector is likely facing the most fundamental change. Engine OEMs often have been their own worst enemy, as troubled development programs led to disgruntled customers and billions of dollars in extra costs. Every one of the "big three"—GE Aviation, Pratt & Whitney and Rolls-Royce—has a story to tell. But fundamentally, business was great until the crisis hit. The CFM56 had proved to be a goldmine for partners GE and Safran. The IAE V2500 was highly successful for Pratt, Rolls-Royce and MTU Aero Engines. A business model that bet heavily on aftermarket revenues had worked well for decades. More recently, engine sales at CFM and Pratt were lifted by brisk demand for the new Airbus A320neo and Boeing 737 MAX narrowbodies. In a fast-growing industry, there was plenty of money to be made.

GE Aviation's GE9X powers the Boeing 777X, which is in flight testing.

And now? "The golden age is over," says Sash Tusa, an aerospace analyst at Agency Partners in London. The aircraft production and aftermarket services markets have been hit with severe downturns at the same time. "That has never happened before," notes Kevin Michaels, managing director of AeroDynamic Advisory.

For OEMs, the coming years will be characterized by lower profit margins and higher risk. Even before the pandemic, GE, Safran and their suppliers were suffering from the grounding of the Leap 1B-powered MAX and a stalled buildup of Leap 1A engine production for the A320neo. COVID-19 has walloped engine-makers just as they were preparing for much larger volumes, making massive investments to boost capacity only to be forced to retrench. They are also under pressure, particularly from governments in Europe, to accelerate development

of a new generation of environmentally friendly powerplants.

The approach of hyper-disruptive technologies will challenge engine OEMs more than aircraft manufacturers or airlines. While they may hope to be able to play a key role in the upcoming push to use hydrogen—particularly if it is treated as a drop-in solution based on existing engine architectures—there is no guarantee that today's incumbents have what it takes to lead in electric propulsion. After all, their specialty has long been burning hydrocarbons as safely and efficiently as possible.

"Electric is still engineering," says Avitas Senior Vice President Adam Pilarski. But it is very different engineering. Because of these emerging technologies, engine life cycles are likely to be shorter than the 20 years with which industry incumbents have grown comfortable.

It is at this inflection point that David Joyce leaves the stage as the long-time CEO of GE Aviation, and John Slattery enters as his successor. Slattery, an ambitious leasing executive from Ireland, built his career in aerospace manufacturing running Embraer's Commercial Aviation unit. He was the driving force behind the deal to merge the unit into Boeing, which would have launched major growth in joint future projects, he hoped. GE declined to make either Joyce or Slattery available for an interview.

BOEING

While Joyce doubled GE Aviation's sales and expanded its backlog tenfold during his 12 years at the helm, he departs amid a bloodbath caused by COVID-19. In the second quarter of 2020, new engine installations were half the level of a year earlier, while spares and aftermarket shop visits each declined by 55%. Even with the buffer of a strong military engines business, quarterly sales were down 44%, to $4.4 billion. GE Aviation was forced to cut 5,400 jobs as it posted a quarterly loss of $700 million. GECAS, GE Aviation's sister company, decided to cancel almost half of its outstanding orders for Boeing 737 MAXs, a total of 69 aircraft, all of them powered by Leap 1B engines.

The collapse of the Boeing-Embraer deal occurred at the same time as GE Aviation's parent company, led by Larry Culp, was looking for an outsider to succeed Joyce, who was nearing the end of his 40-year career at GE. Slattery, who is widely viewed as a change agent, faces the challenge of making GE Aviation operate more efficiently as it adjusts to lower output.

GE's pick of Slattery "makes 100% perfect sense," Pilarski says. "[Joyce and Slattery] are very different people who fit the requirements of GE Aviation at a given time. David is a superb engineer, and John is more the business type. Both are leaders. They set visions, and people follow them."

The base from which Slattery will start work was built by Joyce. GE is known for superbly engineered engines. But beleaguered airlines and lessors will have little to no money to spend on those engines, and it remains unclear when Boeing will be able to afford to launch a successor to the 737 MAX narrowbody family.

GE AVIATION

John Slattery, incoming GE Aviation CEO

"Guys like Joyce are not really needed right now," Pilarski says. "Things have changed, and you have to think about the industry in new terms. Slattery knows how the business works and has the creativity to deal with the situation."

Pilarski's advice to Boeing is to keep the MAX going for as long as it can. "And then we will need a moonshot in the next 15 years, a revolutionary approach, something new," he says. "We need totally green aircraft, and you don't get there in small steps."

What that moonshot is going to look like and when the industry will be ready for it is a matter of discussion. Tusa believes that hybrid-electric propulsion will be the technology of the 2030s, followed by hydrogen as the technology of the 2040s. Michaels says conventional engine technology will continue to play a big role longer because neither of those two new paths is realistic in the short term. "It is going to take much longer to transition to hydrogen and electric," he predicts.

Slattery is known for thinking several steps ahead as he takes into account technology trends and likely moves by his competitors. But with so many questions about the future of propulsion unanswered, he faces a daunting challenge at GE.

The longer it takes for a revolutionary engine to take shape, the easier it will be to put together a workable business case for interim technologies. Unlike Pratt, neither GE nor Rolls-Royce have a geared turbofan (GTF) in production. "Eventually, they have to go down the GTF path," Michaels says. He thinks it is likely that GE is working on a geared turbofan behind the scenes while Rolls is developing the UltraFan large geared turbofan.

The Leap engine with a fan-drive gearbox would likely be around 3% more fuel-efficient than the current-generation Pratt GTF, estimates one senior industry source. The executive noted that the current Leap engine is also lighter than the competing powerplant, enabling additional savings. The direct-drive Leap was GE's response when it was forced to detour from its long-term technology development road map as Boeing launched the 737 MAX in response to the Airbus A320neo and needed an engine quickly from incumbent CFM.

With demand slumped, Slattery has time to map out a long-term strategy to take on Pratt and Rolls.

Meanwhile, service entry lies ahead for the 105,000-lb.-thrust GE9X powering the Boeing 777X, the world's most powerful commercial aircraft engine. Engine durability issues had delayed the first flight of the aircraft by more than half a year into January 2020. Now the COVID-19 crisis has hit an already weak market for large widebodies. If anything, smaller long-haul aircraft such as the Boeing 787-8 and -9 are increasingly attractive to airlines because they combine lower unit costs with much lower trip costs than the 777X. At some point, a large widebody will be needed on some routes, but doubts are growing that the 777X's initial business case can be met.

As for that moonshot, the adoption of biofuels on a much larger scale

could significantly reduce carbon-dioxide emissions with existing engines until the industry is ready. Michaels believes biofuels may be the way to go for long-haul aircraft even for decades, given that there is no obvious alternative in sight. That would certainly boost the 777X's prospects.

"Looking back, 2010-20 can be viewed as the golden era of innovation," Michaels says. He points to Pratt's introduction of the GTF, which marked its return to the narrowbody market, and GE's development of the Leap family of engines succeeding the CFM56. "We are now going to take a pause," he adds.

But taking pauses is not something Slattery is used to. At Embraer, he pushed hard for the launch of a new turboprop that would compete with the ATR 72 and de Havilland Canada Dash 8-400. The project was to be based on a more modern yet conventional engine that would have been open to hybrid elements down the road. The Embraer board was skeptical, and the project was shelved when the sale to Boeing collapsed.

Slattery brings to GE a fresh pair of eyes that likely will see opportunities someone like Joyce, who has grown up inside the system, may not have. And while cost efficiencies might not have been a top priority when business was booming, they will be much more critical in a time of crisis.

"GE Aviation was scaled for a lot of growth and is already horribly damaged by MAX" before the pandemic, Tusa says. He predicts that the MAX, on which the Leap has a monopoly, will continue to lose share to the A320neo in the narrowbody market. Since the beginning of 2020, more than 800 MAXs have been cut from the backlog as customers exercise clauses that become applicable after delivery is delayed by one year. While Boeing has projected the MAX and A320neo families will roughly split the market, Tusa thinks Boeing's share could drop as low as 35%.

On the A320neo, the Leap must compete against the GTF for a shrinking number of aircraft. Airbus has reduced Neo production by about one-third from 2019, to 40 per month, and Tusa believes the airframer could be forced to scale down to 25 per month because of weak demand.

While there is an obvious correlation between the number of new aircraft produced and the number of engines needed, aircraft and engine OEMs are not equally affected. With fewer new aircraft coming into the market, some older ones may stay in service longer in spite of the current spike in retirements. And as engine-makers traditionally make most of the money with heavy checks, there would be some positive opposite effect.

The flight-hour agreements that have become so popular with the engine OEMs are an interesting case, and it is not yet clear how they will weather the crisis. The traditional shop-visit-based model meant that OEMs were waiting years for serious maintenance, repair and overhaul revenues to come in, typically seven years based on the cycles for heavy checks. The flight-hour agreements typically cut that into seven annual installments of roughly one-seventh the cost of the overhaul. More cash comes in upfront, and the engine manufacturer can decide to some degree when to bring the engine in for an inspection, based on the maintenance and inflight data generated during routine operations.

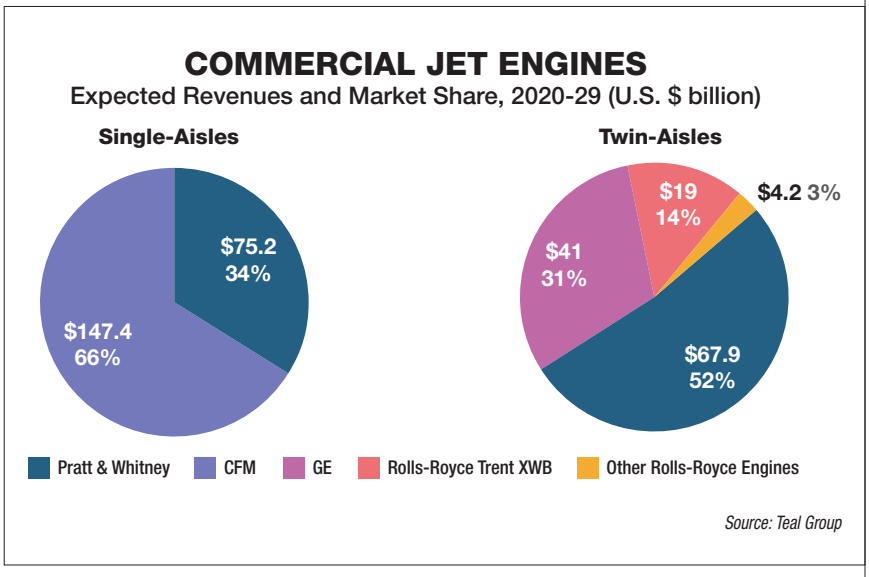
"It is very smart," Tusa says. "The problem is: If airlines don't fly the engine, they don't pay as much." To make matters worse, if aircraft are retired and are broken up, the market is flooded with relatively inexpensive engine spares, particularly when demand for them is so low. This is a further dent in the potential market.

These total-care packages also usually do not transfer when an engine is sold to a new owner, a factor of uncertainty in times of high volatility. Big airlines want to do their engine maintenance in-house anyway, and they will plan to keep it that way for strategic reasons as long as they can.

"It is hard to see a super-happy picture for anybody in this," Pilarski says. But he expects Slattery will find creative ways to deal with customer arrangements while at the same time protecting GE Aviation's interests. "When aircraft get older, virtually all the value is in the engine," he notes. "But what is the value of the engine these days?"

At GE, there are also more structural questions to be answered. In 2007, GE Aviation acquired Smiths Aerospace for $4.8 billion, a lot of money then and even more by today's standards. Smiths' products include flight management systems; power generation, distribution and conversion; actuation products for flight control systems; landing gear and thrust reversers as well as several engine components. The takeover was part of GE Aviation's drive to broaden its portfolio beyond the core engine business. In hindsight, the Smiths deal is something the company may now not be happy about and something that was not really necessary, Pilarski argues.

So will the crisis lead GE Aviation to focus on what is really core—building great engines—and leave vertical integration to rival Raytheon Technologies? The answers are another big part of Slattery's next game of chess.



GENERATION JUMPSTART

> PRATT & WHITNEY STUDIES HYBRIDIZED GEARED TURBOFAN

> ROLLS-ROYCE ACCELERATES AND WIDENS SUSTAINABLE AGENDA

Guy Norris Los Angeles

Staggering under the impact of multiple hits of deferred engine maintenance, the premature retirement of older fleets and wholesale production cutbacks, engine-makers have seen setbacks on all fronts because of the COVID-19 pandemic.

But could there be glimmers of hope amid the gloom? Both Pratt & Whitney and Rolls-Royce believe that, among other side effects, the longer-term impact of COVID-19 may accelerate the adoption of advanced propulsion technology as governments tie stimulus aid to environmental goals and airframers revise product-development strategies.

Pratt & Whitney President Christopher Calio says the pandemic has forced the engine-maker to "really interrogate" its technology road map. "Where do we want to invest our scarce and precious dollars?" he asks. "In some cases, we've said to ourselves, 'Maybe we need to skip ahead to technologies that we thought were further away. This pandemic might actually [offer us an] opportunity to pull forward.'"

Calio, president of the company's commercial engine business prior to assuming his role in January, echoes similar comments made by Airbus and Boeing executives who have indicated a potential shift in strategy to accelerate the adoption of more advanced technology for next-generation designs.

While Boeing indicates it may move more quickly toward a new advanced, but conventional, single-aisle concept later this decade, Airbus is already pivoting to more radical design studies for the 2030s centered on hydrogen fuels and alternative propulsion as part of France's stimulus package and its focus on sustainability. Although it remains uncertain whether these plans can realistically support the development of single-aisle-size aircraft by the early 2030s, they will nonetheless accelerate the maturation of the new propulsion technologies required to achieve this goal.

"We have to make some of those trades and choices to be ready for what's next," Calio says. "Because I think what's next might come a little sooner than the rest of us previously anticipated." Although Pratt believes its PW1000G geared turbofan (GTF) family is still relatively early in its development life cycle, the company is studying next-generation options to improve propulsive and thermal efficiency as well as adaptations to make the engine more compatible with future hybrid-electric power systems.

ROLLS-ROYCE

Rolls-Royce is conducting a final round of low-emissions combustor tests in the buildup to running the UltraFan demonstrator in 2021.

During the first phase of the FAA's Continuous Lower Energy, Emissions and Noise (CLEEN) program, Pratt studied a series of potential propulsive-efficiency improvements, including a short inlet and a low-pressure-ratio fan. More recent work under CLEEN II has shifted to the relatively unexploited thermodynamic potential of the core, where the company has focused on aerodynamic and cooling improvements to the

high-pressure (HP) turbine as well as efficiency gains in the HP compressor. A test rig for the HP turbine is due to run this summer.

The company is also working with NASA on potential next-generation more-electric GTF concept studies that would incorporate embedded megawatt-class generators. Awarded under NASA's Electrified Aircraft Propulsion (EAP) program, the most recent contract is designed to plot a low-risk path toward evaluation on an Electric Powertrain Flight Demonstration (EPFD) flying testbed later in the 2020s. The EAP/EPFD work builds on conceptual work for a developmental hybrid-electric GTF conducted with United Technologies Research Center during the past six years under a 2014 NASA award.

Although details of the work have largely remained under wraps, Michael Winter, senior fellow for advanced technology at Pratt & Whitney, says the company's preferred approach is a parallel turboelectric hybrid with a motor-starter generator mounted on the engine's HP spool and a motor generator on the low-pressure (LP) spool.

"The value proposition here, before you even think about batteries, is that I can optimize the engine at its optimal set points," Winter said at the CAFE Foundation and Vertical Flight Society's Electric Aircraft Symposium on July 29. "I can avoid all the transients and trade all the energy between the spools and use that to essentially take advantage of some of the stall and surge margins that are normally designed into these propulsive systems."

Pratt's analysis indicates the optimized configuration would be worth "about 3-5% energy efficiency for the commercial transports that fly today once it is developed and certified," Winter said. "That technology is likely to be ready for availability for the next round of single-aisles when the aircraft-makers are ready to develop them."

The European-led pivot to studies of a low-emissions hydrogen-based-fuels ecosystem is also factoring into Pratt's future plan, Calio says. "Hydrogen is certainly something that is out there today. I think we'll see that in the smaller aircraft sooner rather than later," he adds. "Obviously, we'll have some space constraints, so we'll have to deal with that, but I do believe that it is a viable option. You've heard Airbus say that is viable in the 2030-35 time frame. So that's something we'll continue to invest in and be focused on, because sustainability is at the core of everything we've done when we designed and manufactured the GTF."

PRATT & WHITNEY

For the foreseeable future, improvements will build on the baseline architecture of the GTF, which remains at the core of the company's commercial strategy, Calio says. "The downturn has required us to be pretty ruthless in how we prioritize our investment and the things that we have to do in the business," he notes. "The one thing that we have absolutely kept front and center is the GTF—that is central to Pratt & Whitney and our future. So we've kept going with the upgrading of the configuration for the GTF, reliability upgrades, life-limited parts upgrades and retrofitting the low-pressure turbine. So we continue to invest both on the production side and also in the maintenance, repair and overhaul [MRO] side.

"We are trying to be as incredibly surgical as we can about what the priorities are, where we need to put our money and being laser-focused on those," Calio continues. "As a team, we are spending a lot of time to try and figure out what our technology map should look like. What does demand look like in 2021 and beyond? And what are the trends in the industry that we are going to have to adjust our plans to?"

In the meantime, Calio says Pratt is focusing on using the downturn to accelerate LP turbine upgrades during shop visits. "This is a horrible situation we're all facing, but we try to make the best of it from an output and MRO perspective, so when this industry finally recovers, which it will, the GTF fleet will be in a much better position than when we came in," he adds. "And so we continue to prioritize MRO and LP turbine retrofits and output in our shops and in our partner shops.

"We did a redesigned LP turbine to enhance robustness, and we really came up with an inventive and agile way of retrofitting the fleet," Calio says. "We had a plan when we came

Pratt & Whitney is studying upgrade paths for future geared turbofan variants, including more-electric adaptations with embedded starter-generators.

into this year about how many we would be able to accomplish, and of course with utilization down, we have been able to schedule more of those LP turbine retrofits than we were able to anticipate. We are accelerating that, so by the time this year is over, we feel the operating fleet that's out there today will be in a much better position. Not only with those that are rolling off the line but those that are coming in for overhaul and getting upgraded."

For Rolls-Royce, also widely affected by the pandemic and the financial woes of correcting long-running durability issues with the Trent 1000 engine, the sharper focus on sustainability may help accelerate future developments on the road to recovery. "It gives us the chance to look at new market opportunities in sustainable propulsion, and I think there is general pressure from both the public and government to try and grow back greener, as it were," says Alan Newby, director of aerospace technology and future programs at Rolls-Royce.

"Therefore, you're seeing a lot of stimulus packages for the industry, not just more of the same, but looking at different ways of growing back in a sustainable manner," Newby says, citing the recently launched UK government-backed FlyZero project to help the country's aerospace industry develop a zero-carbon commercial aircraft by 2030. Led by the Aerospace Technology Institute (ATI), the FlyZero project will begin with an initial 12-month study of the design challenges and market opportunities for potential zero-emissions-aircraft concepts. The study is part of a £400 million ($520 million) investment in aerospace R&D announced by London on July 20.

With £200 million in government grants through ATI matched by industry investment, the funding will support continued development of Rolls' UltraFan next-generation engine family, future wing design work at Airbus UK, a power systems project led by Safran Electrical & Power UK and a cabin systems project led by Williams Advanced Engineering.

"There have also been stimulus packages in France and in Germany looking at advanced technology development, so yes, I think [the fallout from the pandemic] will accelerate that," Newby says. "I think it's a good thing for the industry, and it's a good thing for the environment if we can use this period to actually invest some money in helping the industry get back but also put it back in a more sustainable manner."

This, in turn, may drive the earlier adoption of more ambitious propulsion, airframe and systems technology developments than might otherwise have taken longer to evolve. "Within Europe, we are looking to what their future funding program might look like for a clean aviation program within Horizon Europe," Newby says. "The strategic research innovation agenda has been published, and there's quite a big emphasis on more disruptive configurations. These include looking at more advanced derivatives of conventional designs but also hybrid-electric solutions and potentially hydrogen. So you can see that's the thinking about what future funding programs might veer toward."

The stimulus packages also help sustain research across a wider spread of technology options, particularly for the smaller regional and single-aisle sectors. "It's that middle ground, I think, where it's fascinating because you've got hybrid electric in the mix, you've got fuel cells and you've got hydrogen," Newby adds. "I think you'd be unwise to back one horse at the moment."

Following several years of research into electric propulsion, the industry now has "a more mature view as we understand what some of the challenges are, particularly with respect to battery energy density, for example, and battery weight," he says. "On hydrogen, I think we're on the way up in terms of the level of interest, but there's still a lot of work to be done in terms of how you handle it, the infrastructure and some of the safety and certification aspects as well."

So which will come out on top? "It might end up that it's a kind of time-based solution, where there might be one solution for now via hybrid electric or something, and then maybe a more disruptive one in the future," Newby says. "That's what most of us are looking at now, and that's why I really welcome initiatives like FlyZero."

Similar to Pratt, Rolls-Royce is

exploring new ways to bring the potential operational benefits of hybrid-electric technology into gas turbines for single-aisle and larger applications. "Wholesale propulsive power from electrification will be unlikely for the foreseeable future, but that doesn't mean to say you won't get benefits from it," Newby says. Experience gained on the company's long-running Embedded Electrical Starter-Generator demonstrator with a modified Adour engine—and, more recently, the 2.5-megawatt AE2100-driven generator at the heart of the now terminated E-Fan X hybrid-electric power-generation system—have encouraged further studies. Ground tests of the generator are due to be completed in the company's Bristol, England, facility by the end of 2020.

"We can create some kind of micro-hybridization, where you've got some level of stored energy that you can use to supplement onboard power for transient assist, particularly where we might be able to cut the corner off a particularly arduous part of the operating envelope and trade power across shafts, for example," Newby says. "We've got some quite neat ideas on that."

While work continues to support disruptive propulsion-technology research, Rolls' nearer-term focus remains on encouraging the adoption of sustainable aviation fuels and the realization of its six-year effort to build and run the first UltraFan demonstrator. Parts for the initial engine, which is sized for the thrust needs of current large twin widebodies, are being assembled in readiness for integration and running in 2021.

Incorporating a fan-drive gearbox for the first time on any turbofan of this size, the 84,000-lb.-thrust UltraFan demonstrator is designed to prove not only the viability of the geared concept for widebody applications but also the operability of an architecture that can be scaled anywhere from 25,000 lb. to 100,000 lb.

"It's the blueprint for the next-generation gas turbine engine," Newby says. "From our point of view, whether or not it is fueled by sustainable aviation fuel or even ultimately hydrogen in the long-term future, you're still going to need a highly efficient gas turbine. That's because those fuels may be in short supply as production ramps up, and we're not quite sure what the cost will be. So it's still immensely important, in our view, that you have an engine that minimizes consumption of fuel."

A second phase of ground testing of the UltraFan's advanced low-emissions combustion system has begun at Rolls' Derby, England, site. "We're doing some operability work and some final emissions mapping as well as looking at some control system optimization," Newby says. "This isn't so much about the chemical processes of the combustion—we know that works. This is about integrating it into a system. That is one of the last pieces of the puzzle to come in, and it's now about driving the parts home, and then really getting ready to go on test next year."

CFM's revised production plan includes protection for future rate increases.

PHILIPPE STROUPA

Protection Plan

AS THE AEROSPACE INDUSTRY TRIES TO MANAGE THE STEEPEST DELIVERY ramp-down in commercial jet airliner history, CFM's position has been one of the most challenging. Itself at the head of a complex supply chain, the General Electric-Safran joint venture had dramatically improved its delivery performance to Boeing when the 737 MAX crisis began to bite. Having ended 2018 with 2,162 deliveries to Airbus and Boeing, of which 1,118 were Leap 1s, CFM completed 2019 only marginally lower, with 2,127 shipments. Yet of these, 1,736 were Leap 1s.

Now, with Airbus also slashing production of A320neos in 2020 in response to COVID-19, CFM's containment strategy is focusing on supporting the service reentry of the Leap 1B-powered MAX, balancing Leap 1A/B production rates to match the new market reality and being ready for an eventual recovery. "We have plans in place with both airframers that enable us to continue producing Leap engines at a reduced rate while protecting our ability to accelerate production as needed in the future," CFM President and CEO Gael Meheust says.

With Airbus and Boeing rates stabilizing at newer low levels, CFM's near-term task is helping manage reactivation of the stored MAX fleet. "We've been helping our customers with key activities such as proper engine preservation, completing time-sensitive tasks and pulling forward planned maintenance," says Meheust. "We also developed a 'Re-EIS' (reentry into service) checklist that includes tasks like line maintenance training, spare engine and parts provisioning, and tooling availability, all with a goal of ensuring minimum disruption and maximum aircraft availability. Having this process already in place has become a huge advantage as airlines are now using this checklist to resume and expand flight schedules."

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DIGGING DEEP

> LESSORS CUT CREATIVE DEALS TO HELP KEY CUSTOMERS

> TRAVEL DEMAND DIP CREATES CASH FLOW ISSUES FOR MOST AIRLINES

> AIRCRAFT LEASE PAYMENTS AMONG MOST AT-RISK SHORT-TERM OBLIGATIONS

Southwest Airlines has sold 10 of its Boeing 737 MAXs to lessors.

JOEPRIESAVIATION.NET PHOTOS

Sean Broderick Washington

The profundity of the airline industry downturn and its uncertain pace of recovery are forcing lessors to be both patient and creative as airlines struggle to pay monthly invoices and manage their fleets. In some cases, the strife is creating opportunities that well-managed lessors are leveraging to come out stronger post-crisis.

A common side effect of an airline industry downturn is requests for breaks on leases. With about half of the global fleet under some type of lease, the current crisis is no exception. But the severity of the situation has created some unusual openings for lessors to support customers.

The most extreme example is at Norwegian Air Shuttle, where a group of lessors converted some of the carrier's outstanding lease obligations into equity stakes as part of a larger deal that includes state-provided funding.

"We won't see many of those type of structures happening," says Aengus Kelly, CEO of AerCap, which is now the largest shareholder in Norwegian, with a 15.9% stake. "Obviously, the environment we're in was the reason why [we] and other lessors proceeded with the Norwegian arrangement, which is highly unusual. I can't think of one like this ever before."

While equity in a customer remains rare, deals structured around their aircraft are more common. Usually, these are sale-leasebacks that move assets from the airline's balance sheet to the lessor, putting much-needed cash in the carrier's hands. Virgin Atlantic and Air Lease Corp. recently were party to a more complex deal tied to the airline's attempted restructuring via bankruptcy. Virgin has Airbus A330-900neos and A350-1000s on order, and also has signed up to take some of each from Air Lease. The lessor agreed to swap delivery positions so that Virgin's leased aircraft will come first.

"Their direct buys were rescheduled to later time frames, which means the airline has to pay less in fee delivery deposits to Airbus," says Steven Udvar-Hazy, Air Lease executive board chairman. "Therefore, they can protect their cash liquidity position."

The dire financial circumstances mean that even the most financially solid airlines are turning to lessors for help. Southwest Airlines, famous for paying cash for its Boeing 737s and leasing only to add fleet flexibility, raised $815 million in a second-quarter sale-leaseback of 10 737-800s and 10 737 MAXs to unnamed lessors. Aviation Week Network's Fleet Discovery database shows the carrier leases about 150 of its all-737 fleet, which numbered 737 total aircraft on June 30.

Lufthansa Group, which owns all but 104 of the 760 aircraft its carriers operate, will consider selling some of them to help pay down debt. The airline received a $10.1 billion financial injection arranged by the German government, including a $3.4 billion loan with an escalating interest rate. Selling some of its aircraft could help Lufthansa pay down the loan while the interest rate is low.

Aircraft and engine sales are usually mutually beneficial: They give airlines cash and provide buyers with assets they can use—either via leases or by reselling them. Distressed market conditions can present challenges, however.

"The trading markets have been quite slow recently," says Steve Williamson, vice president of acquisitions and trading at Contrail Aviation Leasing, which specializes in midlife aircraft and engines. "Most sellers are looking to avoid the perception that they are desperate. However, all sales to this point have a stigma of being distressed, and buyers are looking to capitalize."

Relationships are at a premium in these circumstances.

"Many of the lessors are not going for wide [requests for proposals], as was the case pre-COVID[-19], and instead are focusing on smaller groups of known counterparties," Williamson says. "Execution risk is of paramount importance. People do not want their buyers backing out of transactions, as the sellers know that they are not

likely to see higher numbers bringing assets back to market."

While creative deals likely will continue, they will be outnumbered by traditional, straightforward breaks on lease payments. The novel coronavirus pandemic has affected every major air transport market in the world, forcing airlines to ground aircraft and cut flights. The International Air Transport Association sees global airline full-year 2020 revenues falling 50%, thanks to a 54% drop in traffic measured by revenue passenger kilometers. Recovery to 2019 levels, already constrained somewhat by the 737 MAX global fleet grounding, is not expected before 2023 at the earliest. The lost revenue and gloomy outlook have forced airlines into immediate and far-reaching cost-cutting modes.

While employee costs can be reduced by limiting work or reducing staff, expenses such as aircraft and engine lease payments are trickier. Airlines had an urgent problem when the pandemic's ramifications became clear: Revenue needed to pay for their most important equipment was no longer coming in but monthly bills were.

The Lufthansa Group will consider selling some of its 656 owned aircraft, including 16 Airbus A350s, to help pay down debt.

Savvy lessors that have been through previous downturns know the drill, and they are capitalized for it. Their customers ask for deferrals, or abatements in rarer cases, to help with cash flow. The deals vary by customer. But, in general, an airline will ask for a multimonth discount on leases, pledging to repay the difference down the road.

As the pandemic's scope became apparent—January and February for the Asia-Pacific region and slightly later for the rest of the world—airlines approached lessors and asked for help. In most cases, short-term deals were struck, with payment delays of about three months and repayment windows stretching out to about 12 months.

"Deferral requests are considered on a case-by-case basis, with 2-4 months of payment delays not out of the ordinary," Cowen and Co. analyst Helane Becker wrote in a late July preview of second-quarter earnings.

In May, lessors reported that some Chinese airlines granted deferrals were starting to repay the delayed rents, suggesting that the initial wave of adjustment might be sufficient. COVID-19 outbreaks in the region seemed under control, while hotspots in Europe were seemingly being contained.

However, optimism about a steady recovery was soon dashed as COVID-19 cases in key markets including Canada, the UK and the U.S. convinced governments to expand existing travel restrictions or issue new ones. International air links remain minimal, and demand in some major domestic markets remains depressed. Among the consequences: Airlines need more help.

"We are starting to see limited requests for another round of deferrals from certain customers," says Air Lease Corp. President John Plueger. "So far, I can tell you the volume of those inbound requests is much lower than it was for the initial requests. Of course, the impacts of COVID are evolving [in] real-time, and therefore the status of deferrals can change day by day."

As of Aug 6., Air Lease had deferral agreements in place with 59% of its 105 customers, covering $190 million in payments. Most of this—$125 million touching 46% of the customer base—was in place by early May.

"The lower level of deferrals granted over the past three months speaks to the slower pace at which we received additional requests," Plueger says. "And [it] reflects the amount of time we spend to exercise due diligence on each request and understand which customers really need our help," Plueger says.

Most of Air Lease's deferrals cover partial payments, with repayment periods from four to 12 months.

AerCap, which had deferral agreements covering $429 million in payments as of June 30, says the situation appears to be stabilizing. "The level of requests for deferrals has slowed down as traffic has begun to recover," AerCap's Kelly says.

GE's GECAS lessor arm within its GE Capital unit has received deferral requests from 80% of its 225 customers and granted requests to 60% of them.

Perhaps most important, airlines are making good on the modified payment plans, suggesting their financial positions are improving.

"The amount of the payback of these short-term deferrals is now far in excess of any new requests for some small deferrals," says Air Lease's Udvar-Hazy. "It's now flipped into a positive, where cash flow [from] the repayment of deferrals that we made in [the first quarter] and early part of [the second quarter] is coming back in. And those amounts significantly exceed any new requests that [have been] quite limited in the last several weeks."

While the deferral requests may be slowing down, there is evidence the second round of deals includes more favorable terms for airlines as they continue to adjust to lower demand trends. Fly Leasing, which had 86 aircraft and seven engines in its portfolio as of June 30, says it will defer less total rent than previously anticipated. But $32 million of the company's projected $83 million in deferrals, or nearly 40%, is not expected to be repaid until 2022 or later. About half of the lessor's 41 customers are expected to sign deals with an average deferral of seven months.

"At the very beginning of the crisis, pretty much every airline just raised their hand and said they wanted a deferral," says Fly Leasing CEO Colm Barrington. "We are finding that the majority of airlines want to keep the leased aircraft and are prepared to work with us to find ways of doing this. We know that we will succeed only if our customers succeed."

The Challenge for Long-Haul LCCs: Recovery From COVID-19

> NORWEGIAN PLANS TO RESTART SOME TRANSATLANTIC ROUTES IN DECEMBER

> AIRASIA X IS IN HIBERNATION FOR THE FORESEEABLE FUTURE

Helen Massy-Beresford Paris and **Adrian Schofield** Auckland

For long-haul low-cost carriers, a subset of the airline industry that always has had its doubters, the COVID-19 crisis and the profound ways in which it could affect future consumer behavior may bring the final straw.

As the big names in low-cost long-haul travel suffer serious difficulties, the enduring doubts about the sustainability of long-haul low-cost carriers (LCC) have come into focus even more sharply.

"IATA numbers suggest that it will be 2024 before we're back to previous normal," says Patrick Edmond, managing director of Altair Advisory, referring to the International Air Transport Association's latest prediction for overall air travel demand.

"We're now looking at a sustained downturn, and I think that's going to affect long-haul more than it will affect short-haul. The low-cost long-haul model was never as obviously superior as the low-cost short-haul model," Edmond says. "I think in a post-COVID world, low-cost long-haul has an even bigger question mark."

John Strickland, director of aviation consultancy JLS Consulting, agrees. "Yes, there is demand for long-haul travel at good prices," he says. "But the challenge is doing it profitably, and that was not being achieved sustainably even in the good times."

As the world of air travel begins to open up after a months-long shutdown, short-haul routes are leading the way, leaving a tougher challenge for carriers reliant on long-haul operations.

In one way, LCCs are luckier than their legacy counterparts: They rely on leisure travel, which is driving the paltry amount of passenger demand. Airline executives and industry watchers alike agree business-travel demand will take longer to return.

But even that advantage is not straightforward. Leisure travelers always have been price-sensitive, and to convince them to book tickets will be a big challenge amid ongoing uncertainty about the evolution of the virus and rapidly changing travel restrictions, not to mention economic gloom.

"Ticket price will be an important element of getting people back to traveling; but to offer low fares profitably, modern, efficient aircraft are required," Strickland says. Although lease rates may fall, the likes of Boeing 787s or Airbus A350s will still be more expensive than less efficient aircraft, he notes.

"Aircraft type will be important, and narrowbody operators stand a much better chance than widebody operators due to smaller capacity, meaning not only lower costs but also lower risk," Strickland explains.

Norwegian's move to restart operations in December is seen as risky.

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Will those leisure travelers who still want to fly be prepared to commit to long-haul trips?

In the Asia-Pacific region, which has led the way in development of long-haul LCCs, the business model has yet to prove it can be sustainably profitable. One Asian long-haul LCC, NokScoot, a joint venture between Scoot and Thai carrier Nok Air, which operated Boeing 777-200s from Bangkok to China, India, Japan and Taiwan, already has been liquidated.

The pioneer of this model in the region, AirAsia X, is seeking to raise the financing needed to survive. It suspended scheduled services in March and says it expects "to remain in hibernation mode," with no timeline to return to service. AirAsia X has been operating "a handful of aircraft" on nonscheduled cargo and repatriation flights. But its prospects for resuming scheduled operations will depend on recovery of demand and easing of border restrictions.

In Europe, Norwegian Air Shuttle initially predicted its fleet would remain largely grounded until April 2021, but it has scheduled some transatlantic flights for December. Before the pandemic, the carrier was facing financial difficulties after its rapid expansion left it stretched too thin, but it had begun to make progress on a restructuring plan. Now, like other airlines, Norwegian will be forced to focus on surviving the difficult months of a fledgling recovery, with rising operating costs and no guarantee that revenues will follow.

Strickland voices doubts about Norwegian's latest plan, which involves restarting several transatlantic routes this winter. "I'm skeptical as to whether it will happen as stated," he says. "There will be greater uncertainty for people who might ordinarily be thinking about Christmas travel plans, and it's a short-lived peak in the weak winter season. Winter is not the time to be restarting with significant long-haul capacity."

There may be some specific routes and populations for which the long-haul LCC model still makes sense—such as Vistara and SpiceJet's move to secure slots at London's Heathrow Airport, signaling a plan to serve UK-India routes once travel restrictions ease—but they will remain exceptions.

"I don't see any durable reemergence of low-cost long-haul before we get past the current COVID situation—for example with a vaccine," Edmond says.

In the U.S., Regional Carriers Are Hardest Hit by Pandemic Downturn

- EXPRESSJET IS LIKELY TO BE THE FOURTH U.S. REGIONAL AIRLINE TO GO UNDER IN 2020
- MESA, SKYWEST IN STRONG POSITIONS DESPITE INDUSTRY TURMOIL

Ben Goldstein Washington

In the U.S., major airlines have successfully removed near-term bankruptcy risk from the table, helped by massive infusions of public and private funding. The same cannot be said for their regional affiliates.

Of the four U.S. carriers to permanently cease operations since the COVID-19 pandemic swept across North America in mid-March, three of them—Compass Airlines, RavnAir Group and Trans States Airlines—were regional carriers. ExpressJet Airlines looks set to be next, after United Airlines decided late last month to consolidate its 50-seat short-haul operations with CommutAir. Should ExpressJet fail, it would be the largest U.S. carrier so far to go under as a direct result of the crisis.

In a sense, American regionals have been hit twice by the pandemic; not only do they have to contend with depressed demand, but they are also directly affected by decisions made upstream by their distressed major airline partners. Compass and ExpressJet were both casualties of regional-fleet streamlining efforts at Delta Air Lines and United, respectively. Neither carrier had a diversified flying portfolio, and with just one major airline partner each, the consolidation efforts effectively grounded both airlines.

Regionals also can count on fewer available financing options, further restricting their room to maneuver. Because most are privately held, they are unable to tap public capital markets to issue debt and equity. They do not fare much better in the private capital markets either; with fleets of mostly leased or subleased aircraft, they generally have a smaller share of unencumbered assets to raise money against.

While the Coronavirus Aid, Relief, and Economic Security (CARES) Act's $25 billion Payroll Support Program (PSP) provided a temporary lifeline to the industry by funding payrolls during the second and third quarters of 2020, regional carriers say the Treasury Department's one-size-fits-all approach to administering the law was out of line with their financial reality. ExpressJet, for example, was required to repay 30% of the aid it received—the same terms as the country's largest legacy airlines—despite its small footprint and inability to raise cash.

Like other struggling regionals, ExpressJet has also been unable to secure a CARES Act air carrier loan despite months of effort, largely due to the Treasury Department's refusal to budge on stiff collateral requirements that most regionals are unable to meet. To make matters worse, smaller carriers with loan requests below $300 million have been explicitly directed out

IBAGLI/WIKIMEDIA

Mesa Airlines (pictured flying as United Express) was the only U.S. carrier to report a net profit in the second quarter of 2020.

United's decision to consolidate its 50-seat regional flying with CommutAir effectively grounded ExpressJet (pictured in United Express livery).

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of the program by the department, instructed to return only after being denied by an alternate lending program that most will not qualify for.

"Treasury cites the need to protect the taxpayer in this decision," Regional Airline Association (RAA) President and CEO Faye Malarkey Black says. "Ironically, the taxpayer is at high risk if regional airline service to small communities collapse."

Still, major carriers' regional consolidations—and the ensuing airline failures—have left some of the sector's strongest players in an enviable position. Take SkyWest Airlines, the country's largest regional airline, which recorded the best pretax margins of the country's 10 biggest airlines, according to data from Deutsche Bank analyst Mike Linenberg. SkyWest has since found itself in a superior

COVID-19 Slows the Progress of the FAA's NextGen Programs

- INFECTIONS AFFECT MORE THAN 130 ATC FACILITIES
- THE NEXTGEN IMPLEMENTATION PLAN HAS BEEN REVISED

Bill Carey Washington

The novel coronavirus crisis has slowed the FAA's 17-year march toward airspace modernization.

During an online meeting of the NextGen Advisory Committee (NAC) on Aug. 6, FAA leaders affirmed what came as no surprise—the precautions taken to prevent the spread of the coronavirus that causes COVID-19 will delay programs underpinning the NextGen air traffic control (ATC) modernization effort dating to 2003.

Even against the backdrop of dramatically reduced aircraft movements, the FAA has been challenged just to maintain daily ATC operations since the first coronavirus infections appeared in the tower at Chicago Midway International Airport (MDW) on March 17, causing a seven-day closure as the facility was cleaned.

As infections spread across towers, terminal radar approach control and en route facilities, the FAA activated contingency plans to shift air traffic services to adjacent facilities. In some cases, controllers temporarily relocated to airline ramp towers and a parking garage to direct pilots. The agency scaled back the operating hours at 100 towers and organized controller work groups that stayed together during the duty week to reduce the risk of spreading the virus.

Nevertheless, the novel coronavirus proliferated. An FAA-updated website that lists ATC "facilities affected" by confirmed COVID-19 cases or suspected exposure to the disease counted 35 facilities in early April, 50 in June, more than 80 in July and 133 as of Aug. 17.

"I assure you that we have used every bit of our operational engineering and program expertise to innovate and adapt our way in an effort to prevent and mitigate delays" to the NextGen portfolio of programs, FAA Deputy Administrator Daniel Elwell told the NAC. "Unfortunately, a growing number of our FAA and industry programs are now showing delays, some into 2022."

Travel by agency personnel "is extremely limited and nonexistent in many cases," access to the agency's William J. Hughes Technical Center outside Atlantic City, New Jersey, is limited and some system upgrades have been stopped, FAA Administrator Steve Dickson told the advisory committee of aviation operations and technical executives.

BILL CAREY/AW&ST

Separately, the FAA said the Tech Center and the Mike Monroney Aeronautical Center in Oklahoma City, which hosts the agency's ATC academy and other training, "have remained operational to support mission-critical activities" during the pandemic.

Briefers informed the NAC that the NextGen Terminal Flight Data Manager (TFDM) program that aims to improve the efficiency of surface operations by integrating electronic flight data in airport towers has been delayed.

The TFDM program "has been greatly impacted by the inability to travel and access the facilities, which includes the Tech Center and the [ATC] academy," said NAC work group leader Robert Goldman, of Delta Air Lines. "TFDM Build 1 IOC [initial operational capability] in Phoenix is postponed until 2021, and the other milestones contingent upon that are all [to be determined]."

The FAA's Data Communications program to roll out text messaging between controllers and pilots—which was running ahead of schedule after equipping 62 airport towers—now is paused after deployment to the Indi-

financial position to its major airline partners (American Airlines, Delta and United) and has extended a variety of concessions to help them get through the downturn, such as deferral of certain payments and waiving contract minimums.

Mesa Airlines has also fared well during the pandemic, and can even boast of being the sole publicly owned U.S. carrier to report a net profit in the second quarter of 2020. The Phoenix-based airline is set to begin taking delivery of 20 new Embraer 175s from United starting in September and even signed a five-year contract with DHL to operate two Boeing 737-400F freighters beginning in October. In contrast to its two legacy airline partners (American and United), Mesa's management believes the company is in a strong enough financial position to avoid involuntarily laying off any employees this year.

To be sure, the relatively strong performance of Mesa and SkyWest does not accurately reflect the challenges facing the sector's less prominent players. Both companies are publicly owned and have substantially more financing options available than their peers. They also operate large fleets of dual-class jets in the 70-76-seat range, which are currently in higher demand from major airlines than smaller, 50-seat regional jets. And with more diversified flying portfolios, the loss of a major airline customer would not be the fatal blow for either carrier that it was for Compass or ExpressJet.

The RAA has aggressively lobbied for a six-month extension of the PSP, warning that failure to renew the aid program will put additional regional carriers at risk of failing in the months ahead.

"ExpressJet is not the canary in the coal mine," Black says. "Without intervention, this will be the fourth regional airline to fail."

Given that regional airlines drove an estimated $134 billion in economic activity last year alone, along with $36 billion in local wages and tax revenues, according to the RAA, providing them extra support may ultimately be a better bargain for taxpayers than risking additional loss of air service to small communities.

"Lawmakers may feel a sense of security in that their air service has not collapsed presently, but those circumstances may change dramatically when the supports and requirements associated with the CARES act expire," Black says.

The FAA's NextGen branding was on display at a recent Air Traffic Control Association conference.

anapolis, Kansas City and Washington air route traffic control centers, the first three "key" sites of 20 planned. The FAA lists the Washington center in Leesburg, Virginia, as beginning full operation on March 24.

"We have a product in the field right now that is exceeding all performance targets," said Jesse Wijntjes, FAA Data Comm program manager. "We have the best-performing air-to-ground data link capability anywhere in the world by a wide margin at those three facilities.

"The balance of the deployment is on hold due to COVID," Wijntjes added. "But we are ready to go as soon as we are allowed back into the facilities."

Also delayed are projects planned under the NAC-initiated Northeast Corridor initiative to improve air traffic flow and reduce flight delays in the region between Boston and Washington, the nation's most congested for air travel.

"Unfortunately, due to COVID-19 and other impacts, we will see significant delays in the implementation milestones in 2020," said Ralph Tamburro, representing the Port Authority of New York and New Jersey. "Most notably, the [redesign of] Atlantic Coast routes will be delayed for over a year. This project was set to make large-scale changes to the high-altitude route structure along the eastern U.S., from the southeast to New England, connecting the routes already implemented in Florida," he explained.

Progress on NextGen has not completely slowed. Activities such as software development by vendors, virtual training and planning meetings are ongoing, FAA executives said.

"We have not stopped doing NextGen work," said Teri Bristol, chief operating officer of the FAA Air Traffic Organization. "The only work that we have stopped doing is putting folks in the facilities right now to actually deploy equipment or to bring new systems online. With respect to our major acquisitions, that work is still going on, the vendors are developing software; all of that is still happening."

Nevertheless, the FAA has revised the schedule milestones contained in its annually updated NextGen Implementation Plan (NGIP), Elwell said.

"What you will see in the 2020 NGIP update is a list of successes, a list of milestone changes and in some cases TBDs until we can determine an effective [completion] date," Elwell said. "We decided to publish the update with the best information that we have."

U.S. Agencies Take Early Steps To Install Counter-Drone Systems

- SYSTEMS TESTING BEGINS AT NEW JERSEY AIRPORT
- FAA SURVEYS MARKET FOR ENGINE-INGESTION TEST

Bill Carey Washington

In the midst of the COVID-19 pandemic, the FAA and other U.S. agencies have taken steps toward addressing a challenge to aviation that predates the contagion: the risk of disruption to airport operations by drone.

The FAA has also initiated a market survey of companies that may be interested in helping the agency understand what happens when a large jet engine ingests a small drone.

On Aug. 21, the FAA published a call for white papers from vendors interested in supplying counter-unmanned aircraft systems (C-UAS) for evaluation at airports, a project that Congress required in 2018 FAA reauthorization legislation. The agency plans to evaluate at least 10 C-UAS systems designed to detect and track drones in flight and/or "mitigate"—or disable—them from threatening a civil airport.

Electro-optical and thermal cameras installed at an Operational Solutions facility in the UK.

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The congressional language requires the FAA to test systems at five airports. The agency has designated Atlantic City International Airport (KACY) in New Jersey, which hosts the FAA Technical Center, as the first site; it will issue a separate solicitation to choose four other airports.

The FAA expects to deploy the first C-UAS technology at KACY as early as January and install systems at other airports in late 2021. The objective at KACY, a Spirit Airlines base, is to protect an air operations area (AOA) of 3.6 $mi.^2$ with systems extending 5 mi. from the AOA center point.

Following what is expected to be a 60-day evaluation period during which the technologies will be tested against a variety of drones in various weather conditions, a system may then "graduate" to field testing at another airport over 14 months.

"Transition from KACY to the one additional airport will be based on the successful 'graduation' of any selected offeror's technology/system from KACY, meaning that the technology/system performed as advertised, generated reliable and accurate data, and warrants further evaluation in another operational setting. 'Graduation' is not guaranteed," the FAA notice states.

A DJI quadcopter operated with a Boeing 747 in the background.

Ultimately, Congress intended that the FAA develop processes for certifying and authorizing C-UAS installations at airports, making them eligible for Airport Improvement Program grants. The 2018 legislation also required the agency to charter an aviation rulemaking committee to assist in developing standards; the FAA says it has not yet created that group.

In the call for white papers, the agency emphasizes that it will not compare or rank C-UAS systems from the selected vendors, nor will it develop a list of approved vendors based on the evaluation. It will require vendors to install their systems, train FAA personnel to use them "and then depart the site."

The FAA's notice followed the Aug. 17 release of an interagency advisory that provides airports considering C-UAS deployments with an overview of potentially applicable federal laws and regulations. The FAA in May 2019 sent a similar letter with updated guidance to 3,321 commercial, reliever and general aviation airports listed in its National Plan of Integrated Airport Systems. In that letter, the agency said it "cannot confirm the legality" of using C-UAS technologies.

The Federal Communications Commission (FCC) and Justice and Homeland Security departments joined the FAA in issuing the interagency advisory, which offers a similar conclusion. The advisory "essentially

tells you to speak to your counsel's office," Elizabeth Soltys, UAS security advisor to the FAA deputy associate administrator of security and hazardous materials safety, said Aug. 19 during the annual FAA UAS Symposium, held virtually because of the COVID-19 pandemic.

Congress thus far has authorized only the Justice, Homeland Security, Energy and Defense departments to use C-UAS systems under certain conditions to protect "covered facilities or assets," the advisory instructs.

The guidance differentiates between detection systems that detect and track drones using radio frequency (RF), radar, electro-optical (EO), infrared (IR) or acoustic sensors and mitigation systems that disable a drone by kinetic or nonkinetic means. A kinetic system may use nets, projectiles or lasers to down a tracked aircraft. A nonkinetic system disrupts the control of a drone by RF, Wi-Fi or GPS jamming, spoofing or hacking, or nondestructive, directed-energy weapons.

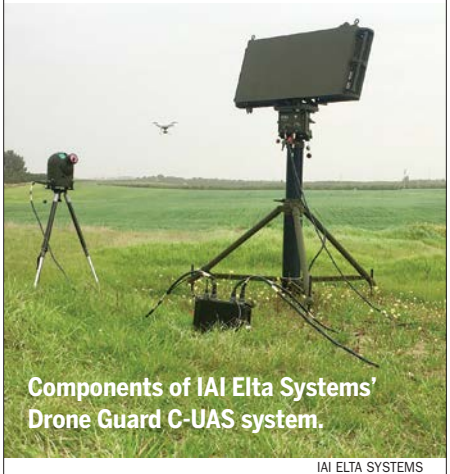
Whether a detection or tracking system involves federal criminal laws relating to surveillance—the advisory calls out the Pen/Trap Statute and the Wiretap Act—depends on whether it captures, records, decodes or intercepts electronic communications between a drone and its controller, the agencies advise. Radar, acoustic sensors or EO/IR systems that emit electromagnetic waves or pulses of sound or light to detect an object based on reflected signals "are less likely to pose concerns under federal criminal surveillance statutes," but must comply with FAA and FCC regulations governing aviation and RF spectrum.

Mitigation systems could run afoul of federal criminal prohibitions against intercepting communications, damaging an aircraft or damaging a "protected computer" used in interstate commerce. Jamming, spoofing and hacking specifically call into question the Computer Fraud and Abuse Act and laws prohibiting interference with the operation of a satellite and the destruction of communications lines.

There is a process available for installing an approved C-UAS system, similar to submitting an FAA Form 7460-1 Notice of Proposed Construction or Alternation for agency review, John Dermody, director of the FAA Office of Airport Safety and Standards, said at the FAA UAS Symposium.

Dermody acknowledged that some U.S. airports have already deployed C-UAS systems, but he declined to say which ones. Four years ago, the FAA and other agencies tested counter-drone technologies at KACY, New York's John F. Kennedy and the Denver and Dallas-Fort Worth international airports. The Transportation Security Administration, a branch of Homeland Security, has established a drone-detection testbed at Miami International Airport, according to the American Association of Airport Executives.

Secrecy attends much of what is being done in the field with C-UAS. Last October, the White House National Security Council quietly approved a concept of operations (conops) that describes a federal response to stopping a drone disruption at one of the U.S. Core 30 airports—those that serve major metropolitan areas with the highest volume of air traffic.



Components of IAI Elta Systems' Drone Guard C-UAS system.

IAI ELTA SYSTEMS

According to Soltys, the White House wanted to prepare the nation's airports to fend off the type of drone disruption that forced London's Gatwick Airport to close twice between Dec. 19 and Dec. 21, 2018, causing 1,000 flight cancellations.

Once the Justice and Homeland Security departments received congressional authorization to use C-UAS systems in the U.S., it became evident that they did not have the equipment to respond to all airports, Soltys said. The Pentagon offered to supply military systems "should there be an egregious situation" at one of the Core 30 airports.

Under the conops, the lead federal agency responding to a drone disruption "is predicate on the intent," for example, the Justice Department would manage a terrorism threat, said Soltys. The Pentagon might send C-UAS systems and train Justice or Homeland Security personnel on their use, but it is prevented from operating the systems by the Posse Comitatus Act, which limits using the military to enforce domestic laws.

Soltys made the point that other tools are available in the drone-deterrence toolbox short of deploying a C-UAS system. The FAA since December 2015 has required the owners of drones weighing more than 250 grams to register online, providing authorities with a way to trace back custody to an errant or malicious operator.

The agency has committed to publishing a "Remote ID" final regulation by year-end that will require drones to signal their identity and position to the ground. Drone manufacturers will likely have two years to comply after the rule's effective date.

For now, the agency is treading carefully on C-UAS. "Does the FAA agree with the expansion of mitigation capabilities and some detection capabilities? The answer is: No, we don't right now," said Soltys. "There is a lot of testing that needs to happen, and [systems need] to be safely deployed."

Also advancing slowly but deliberately is engine research. Congress mandated testing of engine-ingestion of drones in 2016 FAA reauthorization legislation and reiterated the request last September, the agency says. The latest request "aligns with FAA's readiness to conduct the final research phase," involving a live engine, states an Aug. 21 call for information.

The testing aims to provide data from the actual ingestion of a market-representative small drone into a commercial airline mid-to-high-bypass gas turbofan engine with a diameter of approximately 62 in., about the size of a CFM56 turbofan on a Boeing 737NG.

The Alliance for System Safety of UAS through Research Excellence (Assure), a consortium of universities that serves as the FAA's center of excellence for drones, released a study on midair collisions of manned and unmanned aircraft in November 2017.

The research concluded that drones made of rigid materials can cause more structural damage to a large manned aircraft in a collision than birds of the same weight.

Family Affair

- SIKORSKY S-97 RAIDER FLIGHTS REDUCING RISK FOR FARA BID
- SIKORSKY BOEING SB-1 DEFIANT IS POISED FOR A RUN AT HIGH-SPEED GOAL

Graham Warwick Washington

In late July, two sleek rotorcraft raced together over the cypress wetlands of southern Florida, the pair exceeding 180 kt. as the Sikorsky S-97 Raider and Sikorsky-Boeing SB-1 Defiant high-speed helicopters flew together for the first time.

The flight over Sikorsky's West Palm Beach development flight center was staged for U.S. Army acquisition chief Bruce Jette. The Raider and Defiant are competing for two of the Army's top modernization priorities: the Future Attack Reconnaissance Aircraft (FARA) and Future Long-Range Assault Aircraft (FLRAA), respectively.

For Sikorsky, now a Lockheed Martin company, the formation flight held added significance because it came almost 10 years after its company-funded X2 technology demonstrator had set an unofficial speed record for helicopters of 250 kt. in level flight. Both the Raider and Defiant use the X2 coaxial rigid-rotor compound helicopter configuration.

Together, the X2, Raider and Defiant demonstrators represent a $1 billion investment by Sikorsky and its industry partners, now targeted squarely at winning the FARA and FLRAA.

In 2005, flush with cash from producing H-60-series helicopters for the U.S. military and export customers, Sikorsky launched the X2 program. Looking to guarantee its future with a new generation of helicopters, the company studied a wide range of designs, including tiltrotors, before deciding to revisit the coaxial rigid-rotor compound configuration it pioneered with the XH-59A Advancing Blade Concept demonstrator.

First flown in 1973, the XH-59A was fast, reaching a maximum level speed of 238 kt. But it was complex, with high fuel consumption, noise and vibration. Operating the four engines—two turboshafts for the rotors and two turbojets for propulsion—required a two-person crew.

Taking advantage of advances in technology during the intervening decades, Sikorsky simplified the concept to produce the X2: a single-seat, single-engine rotorcraft with fly-by-wire flight control, composite blades and airframe as well as active vibration control. The X2 demonstrator flew in 2008.

In 2010, after the X2 reached 250 kt., Sikorsky launched an industry-funded program to build two S-97 Raider light tactical helicopter prototypes using the configuration. Aircraft 1 flew in May 2015 and logged about 20 hr. before suffering damage during a hard landing caused by a flight-control software flaw. Aircraft 2 has now logged almost 69 hr., reaching a maximum speed of 207 kt. and angle of bank of 60 deg.

Flight testing of the S-97 is now dedicated to optimizing Sikorsky's Raider X design for FARA, focused on tweaks to minimize drag at high speed. "Those flight hours mean someone had a question," says Jay Macklin, Sikorsky director of Future Vertical Lift (FVL) business development. And while the S-97 is flying, Sikorsky is making progress with the Raider X prototype. "The build is on," he says.

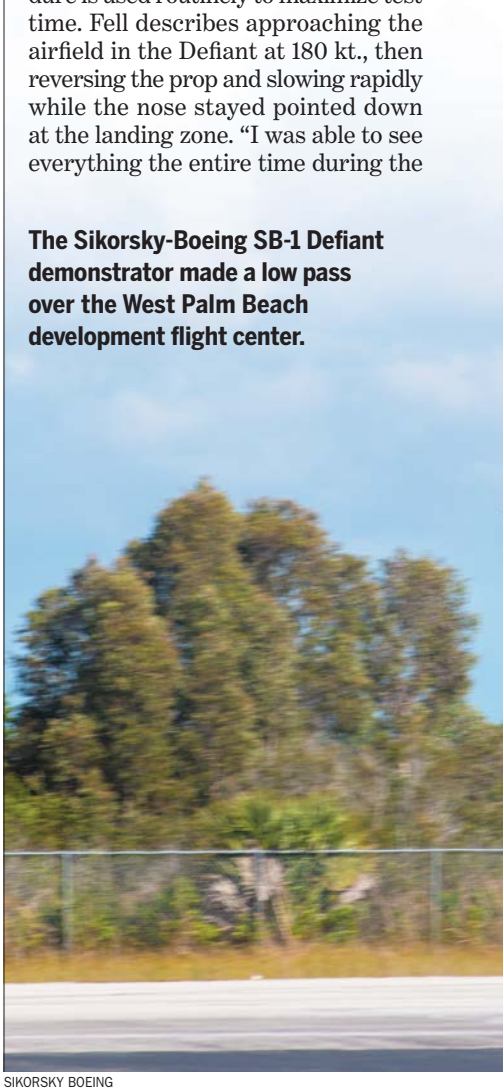
The Defiant, meanwhile, has logged 20 hr. of flying since taking to the air for the first time in March 2019 and has exceeded 200 kt. and a 30-deg. angle of bank. Whereas the single-engine Raider was designed for 220 kt., the twin-turboshaft Defiant is designed for 230 kt. but with a speed goal "closer to 250 kt.," says Bill Fell, Sikorsky's chief test pilot. A flight to achieve that speed goal is imminent, the team indicates.

Sikorsky and FLRAA teammate Boeing emphasize that both the Raider and Defiant combine high speed and maneuverability with the low-speed agility of a conventional helicopter. There are differences, however. The Raider and Defiant have no tail rotor; instead, differential torque on the coaxial rotors is used to turn at low speed. The yaw rates generated are the same and can be tailored to the mission requirement, test pilot Christian Corry says.

Both machines can fly like a helicopter at speeds of up to 150-160 kt. using conventional collective and cyclic control, Fell says. But when the tail-mounted propeller is engaged to provide propulsion, the coaxial rotors become rotating wings, Corry says, and collective pitch is automated to maximize lift and minimize drag at high speed.

Airspeed is controlled through the prop pitch, using the throttle, and flight control relies on rudders and elevators on the tail. "It's more of an airplane than a helicopter," Corry says. Unlike a conventional helicopter, whose nose must be pointed down or pulled up, the propulsor enables level-attitude acceleration and deceleration.

Reversing prop pitch "is like throwing a parachute out there," Fell says. "It acts like a big brake." This procedure is used routinely to maximize test time. Fell describes approaching the airfield in the Defiant at 180 kt., then reversing the prop and slowing rapidly while the nose stayed pointed down at the landing zone. "I was able to see everything the entire time during the



The Sikorsky-Boeing SB-1 Defiant demonstrator made a low pass over the West Palm Beach development flight center.

SIKORSKY BOEING

approach, which you cannot do in a helicopter," he says.

On the formation demo, the two rotorcraft stopped in about the same distance, despite the Defiant's larger size, notes Randy Rotte, Boeing director of global sales and marketing for FVL, cargo and utility. The Defiant so far is cleared to use only half the negative prop-pitch range, Fell adds. Once the full range is cleared, "we will see much more rapid deceleration," he says.

And whereas a tail rotor is required for control throughout the flight envelope of a conventional helicopter, on the Defiant—as on the Raider—the propulsor can be disengaged, reducing the acoustic signature and improving survivability.

High speed, not hover, drives the power requirement in both aircraft. Powered by two 4,000-shp-class Honeywell T55s, the Defiant is "loafing" at 180 kt. on less than 50% power, Fell says. "At the weights we are flying, we have hover power on one engine. That means contingency and high-hot capability," he adds.

Even the single-engine Raider has "excess power you don't see in a conventional helicopter," Corry says. The competing FARA prototypes will both be powered by the 3,000-shp-class General Electric T901, a new engine that is expected to increase in power output over time. "Counter-rotating rigid versus fully articulated [rotor] provides growth potential," Macklin says. "We can add power to the engine, and the design can take it."

The coaxial rigid rotors also provide high control responsiveness. The 30,000-lb. Defiant "flies like a 20,000-lb. machine," Fell says. "The crisp response from the rotors shrinks the machine." The 11,000-lb. Raider "is more compact. It has that small, agile scout feel." But both rotorcraft "fly the same" despite the difference in size.

"It is the entire integrated weapon system that creates survivability, but it starts with the speed, maneuverability and agility of the aircraft," Macklin says. "It's the packaging that provides the transformational capability," Rotte notes. "It fundamentally changes the way you can fight—range, speed and maneuverability translate into survivability in a contested environment."

Sikorsky and Boeing are locked in competition with Bell for the FARA and FLRAA that will play out over the next three years. But for Sikorsky, more than a decade after betting its future on the X2 configuration, flying the Raider and Defiant together was a milestone—and a glimpse of how the Army could use them together in multidomain operations. "Seeing them in formation seemed like a natural evolution," Macklin says.

Bell Emphasizes Flight-Test Experience

IF THE COMPETITIONS BECOME ABOUT DESIGN MATURITY, BELL IS CONFIDENT its contenders for the U.S. Army's Future Attack Reconnaissance Aircraft and Future Long-Range Assault Aircraft have the chops to win.

The Bell V-280 Valor demonstrator for the FLRAA has logged almost 180 flight hours since its first flight in December 2017, and four Army pilots have now flown the advanced tiltrotor, Bell says. "There is no ground-testing substitute for expanding the envelope in actual flight," the company adds.

The V-280 has reached speeds in excess of 300 kt. and demonstrated hover-out-of-ground effect in 6,000-ft., 95F conditions as well as low-speed agility, meeting the Army's Level 1 handling qualities requirements, Bell says. Testing continues under Phase 2 of the Army's Joint Multi-Role demo.

Parts for the Bell 360 Invictus prototype for the FARA are being released for manufacture. Aircraft production will begin in Amarillo, Texas, in October. The first flight is planned for November 2022, with Army testing scheduled to begin in the summer of 2023 at Redstone Arsenal near Huntsville, Alabama.

With a single main rotor and a speed target of at least 185 kt., the 360 is an all-new design, but its four-blade, fully articulated rotor system is based on "high-speed-capable" technology developed for the Bell 525 Relentless commercial helicopter, the company emphasizes.

Four 525 test aircraft have accumulated more than 1,600 flight hours and 2,200 hr. of rotor turn time, the manufacturer says.

Self-Flying Feeder

- XWING AUTOMATES CARAVAN TO TRANSFORM EXPRESS LOGISTICS
- DETECT-AND-AVOID SYSTEM ENABLES COLLISION AVOIDANCE
- DIGITAL AUTOPILOT EQUIPS CARAVAN FOR UNMANNED OPERATION

Graham Warwick Washington

Demand for "middle-mile" express logistics driven by growth in e-commerce is fertile ground for startups looking to transform the economics of regional air cargo through innovations ranging from electric propulsion to unmanned aircraft.

San Francisco-based Xwing has targeted the Cessna 208B Grand Caravan—the aircraft most associated with that market—and set out to reduce its operating costs and increase its utilization by taking out the pilot. The startup is testing a Caravan modified for autonomous flight and plans to begin a piloted regional cargo operation as a step toward introducing an unmanned air logistics service.

Since December, the company has completed more than 70 autonomous flights from takeoff to landing with the converted Caravan. Xwing has also acquired a Part 135 operator and plans to begin cargo flights, initially piloted, to collect the data needed to certify the modified aircraft.

The Caravan has been retrofitted with Xwing's Autoflight system, which comprises a multisensor detect-and-avoid (DAA) system coupled to a new digital flight control system (FCS). Autoflight can fly the aircraft autonomously from takeoff to landing and includes automatic collision avoidance. Automated taxiing and braking will be added this summer, says Maxime Gariel, chief technology officer.

The startup plans to obtain FAA supplemental type certification (STC) to use the DAA system in piloted operations, following up with certification for the FCS and finally for the fully coupled system enabling autonomous operations.

"We're taking a pragmatic approach," Gariel says. "Our goal is to bring the minimum amount of technology to this aircraft to be able to integrate into the airspace. It's not about what will be in 10 years—it's what can we have in six months, in a year or in two years."

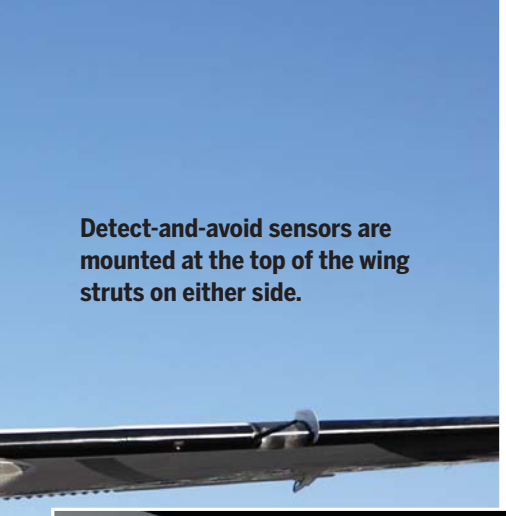
The startup is already working with Bell, and its DAA system will fly on the rotorcraft manufacturer's APT 70 cargo drone this year under a NASA project to demonstrate unmanned aircraft integration with the national airspace system. But the Caravan modification will be its first commercial product.

Xwing's approach is to "begin commercial operations with a DAA system flying, collecting data and proposing avoidance maneuvers to the pilot, where the pilot has the choice to use them or not," Gariel says. "And then, once we have enough data, we can work with the FAA to certify it and be able to remove the pilot."

The company is targeting the regional cargo market, in which FedEx Express alone operates more than 300 Caravans in the U.S. Converting the utility turboprop to an optionally piloted vehicle will allow a remote pilot on the ground to manage more than one aircraft, increasing operator utilization by a factor of three and reducing costs by 20-30%, Xwing calculates.

Both aircraft and pilots in regional cargo feeder operations suffer low utilization, flying once in the morning and again in the evening, CEO Marc Piette says. "By moving to ground operators, we can tackle the operator utilization issue—a single operator for three aircraft per day—even if we at first only allow one aircraft in flight per operator," he says.

Xwing expects to substantially reduce fuel costs, too, by flying the aircraft more precisely at its peak operating efficiency points on optimized trajectories. Also, a Caravan stripped of the systems required for pilots will carry more payload, and



Detect-and-avoid sensors are mounted at the top of the wing struts on either side.

Camera imagery is overlaid with terrain data, flight symbology and target tracks.

XWING PHOTOS

operations will be freed from traditional geographic constraints on pilot rest times, Piette says.

The detect-and-avoid system fuses data from automatic dependent surveillance-broadcast (ADS-B), onboard radar, camera and lidar sensors as well as a digital terrain database to provide situational awareness in the air and on the ground. When coupled to the full-authority digital autopilot, the system provides automated collision avoidance.

The DAA system has two clusters of sensors mounted where the struts meet the wing on the Caravan. Each cluster has two visual cameras, a radar and a lidar as well as either an infrared camera on the left wing or a long-range camera on the right wing. Together, they provide a +/-110-deg. field of view in azimuth.

While ADS-B data is used to identify transponder-equipped aircraft, radar allows the system to detect and track noncooperative targets. The cameras are used to validate ADS-B and radar targets as well as to augment GPS during approach, landing and taxiing. Lidar provides ground-obstacle detection.

Camera imagery is presented to the remote operator, or to the pilot in the aircraft, on a display that is overlaid with terrain information, headup display symbology and track data from the ADS-B and radar. The 3D display can be rotated through 360 deg. using the touch screen to look for traffic behind the aircraft and outside camera range. A top-down view at the bottom of the display shows ownship position, current flightpath, alert contours and safe-maneuvering track bands. Xwing is using a 2,000-ft. avoidance distance based on industry consensus standards to trigger maneuvers.

"We are taking this pragmatic approach," Gariel says. "It's a mix of ADS-B and radar for the certifiable initial system. And the vision system is flying at the same time and collecting data so that we can use the traditional sensors to train the system. We don't rely yet on the vision system, but that will be coming in the future to lower the cost and improve the reliability."

"Part of the reason we start commercial operations with pilots on board is it enables us to do a lightweight STC to add sensors on these commercial aircraft and start collecting data from a DAA perspective in order to be able to certify those systems more easily," Piette says. "We're going to be collecting a ton of data using these piloted operations over the next 12 months."

Xwing has developed the prototype system using off-the-shelf components so it can focus its resources on rapidly developing the software. But it is now working with aerospace supplier partners to develop the certifiable DAA and FCS hardware along with the associated data links and ground station. The startup completed a Series A funding round this year and has so far raised about $14 million, Piette says.

Xwing's modified Grand Caravan made an autonomous landing near San Francisco.

BLURRED LINES

> COMPETITION FOR U.S. LONG-RANGE STRIKE MISSION HEATS UP

> USAF PUSHES BACK ON "DUPLICATIVE" SPENDING

Steve Trimble Washington

Long-range strike as a sector of U.S. military investment has not been so popular since perhaps Gen. Curtis LeMay's Strategic Air Command reigned supreme over the Air Force in the 1950s. Whether in terms of missiles—hypersonic, supersonic or subsonic—or a new platform such as the stand-in Northrop Grumman B-21 or reengining of the standoff Boeing B-52H, the Air Force has multiple, overlapping development programs in progress.

For the first time, however, the popularity of the long-range conventional strike mission is no longer reserved for the Air Force. Since the signing of the now-defunct Intermediate-Range Nuclear Forces (INF) Treaty in 1987, which led to the retirement of the Army's Pershing II missile system, the Army has depended solely on Air Force surveillance and striking power to hit any target more than 185 mi. away.

That division of responsibilities was partly intended to establish clear lines of authority for weapons release on a dynamic battlefield to minimize the chances of a friendly fire incident. The other services also appeared content to focus their limited fiscal resources on other areas while the Air Force shouldered the financial burden for maintaining the long-range strike mission.

A year after the Trump administration withdrew from the INF Treaty, in 2019, the old division of responsibilities among the services for long-range strike is eroding. As the Defense Department prepares the fiscal 2022 budget request amid new resource constraints, some senior U.S. military officials are calling for dissolving those lines altogether. The goal would not be merely to free services besides the Air Force to invest in long-range strike capabilities but to impose new requirements that would make the Army, Navy and Marines as capable as the Air Force in the long-range strike mission.

LOCKHEED MARTIN

On April 30, Lockheed Martin staged the second test of the Precision-Strike Missile. Upon fielding in 2023, it will become the Army's longest-range strike option since the retirement of the Pershing II missile in the late-1980s.

The new approach is championed by senior leaders, including Gen. John Hyten, a veteran Air Force officer who is vice chairman of the Joint Chiefs of Staff. The transition to a new warfighting doctrine—initially defined by the Army—called multi-domain operations (MDO) fundamentally changes how each of the services must approach the long-range strike mission, Hyten says.

"We have a joint doctrine now that says we establish the forward edge of the battle area, the fire support coordination line, the forward line of troops," Hyten said during a videoconference

Su-57 production nears **p. 43**

hosted by the Hudson Institute on Aug. 12. "We say Army can operate here. The Air Force can operate here. . . . Naval forces can go here. Allies can go here."

The MDO doctrine changes that paradigm. Automated systems now in development under the Joint All-Domain Command and Control (JADC2) concept will assign targets to any "shooter" on the battlefield, not just the Air Force's long-range strike platforms and weapons. In theory, a target detected by satellite hundreds of miles deep into enemy territory could be assigned to a new Army artillery system such as the 300-mi.-range Precision-Strike Missile (PrSM) or the Navy's hypersonic Intermediate-Range Conventional Prompt Strike weapon.

"Everything [now] is about lines," Hyten says. "But in the future, those lines are eliminated, which means an army capability can have on its own platform the ability to defend itself or strike deep into an adversary area of operations. A naval force can defend itself or strike deep. The Air Force can defend itself and strike deep. The Marines can defend themselves or strike deep."

Such a vision implies significant new investments by the Army, Navy and Marines in long-range fires and perhaps by the Air Force in new ground-based defensive systems. At the same time, the Air Force is seeking to expand future B-21 production; the service's leadership is now openly discussing a need for up to 240 aircraft instead of the original plan to buy 80-100 new bombers. The Air Force also is developing concepts for a new, nonstealthy "arsenal plane," which could increase capacity for long-range strike with standoff munitions.

But budgets are growing tighter. For the first time since 2015, the Pentagon requested less overall funding in fiscal 2021 than the year before. Most expert forecasts predicted flat defense budgets beyond fiscal 2021 before the impact of the COVID-19 pandemic, which depressed the economy and triggered trillions of dollars in new spending for relief. If budgets remain flat or decline, some Air Force officials say they would call for less "duplicative" spending by other services on the long-range strike mission.

"I do think that we as a [Defense Department] and the Air Force have to look at duplicative activities," said Lt. Gen. David Nahom, in public remarks in April. "We bring up the long-range fires . . . and I know [the Pentagon] and certainly the [Cost Assessment and Program Evaluation office] are looking at this. If the Air Force can do something in long-range strike, maybe one of the other services doesn't have to do it.

"All of us investing in a single area, just in a slightly different way, is just not going to be affordable, especially if those flat budgets actually become less than flat," added Nahom, the Air Force's deputy chief of staff for plans and programs.

The leadership of the Army, however, believes long-range strike has become a core mission set. Since the INF Treaty-imposed retirement of the Pershing II in the late 1980s, the Army's weapon with the longest range has been the MGM-140 Army Tactical Missile System, with a range of up 185 mi. While the INF Treaty was still in effect, the Army publicly listed the objective range of PrSM at no more than 310 mi., or 0.6 mi. short of the threshold banned under the treaty. Since the treaty expired in August 2019, the Army reset the minimum range of PrSM to 311 mi., with future plans to extend the weapon system to about 500 mi.

But the Army's interests in long-range fires go beyond the PrSM program. The Strategic Long-Range Command seeks to field a new capability by 2025 that can fire an artillery shell at targets more than 1,150 mi. away. Even sooner, the Army hopes to field the Long-Range Hypersonic Weapon, featuring a rocket-boosted glide body, by 2023. The Defense Department also is working on a new, intermediate-range ballistic missile but has not confirmed the fielding schedule.

In addition to developing long-range striking power, the Army is aiming to reduce dependence on the Air Force for reconnaissance, surveillance and target acquisition. The Multi-Domain Sensor System (MDSS) program seeks to deploy by 2028 a new, Army-funded fleet of manned and unmanned surveillance aircraft. In fact, the Army deployed the Airborne Reconnaissance and Targeting Multi-Mission Intelligence System (Artemis), a chartered Bombardier Challenger 650 equipped with a suite of intelligence sensors, in July to Okinawa. The Artemis deployment's objective is to test concepts of operation for the most advanced element of the MDSS: a business-jet-class airborne intelligence, surveillance and reconnaissance aircraft that would perform a mission similar to the Air Force's E-8C Joint STARS, which is scheduled for retirement by 2025.

Brig. Gen. John Rafferty, the Army's cross-functional team leader for long-range fires, spoke last year about his service's motivation to spend billions of dollars on a mission area that had once belonged to the Air Force, saying that aircraft such as bombers and fighters are too vulnerable against a peer adversary equipped with integrated air defense systems. The Army needs the ability to lob surface-to-surface missiles or artillery hundreds or thousands of miles downrange, he says. And his position has not changed.

"I'm convinced that across the joint force, we all recognize that enough targets are out there for all of us," Rafferty said during a Heritage Foundation videoconference on Aug. 24. "And we're going to have to figure out how to sort this out."

AIR FORCE RESEARCH LABORATORY

A Cargo Launch Expendable Air Vehicle with Extended Range pallet deployed from an MC-130 in a January flight test, demonstrating a possible new role for airlifters as an "arsenal plane" loaded with long-range standoff missiles.

USAF Errantly Reveals Research on ICBM-Range Hypersonic Glide Vehicle

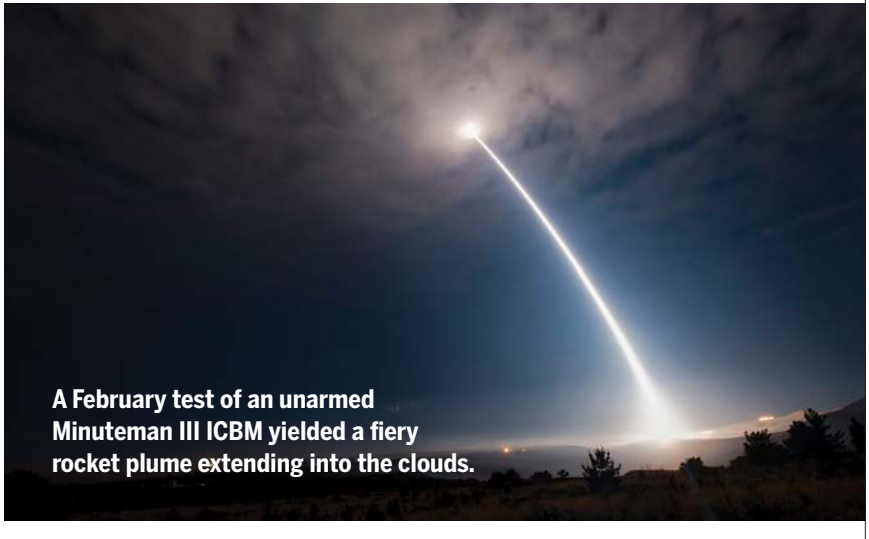
> AIR FORCE REMOVED DOCUMENT FROM PUBLIC WEBSITE

> PENTAGON REMAINS COMMITTED TO NON-NUCLEAR ROLE FOR HYPERSONICS

Steve Trimble Washington

The U.S. Air Force agency that manages the service's nuclear arsenal has started research on enabling technology for an intercontinental-range, hypersonic glide vehicle, according to a document that was briefly published in error on a public website.

Although the document shows that a U.S. nuclear weapons agency is researching hypersonic glide vehicle (HGV) technology, senior Defense Department officials say there has been no change to a policy that "strictly" limits the emerging class of hypersonic gliders and cruise missiles to non-nuclear warheads.



U.S. AIR FORCE

A February test of an unarmed Minuteman III ICBM yielded a fiery rocket plume extending into the clouds.

A request for information (RFI) published on Aug. 12 by the Air Force Nuclear Weapons Center asks companies to submit ideas across seven categories of potential upgrades for ICBMs designed with a "modular open architecture." The Air Force often describes the future Ground-Based Strategic Deterrent (GBSD) ICBM as featuring a "modular systems architecture," in contrast to the aging Minuteman III, which does not.

Among the seven items on the upgrade list, the Air Force called for a new "thermal protection system that can support [a] hypersonic glide to ICBM ranges," according to the RFI, which is no longer publicly available on the government's procurement website.

The RFI may have disclosed information that the Air Force's nuclear weapons buyers had not intended to be made public.

Each of the seven items listed in the RFI's "scope of effort" for ICBM upgrades included a prefix designation of "U/FOUO," a military marking for information that is unclassified but for official use only. Although not technically a classified secret, information marked as "FOUO" is usually withheld from the general public. The RFI was removed from Beta.sam.gov on Aug. 17 after Aviation Week inquired about the document with the Air Force and the Office of the Secretary of Defense.

The Defense Department has three different operational prototypes for HGVs in development now: the Air Force's AGM-183A Air-Launched Rapid Response Weapon, the Army's Long-Range Hypersonic Weapon and the Navy's Intermediate-Range Conventional Prompt Strike. Once fired from an aircraft, a ground-launcher or submarine, all three are designed to strike targets with conventional warheads at intermediate range, defined as 1,500-3,000 nm by *The Department of Defense Dictionary of Military and Associated Terms.*

But the Pentagon has no acknowledged plan to develop an HGV with a range beyond 3,000 nm and maintains a policy that "strictly" prohibits arming any such weapon—regardless of range—with nuclear warheads. The two most senior staffers leading the hypersonic weapons portfolio reiterated that policy during a press conference on March 2.

"Our entire hypersonic portfolio is based on delivering conventional warheads," said Mike White, assistant director of defense research and engineering for hypersonic weapons.

"Right," agreed Mark Lewis, the director of defense research and engineering for modernization programs. "Strictly conventional."

The Pentagon has not changed the policy since March 2, said Lt. Col. Robert Carver, a spokesman for Lewis' office.

"[The Defense Department] is not developing nuclear-capable hypersonic weapons," Carver wrote in an email. "There are common technology needs between the nuclear enterprise and hypersonic systems. Particularly in the area of high-temperature materials, we typically collaborate on the development of advanced dual-use materials technology. I will reiterate that our entire hypersonic program portfolio continues to be based on delivering conventional effects only."

The threshold requirements for the initial version of GBSD entering service in 2030 do not include an HGV for the reentry system, said Lt. Gen. Richard Clark, the Air Force's deputy chief of staff for strategic deterrence and nuclear integration. However, Clark, who spoke during an Aug. 19 webinar hosted by the Mitchell Institute, noted the GBSD is designed with a flexible architecture, allowing future variants to add new capabilities easily.

"GBSD does have an open architecture," Clark said. "It gives us an ability to incorporate emerging technologies or technologies we need to counter whatever threats we face in the future. If we decide down the road that there's a particular technology that needs to be incorporated, we will be able to do that."

Although the Pentagon upholds the conventional-only policy for hypersonic gliders and scramjet-powered cruise missiles, the source of the RFI raises questions, says James Acton, co-director of the Nuclear Policy Program at the Carnegie Endowment for International Peace.

"The fact that [this RFI] is coming from the Nuclear Weapons Center, it makes it sound an awful lot like this would at least be nuclear-armed or conceivably dual-capable," Acton says.

Although the RFI confirms research is underway, the Defense Department still has no acknowledged plans to proceed from basic research into the acquisition phase of an ICBM-range hypersonic glider, whether carrying a conventional or nuclear warhead. If the thermal-protection system technology is limited only to research, the RFI by the Air Force's nuclear weapons organization may not violate the Pentagon's policy, which may apply only to fielded weapons.

"[The Defense Department] does a lot of research on a lot of different things, and the vast majority of these programs never turn into an acquisition," Acton says. "It could turn into something, but sophisticated observers recognize that it may not."

The Pentagon's conventional-only policy for maneuvering hypersonic weapons stands apart from other countries in the field. Russia, for example, has deployed the nuclear-armed Avangard HGV on the SS-19 ICBM. In February, the head of U.S. Northern Command, Gen. Terrence O'Shaughnessy, said in written testimony submitted to Congress that "China is testing a [nuclear-armed] intercontinental-range hypersonic glide vehicle, which is designed to fly at high speeds and low altitudes, complicating our ability to provide precise warning."

The Pentagon has never had an announced weapons-development program for a conventional- or nuclear-armed intercontinental-range HGV but has experimented with air-launched gliders. DARPA's Hypersonic Test Vehicle 2 program attempted to demonstrate a range of 4,170 nm, but each experimental glider in two tests staged in 2010 and 2011 failed about 9 min. into a planned 30-min. hypersonic glide.

The leading edges of an intercontinental-range HGV could be exposed to temperatures as high as 7,000K (12,000F) on reentry, then endure a prolonged glide phase compared with an intermediate-range system, says Christopher Combs, who researches hypersonic aerodynamics as an assistant professor at the University of Texas, San Antonio.

"The bottom line is it's just crazy temperatures," says Combs. "They're not dealing with space shuttle or Apollo [capsule] temperatures, but it's still really hot."

The rescinded RFI, meanwhile, also may provide a rare glimpse into the Air Force's plans for the new ICBM developed under the GBSD program.

Apart from the thermal protection system for a hypersonic glider, the scope of effort in the RFI sought industry input on a variety of topics, including the following:

- Fusing data from lower-fidelity onboard sensors to improve guidance, navigation and control;
- New navigation aids to correct inertial measurement unit drift on long-time-of-flight missions;
- A lighter, smaller and more efficient "future fuze" that also could "accept inputs from external subsystems";
- Radiation hardening techniques for advanced microelectronics such as a system on a chip or system in package;
- Improved computer hardware and software including artificial intelligence algorithms;
- A more secure architecture and better security sensors for ICBM ground facilities.

The Air Force plans to award the contract to Northrop Grumman by the end of August to launch the engineering and manufacturing development contract for GBSD. Northrop remained the sole bidder for the program to deliver more than 600 new ICBMs to the Air Force after a Boeing-led team withdrew from the competition last year.

Check 6 *Aviation Week editors discuss the new information revealed about the U.S. hypersonics program:* **AviationWeek.com/podcast**

New Factory Opening Launches Hypersonic Industrial Phase

> DYNETICS FACILITY OPENS IN OCTOBER

> LOCKHEED AND AEROJET ALSO ADD PRODUCTION CAPACITY

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

Another first in U.S. hypersonic history will take place in November, but not in a wind tunnel nor during a flight test. As military orders shift from minuscule batches of experimental craft to mass-produced missiles, Huntsville, Alabama-based Dynetics will open the first U.S. factory publicly assigned to deliver hundreds—perhaps even thousands—of hypersonic glide vehicles (HGV) during the next several years.

The Defense Department's $10 billion plan to field at least three different HGV programs by 2025 has fueled rapid development of a new industry sector. The Air Force's AGM-183A Air-Launched Rapid Response Weapon (ARRW) is scheduled to enter service at the end of 2022, followed by the Army's Long-Range Hypersonic Weapon (LRHW) in 2023 and the Navy's Intermediate-Range Conventional Prompt Strike (IRCPS) in 2025. As the military's chosen weapon system integrator for all three programs, Lockheed Martin is the clear industrial leader of a nascent HGV market with two geographic centers: Huntsville and Palmdale, California.

On the heels of the first wave of HGV programs, the Air Force plans to start developing another arsenal of scramjet-powered hypersonic cruise missiles. The Future Hypersonics Program seeks to develop a follow-on to the Hypersonic Air-Breathing Weapon Concept (HAWC), and the newly revealed Mayhem program by the Air Force Research Laboratory seeks to develop a demonstrator for an advanced air-breathing propulsion system.

In Huntsville, Dynetics will assemble the Common Hypersonic Glide Body (CHGB) for the Army's ground-launched LRHW and the Navy's IRCPS, then ship the completed gliders to a nearby Lockheed facility. Lockheed's workers will integrate the CHGB onto a common two-stage, 34.5-in.-dia. missile. The ground-launched version will then be delivered to a new Army artillery unit, and the Navy version will be inserted into a special launch system in development for Virginia-class submarines.

The Air Force's industrial plans for the ARRW are less clear, but the city of Palmdale announced last December that Lockheed plans to open a new 208,000-ft.^{2} Low-Bay Advanced Manufacturing Facility in 2021 on the Skunk Works campus, which is also known as Site 10 within the Air Force's highly secretive Plant 42 complex. The ARRW all-up round includes a smaller-diameter, single-stage booster with an advanced high-lift-to-drag-ratio HGV front end.

By contrast, the Army has been far more public about the industrial plans for the CHGB front ends for LRHW and IRCPS. In August 2019, the Army awarded Dynetics a nearly $352 million contract to deliver the first 20 CHGBs, which will support a series of LRHW and IRCPS flight tests starting in 2021.

Assembly of the first glide body has begun in Albuquerque, New Mexico, the home of Sandia National Laboratories. The CHGB is a derivative of the Sandia-manufactured Advanced Hypersonic Weapon program, which itself was based on the Sandia Winged Energetic Reentry Vehicle. Dynetics is technically the supplier for the first CHGB, but its workers are now shadowing Sandia's experienced team in Albuquerque. The Sandia team will then travel to Huntsville this fall, where they will shadow Dynetics staff as they assemble the second CHGB.

"The glide body itself is a complicated beast," says Paul Turner, Dynetics' hypersonic program manager. "There are tolerances that are very tight in some locations."

To support the assembly of the second CHGB, Dynetics plans to open the production area in the new Huntsville facility as part of Phase 1 operations in October, Turner says. After securing a certificate of occupancy at a location adjacent to the former Mid-City Mall, Dynetics will be able to start moving heavy equipment, including test chambers, into the production area. Phase 2 will open a high-bay area for final integration and testing, which is scheduled to be completed in mid-December.

A network of suppliers will be feeding subassemblies into the Dynetics production line. The Army will deliver the critical thermal protection system, which is in development under a separate contract. General Atomics Electromagnetic Systems is a subcontractor to Dynetics, producing "a couple of subassemblies" along with the cables for the glide body, Turner says. Raytheon Technologies is responsible for delivering the control module for

SGT. JAMES HARVEY/U.S. ARMY

Army Secretary Ryan McCarthy on July 1 visited Dynetics' new Common Hypersonic Glide Body factory, which opens in October.

the CHGB's four elevon-based flight control surfaces.

"We are building all of the other avionics components within our main campus area" in another area of Huntsville, Turner says. "Those will be delivered to the Mid-City area for final testing, integration and assembly into the glider. In order to be successful, one company can't do it all. We went through and figured out who has the expertise in the right areas. And we are using that expertise and each other's strengths to ensure that we deliver what we say we will."

Anticipating a huge surge in demand for hypersonic propulsion systems, both boosted and air-breathing, Aerojet Rocketdyne is systematically expanding existing manufacturing sites and adding new capabilities through growth and acquisition.

"We've invested in the infrastructure and the capital to provide a broad range of capabilities to support hypersonics in the areas of scramjets, solid rocket motor boosters, warheads and targets," says Tyler Evans, senior vice president of the company's Defense Business Unit. "We've co-located similar methods and manufacturing skills in order to leverage economies of scale, and we've created computational tools that improve our ability to repeat and develop incremental improvement."

Although many of the offensive and defensive hypersonic efforts the company is currently involved in are still developmental in nature, they each provide the potential basis for substantial follow-on operational programs with high production volumes. These range from DARPA's Glide Breaker and Operational Fires (OpFires) programs to the Advanced Full-Range Engine TBCC propulsion system and the HAWC with Lockheed Martin.

Some of the boosted initiatives have nearer-term production potential than the air-breathing programs. In July, for example, Aerojet Rocketdyne revealed it had successfully completed cold gas tests of the OpFires propulsion system, marking another milestone toward potential transition of the DARPA-led effort to create an operational production version of the ground-launched hypersonic tactical missile. Developed with Lockheed Martin and the U.S. Army, the OpFires missile is due to begin flight tests in 2022.

Much of the initial industrialization focus has been on expanding booster production capability at sites such as the advanced manufacturing facility (AMF) at Huntsville, which opened in 2019, and the follow-on engineering, manufacturing and development (EMD) facility in Camden, Arkansas. In addition to hypersonic work, the 136,000-ft.^{2} AMF is producing solid rocket motor cases and related hardware for Standard Missile-3, Terminal High-Altitude Area Defense and the Air Force's next-generation Ground-Based Strategic Deterrent program (GBSD).

Aerojet Rocketdyne says the Camden expansion builds on the company's decades-long history of solid rocket motor production at the site. "The EMD was specifically designed to serve as the developmental gateway to future large solid-rocket-motor product opportunities, to include GBSD, hypersonics, missile defense targets and small launch vehicles," it adds.

But with the ramp-up in air-breathing hypersonic weapons and the beginning of new acquisition programs such as the Air Force's recently disclosed scramjet-powered cruise missile HAWC follow-on, the company is also growing new cost-cutting additive-manufacturing capabilities. Leading this drive was the 2019 acquisition of Florida-based additive-manufacturing specialist 3D Material Technologies (3DMT), which is designed to lower Aerojet Rocketdyne's production costs across its range of solid and liquid rockets as well as scramjets. Additive manufacturing is "integral to our solution," Evans says.

As the developer of the scramjet engine for the Air Force's Boeing X-51 in the 2000s, Aerojet Rocketdyne aims to capitalize on its experience of being the first U.S. manufacturer of a serially produced air-breathing hypersonic propulsion system. "The X-51 was a propulsion demonstrator that showed we could tame the science of supersonic combustion, and it did that. And so, 10 years later, we're focused on making scramjets practical, making them repeatable, making them affordable," he adds.

The 3DMT is a key element of the plan, Evans says. "That's really [based on] having the tools and methods and the capabilities to repeat and affordably produce what we demonstrated 10 years ago. Additive manufacturing gets talked about a lot out in aerospace and defense," he adds. "Since the X-51, as we've looked at the challenge of practicality, additive manufacturing has really proved to be a disruptive enabler of cost improvement and schedule improvement."

Russia Reveals Weapons for Altius Unmanned Aircraft

> ALTIUS REMAINS FAR FROM OPERATIONAL READINESS

> THE RUSSIAN DEFENSE MINISTRY HAS NOT APPROVED A WEAPONS DEVELOPMENT PROGRAM FOR UNMANNED AIRCRAFT

Piotr Butowski Gdansk, Poland

This summer, Russian Deputy Defense Minister Alexey Krivoruchko visited a local branch of the Ural Works of Civil Aviation in Kazan to evaluate the progress of the Altius (a Russian acronym) high-altitude long-endurance unmanned aircraft ordered by the Russian military.

Despite the word "civil" in its name, the Ural Works of Civil Aviation (UWCA), headquartered in Yekaterinburg, supplies the Russian defense ministry. Its workers also assemble the Forpost UAV, which is an Israel Aerospace Industries Searcher Mk. 2 and the largest and most advanced reconnaissance UAV at the disposal of the Russian Armed Forces.

At the UWCA's Kazan airfield in June, Krivoruchko was shown a test specimen of the Altius-U with the number 881 during the first presentation of a weapon for the aircraft, according to a Russian television report.

Two bombs of an unknown type lay in front of the UAV, and another bomb was hanging under the wing. The

RUSSIAN DEFENSE MINISTRY

Russian defense officials are evaluating the progress of Russia's Altius high-altitude long-endurance UAV.

weight of the bomb can be estimated at about 100-150 kg (220-330 lb.); it is supposedly guided by inertial navigation supported by a satellite navigation receiver. A satellite communications antenna under the dismantled cover at the top of the Altius front fuselage and an electro-optical turret under the central part of the fuselage were shown for the first time. Ground operator positions were also revealed.

The UWCA is not the original developer of the UAV. Control of the program was transferred to the UWCA from OKB Simonov in 2018, after OKB's CEO and chief designer Alexander Gomzin was arrested on charges of malpractice and embezzlement of government funds. When the UWCA took control of the program, its code name changed from Altius-O to Altius-U. At the time, one technology demonstrator, 01, and two prototypes, 02 and 03, had been built. The 03 aircraft features satellite communications and other equipment as well as a recently installed electro-optical turret.

On Aug. 20, 2019, the Altius-U UAV made a widely advertised first flight. Although the airplane shown in the Russian military was numbered 881, it was probably the previous 03, which had already flown and was then repainted. It is unknown what changes were introduced after the UWCA takeover.

In December 2019, the defense ministry ordered more R&D work from the UWCA on an Altius-RU variant. There is no information on how the version would differ from the previous one, though it likely denotes that foreign components on the aircraft were replaced by Russian ones. Krivoruchko says the Altius-RU will be "a reconnaissance-strike system with long-endurance UAVs of a new generation, equipped with a satellite communications suite and elements of artificial intelligence, which can cooperate with manned aircraft."

In the summer of 2019, the UWCA established a branch in Kazan and since then has been expanding by purchasing areas and buildings near the airfield and gradually poaching the staff of OKB Simonov. The UWCA likely will place Altius' future production in Kazan and may transfer its UAV production from Yekaterinburg.

Since 2012, the UWCA has assembled about 60 Forpost UAVs from components supplied by Israel. In December 2019, Russia's defense ministry ordered another 10 unmanned aircraft systems (UAS)—each UAS comprises three UAVs and a ground control station—in the new version of Forpost-R and promised to order 18 more systems, with delivery by 2027. Forpost-R is a version of Forpost made within the "import substitution" program—that is, completely from Russian components.

The Altius project has not been easy. During nine years of development, only three test aircraft have been created, and the mission equipment remains incomplete. The transfer of the Altius project to another company and the unclear situation inside the design team may have caused additional disruption. Also, Russia does not have a coordinated UAS weapons development program, even if armaments for Forpost, Inokhodets (Orion) and now the Altius have occasionally been displayed. The work is still the initiative of individual companies in Russia.

There is no clarity about the Altius engine, either. Test aircraft are powered by two 373-kW (500-hp) A03/V12 diesel engines made by RED (Raikhlin Aircraft Development), founded in Germany by Russian immigrant Vladimir Raikhlin. Engine production was to be located in Russia, but those plans are currently unrealistic. Instead, the Moscow Central Institute of Aviation Motors has designed a new 500-hp engine for the Altius based on the car engine from the Aurus limousine, the most technologically advanced piston engine in Russia.

Altius Specifications

Dimensions (m [ft.])

Wingspan	28.38 (93)
Length	12.41 (41)

Weights (kg [lb.])

Max. takeoff	7,000 (15,432)
Max. payload	2,000 (4,409)

Performance

Operational speed	150-250 km/h (93-155 mph)
Altitude	12,000 m (39,370 ft.)
Endurance	48 hr.

Source: Piotr Butowski

Russia Nears Start of Su-57 Production

- SU-35 MANUFACTURING WILL CONTINUE UNTIL AT LEAST MID-DECADE
- DEFENSE MINISTRY IS FOCUSED ON REDUCING SU-57 PURCHASING AND OPERATING COSTS

Piotr Butowski Gdansk, Poland

Russia's Sukhoi Su-57 multirole fighter aircraft, years in the making, is nearing the start of production. However, the ramp-up will still take several years, especially in light of the Russian military's effort to save on the program's manufacturing and operating costs. In the meantime, United Aircraft Corp. subsidiary Sukhoi's Far East production facility will remain focused on manufacturing the export-intended Su-35.

Russia's defense ministry is concluding its decade-long state armaments program this year and is in the process of negotiating a new round of contracts for aircraft. Defense Minister Sergei Shoigu visited two of United Aircraft Corp.'s fighter aircraft manufacturers, in Komsomolsk-on-Amur in Russia's Far East and in Irkutsk, on Aug. 12, promising to purchase new aircraft.

During Shoigu's visit to the assembly hall in Komsomolsk-on-Amur, the company rolled out the second preliminary series Su-57, or T-50S-2 (T-50 is the internal designation for Su-57 prototypes; T-50S is the initial production version). Since the first aircraft, T-50S-1, crashed on Dec. 24, 2019, during a handover flight, the first aircraft delivered to the Russian Aerospace Forces will be the T-50S-2.

The T-50S-2 on display was still not fitted with at least one of the engines, some covers were not yet in place, and it had a makeshift radar nosecone. The tailfins were a bit of a mystery. They wore a pixel camouflage typical of Su-57 prototypes, while the rest of the aircraft was still unpainted, raising the question: Were the fins from another, earlier aircraft?

The aircraft was to be moved to the flight station on Aug. 20, according to Alexander Pekarsh, Komsomolsk-on-Amur plant director. "By Oct. 30, it is to be handed over for operations." The aircraft will likely go to the 23rd Fighter Aviation Regiment at Dzyomgi, which is also the airfield of the Komsomolsk-on-Amur plant. It is typical for new aircraft to be initially delivered to a neighboring unit to ease qualified maintenance.

According to a chart presented to Shoigu, the T-50S-2 will be the only Su-57 made this year, while the plan for 2021 envisages the production of four Su-57s. Production volume will increase in the following years. In July 2019, the defense ministry placed an order for 76 Su-57 fighters by 2028.

Shoigu stressed during his visits to Komsomolsk and Irkutsk that purchase price and operating costs are of key

UNITED AIRCRAFT CORP.

The second preproduction version of the Su-57 is also denoted the T-50S-2.

importance for the military. Pointing to the Su-57 price chart, he told industry representatives: "The lower [the price] goes, the stronger our friendship with you will be." He called for a reduction in flight-hour costs and for future contracts covering the entire life cycle of an aircraft.

Production of the first T-50 airframe in 2010 required 785,000 worker hours. The T-50S-2 required just 247,000 worker hours. In 2022-23, the labor rate of one Su-57 airframe will drop below 200,000 worker hours and be reduced to 146,000 worker hours by 2028. By comparison, the production of one Su-35S requires 120,000 worker hours. A program to improve the quality of material is also being implemented. Production of one Su-57 requires 78 tons of aluminum and 16 tons of titanium; the target is 64 and 14 tons, respectively. The plant has started managing the Su-57's production flow.

With Su-57 production just beginning, the main product in Komsomolsk remains the Su-35/Su-35S (the version without a letter is intended for export; S denotes the version for Russia). According to Pekarsh, the Su-35S' share of total 2020 production will be 42% (including remanufacturing), while export deliveries of the Su-35 will constitute 31% and the Su-57 20%. Civil production—the fuselage and outer wing panels for the SSJ-100 passenger aircraft—is set at 7%.

The defense ministry previously ordered two batches of the Su-35S: 48 fighters completed in 2011-16, and 50 fighters with delivery in 2016-20. Pekarsh says this year the factory will deliver the last 10 Su-35S fighters from the second contract. "We delivered four airplanes in June, three will be handed over in September and three in November." The chart shown to Shoigu indicated one more previously unknown contract for six Su-35S fighters with delivery in 2021-22; it may be an order to supplement aircraft retired for various reasons.

According to Pekarsh, the plant has a full load for this and next year. However, for financial stabilization in 2022-24, "it is necessary to contract 20 Su-35S aircraft soon."

Shoigu says: "We plan to conclude an additional state contract for the supply of multifunctional Su-35S aircraft. The contract amount will be 70 billion rubles [$940 million]." This indicates that the current price of one Su-35S is 3.5 billion rubles, about $47 million. The export price is much higher; Indonesia's canceled order of 2018 for 11 aircraft was worth $1.14 billion, or $104 million apiece.

The financial stabilization of the facility in Russia's Far East has an important social context. The plant employs 9,600 people in a city with a population of 250,000, and so a large portion of the meeting was devoted to employment stability. During his visit, the defense minister was accompanied by the new governor of Khabarovsk, where protests have been going on for weeks.

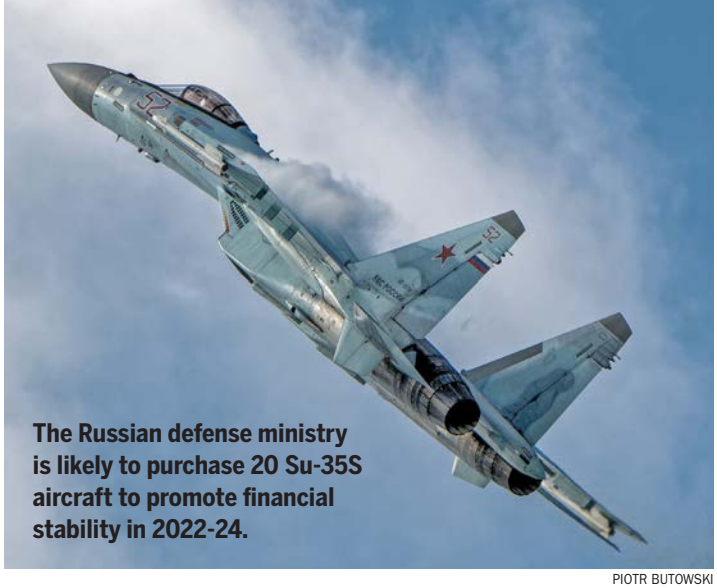
An interesting question is why the government is buying Su-35S fighters for "financial stabilization" rather than Su-57s. Perhaps the Russian Aerospace Forces do not want to increase the order for the Su-57 until the planned modernized Su-57M (T-50M) version with new engines enters production. The modernized fighter is expected to enter service in the middle of this decade, Deputy Defense Minister Aleksey Krivoruchko has said.

PIOTR BUTOWSKI

Russia plans to order 21 Su-30SM2 fighters, which denotes a new upgrade program, possibly with an expanded weapons suite.

During the Russian defense minister's visit, there was no talk of export orders. In the long run, however, the market for the Su-35 is abroad. Russia does not plan further orders after the current "stabilizing" contract for 20 fighters. The first foreign buyer, China, received 24 Su-35 fighters in 2016-18. Indonesia placed its order for 11 fighters in February 2018, then terminated the contract due to U.S. pressure resulting from the Countering America's Adversaries Through Sanctions Act.

In the chart shown to Shoigu, export production of the Su-35 was presented in two lines, suggesting that there are



The Russian defense ministry is likely to purchase 20 Su-35S aircraft to promote financial stability in 2022-24.

PIOTR BUTOWSKI

two export contracts. For one of those customers, 22 Su-35 fighters are to be delivered this year and eight the next year, a total of 30. Almost certainly this customer is Egypt, which is known to have signed a contract for such a batch of Su-35 fighters in March 2018. This July, five Su-35 fighters without any nationality marks, but in a paint similar to other Egyptian Air Force aircraft, were spotted in Russia.

The second Su-35 export contract remains a mystery. According to the chart, the second contract provides for the delivery of 12 aircraft in 2022, 14 in 2023 and probably 6-8 in 2024 (the picture of the chart is blurred), i.e., a total of 32-34 fighters. The customer could be China again. Other countries known to have negotiated the purchase of Su-35s include Algeria, the United Arab Emirates and Vietnam.

Shoigu held a similar conference at the Irkutsk Aviation Plant and declared that the defense ministry would order 21 Su-30SM2 fighters and 25 Yakovlev Yak-130 jet trainers. The contracts are to be worth "over 100 billion rubles" in total. Such orders would mean more than a year of work at the Irkutsk plant.

The contract for Su-30SM2 fighters is particularly interesting, as such a modification has been previously unheard of. In 2016, Sukhoi launched an Su-30SM upgrade program, which provided for a new computing system, an improved radar antenna and more powerful transmitter and a new Khibiny-U self-defense suite. The weaponry was to be expanded with new Kh-31M, Kh-35U and Kh-38M air-to-surface missiles, as well as heavy "izdeliye 620" ("izdeliye" is Russian for "product") air-to-air missiles. Most likely, the Su-30SM2 is an aircraft modernized according to this program.

Another upgrade program is the Su-30SM(D), where the current 12.5-ton AL-31FP turbofans are being replaced with 14.5-ton AL-41F-1S engines from the Su-35 (hence the D, for Dvigatyel engine, in the designation). The first Su-30SM(D) retrofitted with AL-41F-1S engines is ready but has not yet started flight tests.

AIR COMBAT BY ALGORITHM

> AI'S MACHINE-PRECISION CONTROL OF F-16 WINS THE DAY

> REINFORCEMENT LEARNING INVOLVED BILLIONS OF DOGFIGHTS

Graham Warwick Washington

Falco is an artificial intelligence agent, a machine-learning algorithm that is barely a year old but has the equivalent of 30 years' experience flying the Lockheed Martin F-16.

Banger, identified only by his call sign for security reasons, is a graduate of the instructor course at the U.S. Air Force Weapons School with more than 2,000 hr. flight time in the F-16.

On Aug. 20, in the final event of DARPA's AlphaDogfight Trials (ADT), Falco beat Banger 5-0 in air combat between two simulated F-16s. Falco had already beaten artificial-intelligence (AI) agents from Lockheed and six other finalists to win the right to fight the human.

With a winning tactic of maneuvering hard from the outset to take high-angle gunshots against its opponent, the "hyperaggressive" Falco showed "superhuman aiming ability," according to DARPA's competition co-commentators, Chris Demay and Justin Mock—fine motor control that was honed by deep reinforcement learning over at least 4 billion training examples, says Heron Systems, Falco's developer.

That was not true at the first trial, in November 2019, where the AI agents struggled to simply fly the aircraft. But progress was rapid, and by the second trial in January, "they were doing things that our pilots really thought looked a lot like basic fighter maneuvers," says Col. Daniel Javorsek, manager of DARPA's Air Combat Evolution (ACE) program.

"Even a week before Trial 1, we had agents that were not very good at flying. We were able to turn that around, and since then we've been really in first place," says Benjamin Bell, lead developer of Falco at Heron, a small business based in California and the Washington, D.C., area.

The AlphaDogfight Trials were a precursor to ACE, which will culminate in live flight tests of AI-enabled automated dogfighting between full-size aircraft. The rapid progress in AI agent capability over the trials has given DARPA more confidence the algorithms will scale from simple 1v1 dogfighting to more complex, campaign-level air combat.

"The AlphaDogfight part of the program will increase the performance and trust of local combat autonomy, these individual, 1v1, tactical behaviors," Javorsek says. "Then we're going to expand that to team tactical behaviors, 2v1 and 2v2. Our hope is we'll be able to scale these trusted algorithms to more complex campaign levels with multiaircraft operational behaviors."

"I don't think you're seeing the end of a human fighter pilot;

I think you're seeing the refinement into a human weapon system"

DARPA chose dogfighting because it is "a closed-world problem that an AI algorithm can learn really well," says Tim Grayson, director of DARPA's Strategic Technology Office. "At the same time, there are higher-level cognitive problems, the battle management, more strategic things, the intuitive decision-making that for machines are still a long way off."

Quoting a former Air Force Warfare Center commander as saying "I've got to stop spending so much time training fingers and more time training brains," Grayson himself says: "Imagine a skilled fighter pilot who can move from aircraft to aircraft without having to go through laborious training and recertification every time because the AI is doing the hard part—how to control the aircraft and do the tactical maneuvers. That intuitive battle management skill that the pilot has can then transfer from system to system."

The outcome of the ADT comes with several caveats. The simulated dogfights took place between two unclassified JSBSim open-source models of the F-16. The AI agent had perfect-state information on its own aircraft and its opponent's, which enabled it to exploit its fine-precision control. The pilot had a chair, replica controls and a virtual-reality headset but did not have to endure the physiological effects of the sustained high-g maneuvers that ensued.

Engagements were limited to simple 1v1 basic fighter maneuvers (BFM) and gun attacks. But instead of a gun, damage was inflicted by maneuvering a 3,000-ft.-long 1-deg. cone onto the target. This avoided the need to train the AI agent when to pull the trigger, data for which is "really sparse," admits Bell.

Crucially, the simulations did not include the "bubble" around each aircraft required by training safety standards to avoid collisions. These rules do not allow pilots to pass within 500 ft. of each other and restrict gunshot angles to no more than 135 deg.—limits both aircraft "were violating routinely," says Javorsek.

While such limits would not apply in real air combat, adhering to the training rules builds habits into human pilots, Banger contends. "I may not be comfortable pulling my aircraft into position where I might run into something else or take that high-aspect gunshot, and the AI would exploit that."

Also the AI agents were not allowed to learn during the trial events. But the pilot was. This was clear in the fifth and final engagement, when Banger tried a different tactic: taking combat down to the minimum altitude or "hard deck." In earlier trials, "our agents were hard-decking almost 50% of the time in defensive situations," says Bell. Heron's focus for Trial 3 was on zero hard decks. "You see the pilot trying to take advantage of that in the final example, and thankfully we didn't hard-deck," he says.

Heron credits Falco's fine-pointing of the F-16 to a control strategy

DARPA

U.S. Air Force F-16 instructor pilot "Banger" lost five of five dogfights to an artificial intelligence algorithm despite adapting his tactics to counter AI-agent Falco's aggressive maneuvers.

that emphasized smoothness. "We're controlling it around 10 Hz. It looked like a lot of our competitors were controlling at 50 Hz," Bell says. That limited update rate required the AI agent to know its trajectory for the next 3 sec. to keep its opponent within the 1-deg. cone of the "gun."

"We saw that a lot with Lockheed, where we're both nose-on, we're both doing damage, but for whatever fractions of a second that they don't have us in their 1-deg. cone, that's when we're racking up damage and they're not," he says. "That's how we won a lot of those engagements."

Bell also credits Falco's success to Heron's approach to reinforcement learning, a technique in which an AI agent is trained by being rewarded for certain actions. Falco was trained over a total of about five weeks through billions of dogfights against a league of 102 unique AI agents.

"We started off early with a league of agents," he says. "We wanted to create multiple different agents that are all flying in certain patterns. They have different reward structures, different ways of controlling the plane and different neural network architectures. The league gave us the robustness so that, across the board, we were able to beat any opponent, including the human, that we went against."

Heron used model-free reinforcement learning. "There's no model of how the environment's going to run. We're not predicting the future state of the other plane or our own. It's much easier," says Bell. By avoiding the complex problem of modeling, Heron was able to start training Falco on Day 1. "It's hard to do and if your model's bad, then your agent's going to end up worse," he says.

Over in just 10 min., the human pilot's one-sided loss to a machine unleashed a spate of comment and speculation online, ranging from "end of an era" to "just one more overhyped AI demonstration." But DARPA has not set out to replace the human pilot. Instead, its ACE program aims to build trust in AI so that the pilot can focus on battle management while the machine flies the aircraft.

"If we convinced even a couple of pilots that what they were seeing out of this Heron autonomous agent looked like something that was intelligent and creative and making smart decisions in this dynamic BFM engagement, then I'm considering it a success because those are the first steps I need to create trust in these sorts of agents," Javorsek says.

"If I were to walk away from today and say, 'I don't trust the AI's ability to perform fine motor movements and achieve kills and [damage] that I'm uncomfortable with,' I'd have a lack of integrity," Banger says.

The mystery fighter pilot also joined in the speculation on how AI-controlled autonomous aircraft could change the face of air combat. "If I have an autonomous system out there, and we're in combat against a singular adversary, I would love to have it take that high-aspect gunshot on the enemy," he says.

There is also potential for "developing a wingman that has learned my assumptions so well that it's able to predict with 98-99% probability what I'm going to do, and so we as a combat pair or four-ship become even more lethal," he says. "For that reason, I don't think you're seeing the end of a human fighter pilot; I think you're seeing the refinement into a human weapon system."

FINAL COUNTDOWN

- SEVEN SITES ARE PROPOSED FOR SMALLSAT LAUNCH ACROSS THE UK
- SUTHERLAND SPACE HUB RECEIVED PLANNING APPROVALS IN AUGUST
- SHETLAND SPACE CENTER HOPES TO ACHIEVE FIRST LAUNCH IN 2021

Tony Osborne London

The UK wants to be the first nation in Europe from which commercial launch companies can send satellites into orbit. The British government often reaches out to stakeholders—particularly those that will be affected by new regulation—for feedback on proposed legislation before it is presented to lawmakers. And now, as the government consults on the regulations that will make local space launches viable, sites across the country are positioning themselves to be ready for the first launch, potentially as soon as late 2021.

The UK's proposed vertical launch sites are situated in Northern Scotland for polar and sun-synchronous orbits and benefit from largely open ocean and uncongested skies to launch through and over. The horizontal launch sites mainly make use of former military airfields with close proximity to the sea and long runways capable of handling large carrier aircraft such as the Boeing 747.

The British gave up their government-funded launch ambitions in the 1960s, preferring instead to focus on the development of satellite technology, an industry that has subsequently thrived. But in a new era of commercial spaceflight, "Britain wants to offer small-satellite manufacturers a direct end-to-end route to launch," Ian Annett, deputy CEO of the UK Space Agency, told a Farnborough Airshow virtual forum in July.

"This will bring new markets into the country," added Annett, noting that launch capabilities could contribute to the government's aim of growing the UK's share of the international space market by 10% by 2030.

Interest in UK launch is not a fad, Chris Larmour, CEO of launch operator Orbex, tells Aviation Week. He sees a "strong desire" from European satellite companies to stay in Europe rather than transport their payload halfway around the globe for launch.

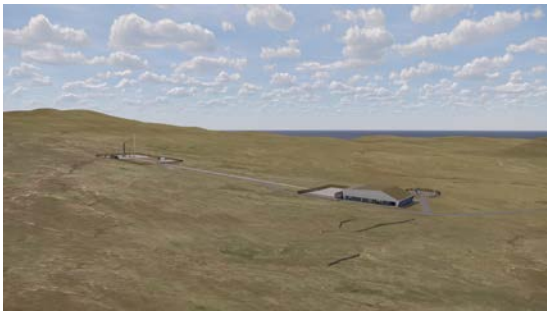
"It seems that people are willing to pay a premium to stay local," Larmour says. "The real issue in the smallsat market is time, not the money. Some of these companies have their satellite stuck in a queue for launch. They can be bumped three or four times, and that hurts their business plans a lot. . . . We can give them that reli-

able on-time departure effectively."

The UK is a useful launch site for small satellites heading to sun-synchronous and polar orbits, particularly for observation and Earth-monitoring missions.

SHETLAND SPACE CENTER

Shetland Space Center



HIGHLANDS AND ISLANDS ENTERPRISE

Space Hub Sutherland

SPACEPORT CORNWALL

Spaceport Cornwall

The Sceptre report—produced by the Elecnor Deimos space consultancy in 2017—examined 12 potential vertical launch sites located across northern Scotland. It concluded that a "significant market" could exist for a UK launch service if logistics challenges posed by the remote areas could be overcome. Since the report's publication, three vertical launch sites have emerged in Scotland: in Shetland, Sutherland and in the Western Isles.

Four sites for horizontal launch are also proposed: Glasgow Prestwick Airport and Campbeltown—the former Machrihanish Air Base in Scotland; the Snowdonia Space Port, a former flight-test airfield at Llanbedr, Wales; and Spaceport Cornwall, which will use the runway of Newquay Airport, also a former Royal Air Force (RAF) station for maritime patrol aircraft.

To kick-start commercial launch, the British government has provided grants to potential launch sites and launch operators. It also has secured international agreements such as the Technology Safeguards Agreement with the U.S. government. That accord permits U.S. companies to operate from UK spaceports and eases the export of space launch technology between the countries—although the full details of the document have yet to be published, as it still must be ratified by the British Parliament (*AW&ST* June 29-July 12, p. 60).

The UK also has secured a memorandum of understanding with the Faroe Islands, a self-governing archipelago of Denmark, for overflight, and work is underway to secure similar agreements with Iceland.

Among the first to receive a grant was Space Hub Sutherland, a site on the picturesque A'Mhoine peninsula proposed by the Highlands and Islands Enterprise (HIE), a regional development agency. HIE received £3 million ($3.9 million) in funding to support infrastructure development for the facility. It was announced by the UK Space Agency two years ago at the Farnborough Airshow (*AW&ST* July 30-Aug. 19, 2018, p. 43).

Launch operators Lockheed Martin and Orbex received $31 million and $7 million, respectively, to support initial launch operations there. The initiative has since successfully navigated hurdles posed by the British planning system, finally securing approvals from local authorities in August despite some local opposition about the environmental impact of the facilities.

The permissions come with caveats, says Roy Kirk, Space Hub Sutherland project director, including "significant mitigation" to make sure the environment is protected and that "this will bring local and regional and national economic benefit." Securing planning permission is only part of the story. Turning this sleepy crofting land into a launch site was not foreseen when Scottish land-use laws were first drawn up in 1886, so the HIE now has to go to the Scottish Land Courts to present its proposals for development and ensure the scheme will bring benefits to the crofting community that is leasing the land to the HIE.

Land Court permissions should enable spades to be driven into the site in early 2021. Under its business plan, the Sutherland Space Hub will be built as a single launchpad capable of up to 12 launches a year. The facility will be run by a launch site operator (LSO) likely to be a consortium. They will work on a build-and-operate model, charge a launch fee and pay rent to the HIE for exclusive use of the site and its facilities. A tendering process for the LSO will begin soon.

Kirk says he is hopeful that Sutherland's first launch will take place in 2022 and could be conducted by Orbex with its Prime launcher.

"We are obviously considering who will be first, but the question is whether we will be making a profit in 10 years' time," Kirk says. "It is really important that this is a commercial model. Sutherland needs to offer a competitive and effective launch service.... There is no doubt at all that if it's too expensive, people will go elsewhere."

With its planning permissions in place, Sutherland has a significant lead on other sites, but it has also cleared a path for others.

On the island of Unst, part of the Shetland Islands, the management behind the Shetland Space Center (SSC) hopes to beat Sutherland by launching a year earlier if the government's regulations are in place to allow it. The SSC's site at Saxa Vord, also the location of an RAF radar station, was named in the Sceptre report as the best location for launch in the UK, in part because it avoids flying over the Faroe Islands and Iceland.

Plans for the SSC are on a larger scale than those at Sutherland, with proposals for three launchpads and three integration facilities potentially enabling up to 30 launches a year, both orbital and suborbital.

"We are in talks with seven or eight

launch providers," says Scott Hammond, operations director for the SSC. "Will they all make it? No . . . but we were always reticent about just being beholden to one single launch provider," he adds. The SSC team is putting together an environmental assessment and will apply for planning permission from the local authority this year.

Hammond says the initiative has strong support from the local population and councils, who see the benefit of diversifying the economy into space and away from the islands' dependence on the oil-and-gas industry.

"People often don't realize what Shetland has to offer," says Hammond. Businesses that currently support the energy industry can also support launch. He cites a local company, Pure Energy, that produces hydrogen. The waste product of their process is oxygen, which could be repurposed into liquid oxygen for use in the launchers. "We want to leverage as much of the local capacity as possible," Hammond says.

In addition to owning the site, the SSC will act as the launch site operator; the model will be like that of running an airport.

"Our biggest worry is [whether] the regulations will be in place ready for launch," says Hammond. "The UK is in a competition with other European countries like Norway, Sweden and the Azores [Portugal], and we are ahead. But the longer we take over the regulations, the more we fall back into the pack."

"There is a sizable market that the UK can benefit from here, and being first to market makes a big difference," Hammond says.

The SSC already has agreements in place with launch providers from North America and Europe, including Canada-based C6 Launch Systems, Scotland-based Skyrora as well as other undisclosed companies. Norfolk, England-based Raptor Aerospace hopes to fly suborbital payload flights from Shetland, while Bristol, England-based B2Space is looking at launching a rocket from a platform suspended under a stratospheric balloon.

At the opposite end of the country, Spaceport Cornwall is envisaged to become the UK base for Virgin Orbit's horizontal launch system, LauncherOne, with funding from the UK Space Agency and the Cornwall Council worth up to £20 million, while Virgin is investing £2.5 million in the project. Virgin Orbit hopes to perform the first horizontal satellite launch from Cornwall in 2022, Spaceport Cornwall Director Miles Carden told a Farnborough Airshow virtual forum in July. The site is one of five Virgin Orbit is setting up in different parts of the world to achieve the orbit trajectories required.

"Our spaceport will be open to all; there is no exclusivity between the two [Virgin Orbit and Spaceport Cornwall]," Carden said.

Work is underway to develop the spaceport infrastructure and ground support equipment "that will provide capability for other providers," he added.

Proposals for a vertical launch site on the island of North Uist have faced objections from locals on environmental grounds, but it is backed by the Western Isles Council and is being developed in conjunction with defense contractor Qinetiq, which operates the Hebrides missile range on behalf of the UK Defense Ministry. Few details about the project have emerged since the novel coronavirus pandemic took hold.

Plans for a horizontal launch spaceport at Campbeltown on the Mull of Kintyre received a £488,000 boost from the UK government in 2019, paving the way for feasibility studies. Reaction Engines has been exploring using the Cold War airfield for flight testing of its Synergetic Air-Breathing Rocket Engine (SABRE). Proposals to use the nearby Prestwick Airport for horizontal launch have been led by Orbital Access Ltd., a company looking at eventually using the SABRE engine for an air-launched spaceplane. Spaceport Snowdonia also has received £500,000 in grants and this year supported the testing of B2Space's stratospheric launch balloon. The airfield, previously a UK Defense Ministry flight-test site, is currently being used by companies to flight-test unmanned aircraft systems and electric urban air mobility platforms.

A Framework for UK Space Launch

Tony Osborne London

THE BRITISH GOVERNMENT WILL generate a framework for UK space launch, covering everything from how a launch should be procured to the operation and licensing of spaceports and providing range-control services.

The legislation will be bolted onto the UK's Space Industry Act, which became law in 2018 and, according to the government, enables the regulation of a wide range of commercial spaceflight technologies, including vertical- and air-launched vehicles, suborbital spaceplanes and balloons.

The launching of a rocket from a fixed-wing aircraft in international airspace will be regulated by the UK rules if the aircraft takes off from a UK spaceport. They will equally apply to sea-launched systems, if the rocket embarks from a UK port.

The legislation includes consideration for human spaceflight. Although such flights from the UK are not proposed yet, tourist flights could emerge in the coming years. Issues around the security of infrastructure, cybersystems and personnel are also being considered in the consultation.

Regulation of spaceflight operations from the UK will be overseen by the UK Civil Aviation Authority, while accidents will be probed by the UK Space Accident Investigation Authority. Launch and launch site operators applying for a license will be required to demonstrate that the risks to the general population created by their operations are "as low as reasonably practicable," or ALARP, an approach used by other high-risk industries including nuclear power as well as oil and gas.

Licenses will be granted for launch, range-control services and launch sites, both vertical and horizontal. Additional licenses will be needed for those operators performing reentry of reusable launch systems into the UK to ensure they are as safe as when they launched.

Interested parties have until Oct. 21 to provide comment on the proposed legislation.

SpeedNews

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Rocket Companies Eye 2022 Launch Date From British Launch Sites

> SKYRORA IS DEVELOPING A THREE-STAGE XL SATELLITE LAUNCHER

> ORBEX HAS CONTRACTED FOR SIX SATELLITE LAUNCHES

Tony Osborne London

Almost 50 years after the UK developed a space launch capability and then abandoned it, a new era of UK space launch is beckoning. Private companies, domestic and international, are pressing ahead with research and development programs that will allow them to conduct small-satellite launches from British shores potentially as early as 2022.

The outlook is broad and diverse, with proposals for a mix of vertical, horizontal and balloon-based launchers provided by a variety of well-established companies and innovative startups, many of which have been inspired by the innovations developed for the Black Arrow during the 1960s.

The government-funded Black Arrow launched the UK's Prospero satellite into orbit from the Australian Outback in October 1971, but the program had already been canceled. Ministers had balked at the cost of developing the capability further, enticed by the promise of cheaper launches on the back of U.S. efforts.

Edinburgh, Scotland-based Skyrora was so inspired by Black Arrow's achievements that the startup decided to fund the transport of the wreckage of the Black Arrow launcher, which lay in waste in the Australian desert for decades, back to the UK for display at a museum in Farnborough, England.

"Black Arrow was lightweight and cost-effective. It was an amazing British design," Jack-James Marlow, Skyrora's head of engineering, tells Aviation Week. He compares the Cold War-era launcher to the cars developed by British company Lotus, a brand known for its approach to developing lightweight sports cars. Like Black Arrow, the company's three-stage Skyrora XL launcher will use high-test peroxide (HTP) as an oxidizer, a catalyst that stores more easily than cryogenics components and allows the rocket to be fueled for longer periods in readiness for weather windows in the often unpredictable British climate.

The use of HTP, says Marlow, is part of Skyrora's approach to ecofriendly launch. That also includes the development of a new fuel, Ecosene, an alternative to kerosene made from waste recyclable plastics. "We will have 45% less [carbon-dioxide] emissions per launch than our equivalent competitors," Marlow says.

"Our customers are becoming more and more environmentally conscious, and they are launching environment-monitoring, data-driven satellites. They need that option to launch," he adds.

The use of peroxide also enables a stop-start capability for the third stage, allowing trajectories to be adjusted for increased orbital accuracy, Marlow adds.

Skyrora is halfway through a six-year research and development program that it hopes will lead to an orbital launch in 2022-23. The company is taking a "step-by-step approach" to derisking its technology development, building up to more complex systems. In May, Skyrora conducted a static test-firing of its Skylark L suborbital launcher, which is capable of flying to altitudes of 100 km (62 mi.) using a road-mobile launch complex.

Skylark L was originally developed as a technology testbed for the Skyrora XL, but the company now plans to offer the launcher commercially as a platform for suborbital launch payloads.

In early August, the company successfully launched its two-stage Skylark Micro 4-m-tall (13-ft.) suborbital rocket from a site in Iceland. Unfortunately, the sustainer and booster stages were lost at sea. But the tests will inform the development of Skyrora XL, a 24-m-tall rocket powered by nine internally developed Skyforce 3D-printed engines in the first stage and a single Skyforce motor in the second. Skyrora says the XL will put payloads of up to 315 kg (700 lb.) into polar and sun-synchronous orbits of about 500 km.

C6 LAUNCH CONCEPT

Technologies for Skyrora XL have been developed in-house, leaning on research and development facilities in Slovakia and Ukraine, "where overheads are five times lower than in the UK," says Marlow. "As a new space company trying to get to market with a six-year financial developmental plan, we have to be innovative where we can," he adds.

Ultimately, the plan is to design, manufacture and launch everything from the UK. But the company has not made a final decision on a launch site and is maintaining discussions with all the UK vertical launch sites. Marlow notes that Skyrora's progress on launcher development is outpacing the development of UK regulation, and he does not rule out performing the first Skyrora XL launch outside the UK.

Canada's C6 Launch wants to send nanosatellite payloads into orbit from Shetland Space Centre with its 15-m, two-stage launcher.

The company's aim is to make the Skyrora XL agnostic to any launch site. The system will essentially be road-mobile, with elements set up in containers, minimizing the need to make physical changes to a launch site to cater for the launcher. It also means the launcher could be moved quickly to a different launch site if required.

Skyrora has 20 letters of intent signed with satellite operators, and Marlow believes the company could be conducting as many 16 launches a year by 2030.

While Skyrora has been open about its ambitions and milestones, fellow Scotland-based launch company Orbex remains under the radar as it targets first takeoff of its Prime launcher from Sutherland, potentially as early as 2022. Orbex was one of the recipients of funding from the UK Space Agency (UKSA) in 2018 to support takeoff from Space Hub Sutherland, and CEO Chris Larmour says launcher development is moving ahead at the company's sites in Denmark and in the UK (*AW&ST* Feb. 25-March 10, 2019, p. 38).

Orbex's Danish site is focused on propulsion development, while the company's Forres, Scotland, facility performs manufacturing, structures, avionics and integration work. The company is also establishing a test stand nearby on the former Kinloss military air station.

Orbex's 19-m-tall two-stage Prime launcher will be able to place payloads of 100-200 kg into orbits from 220-1,250 km, and the company says it is 30% lighter and 20% more efficient than industry equivalents. The Prime will use biopropane, a renewable fuel, and the launcher's stages will be both recoverable and reusable.

Despite the company's stealthy approach, it has secured six launch contracts and has "quite a strong pipeline," Lamour says. Along with receiving the UKSA funding, Orbex is confident about securing work through the European Space Agency's Commercial Space Transportation Services initiative.

Development of Prime's propulsion, an additive-manufactured motor of which the first stage will use six, is "moving along nicely," says Larmour. The company says it is the first commercial launcher company in Europe to use carbon-fiber tanks to hold liquid oxygen. Guidance, navigation control and other avionics systems are undergoing testing as well.

Larmour says the company is not in a race but is instead focused on establishing a sustainable business. He will not say how many launches will be needed to break even.

"We've often had the discussion about [whether we should] be the hare or the tortoise, and a long time ago we decided to be the tortoise," says Larmour. "The launcher will be ready when it is ready."

However, the company believes it will be the first to launch from the Space Hub Sutherland, ahead of Lockheed Martin, which was contracted to pioneer launch from the site but has yet to confirm details of the launcher it will use. Larmour says Orbex has had a major say in the shaping of the Sutherland facility. "The operational concept is very much an Orbex concept. We drove the design of almost all of the technical side," he says.

Orbex is also studying potential launch from the Portuguese Azores island chain.

Other launch providers looking at the UK include newcomer C6 Launch Systems, which announced in June that it plans to use the Shetland Space Centre in Scotland as its primary launch site. The Ontario-based startup is chasing a niche market, focusing on the responsive launch of nanosatellite payloads of up to 30 kg into sun-synchronous orbits of 600 km. The company plans to start work on the integration of the 15-m-long, two-stage launcher later this year, says CEO Richard McCammon. C6 is electing to use off-the-shelf components for the launcher rather than conducting development of the entire rocket and its systems in-house. In particular, the company is looking to make use of rocket motors developed by Colorado-based Ursa Major Tech.

According to McCammon, this approach reduces the risks and costs of the launcher. A suborbital launch is envisaged for 2021, and orbital flights will follow. C6 also established a UK subsidiary, with an address in Edinburgh in late July to support its UK operations.

Other entrants to the UK market include startup Black Arrow Space Technologies, a company named after the Cold War-era British launcher, which is planning a sea-based launch of a two-stage vehicle. Ship launch is being proposed because it offers the option to find new launcher locations to avoid weather, increases security, and eliminates the need for land-based facilities that affect the environment.

UK-Spanish B2Space is proposing lifting a three-stage solid-propellant rocket in a sling with a stratospheric balloon to enable launch from an altitude of 40 km. The company says a 150-kg payload could be delivered to a low Earth orbit of 200-1,000 km. Similar "rockoon"-based proposals are offered by startup Stratobooster. Horizontal launch services are being proposed by Virgin Orbit with its LauncherOne vehicle, to be lofted from a modified Boeing 747-400 airliner.

ORBEX CONCEPT

Orbex has secured launch commitments from several satellite operators for its two-stage Prime launcher.

ASK THE EDITORS

Is the World Large Enough To Support Airbus, Boeing and Comac?

Aviation Week Beijing Bureau Chief Bradley Perrett responds: No major shift is likely to happen before the late 2030s or even the 2040s, because Comac is far from ready to go head to head with the two Western airframe companies. Predicting how the competition will play out so far ahead is highly speculative, so the best that can be done is to mention a few factors.

If Comac has a near monopoly in the local market, it will have a base production rate that will help it achieve the low costs it will need for competing elsewhere. On the other hand, a state company with a guaranteed local market does not have a lot of incentive to work hard at making money abroad. The Chinese Communist Party can address that to some extent.

China could simply subsidize its way into the market if its airliners are reasonably competitive. (Real duds can't be given away.) This raises questions about how the U.S. and Airbus partner countries would react to such subsidies. Would they retaliate by barring Comac from their markets? That would depend on what trade agreements are in place in future decades. But China's international relations are declining so fast that we must wonder whether it will have access to Western civil aeronautics technology in 20 years. Curtailment of Western supply, especially for engines, would set back the Chinese commercial aircraft effort many years.

Why would it take until the late 2030s or later for China to knock Airbus or Boeing into the third spot? Even if the Comac C919 proves to be about as efficient in operation as the Airbus A320neo and Boeing 737 MAX—as it should be, on paper—the program is probably running at least 6-7 years behind the Neo and MAX. After entry into service, more years will be needed to establish a reputation for reliability and support. Production has to ramp up and cost must be gradually driven down. Even if all went well from now on, by the time the C919 began to make progress in the international market, either or both of the Western manufacturers should be close to a next round of product renewal—moving Comac's goalposts and requiring improvement in the C919.

The Chinese-Russian Craic CR929 widebody is now due for first delivery in 2028-29, so it faces much the same problem.

By the 2040s, propulsion technology may have changed. Aircraft and engines may be much more integrated. Comac could be back to square one. Yet Airbus and Boeing could be, too, and they would not have Chinese taxpayers' money to spend on unusually challenging development programs.

Could China Ban Airbus, Boeing but Still Engage Western Engine-Makers?

Bradley Perrett responds: Yes, Chinese commercial aircraft programs are already moving in that direction by limiting opportunities for foreign commercial airframes while leaving those opportunities open for foreign suppliers of engines and onboard systems. The idea is that when Comac gets a sale, Boeing and Airbus will not, but CFM, Honeywell and other suppliers will because they are onboard the C919. Of course, it is intended that eventually the foreign engine and onboard system suppliers also will have a more limited Chinese market. China needs more time, however, to produce domestic substitutes for these products.

This rosy prospect for Comac and its suppliers disappears if foreign governments order a halt to supply. At the time of program launch for the ARJ21 in 2002 and the C919 in 2008, such a political risk would have seemed fanciful. But China's international behavior since 2013—at first called assertiveness, now increasingly called aggression—must have moved the risk from the "fanciful" column to the "possible" column. A wild card in this outlook is whether European countries become as angry with China as the U.S. is. European countries are still years behind the U.S. in hardening their attitudes toward China.

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30 More Years of Traditional Power?

There are decades of life still left in jet propulsion

John Morris New York

It is easy to write off jet propulsion as "old," even as GE Aviation refreshes its whole portfolio of commercial engines for the next 20 years, Pratt & Whitney works on the future road map for its geared turbofan (GTF) and Rolls-Royce develops its UltraFan as the basis for next-generation airliners (see page 19).

There is no doubt the COVID-19 pandemic will affect powerplant development over the next decade or so as new aircraft programs are pushed to the right, airliners remain parked and passenger traffic takes perhaps 2-3 years to recover. With revenues hard hit by a collapse in sales and a slump in aftermarket activity, the engine manufacturers' need to slash costs likely will have an impact on research and development into future technologies, especially for commercial engines.

"The 2020s will be the decade of productivity and cost-out, whereas the 2010s were the decade of new technologies and new programs," says Glenn McDonald, senior associate at AeroDynamic Advisory.

"I don't want to sound too dire, but our view is that we will probably see a reduced pace in developing technologies in commercial aerospace, with a slowdown in new clean-sheet design and in materials technology," McDonald adds. The focus will shift instead to manufacturing processes, cost reduction and efficiencies such as lower scrap rates.

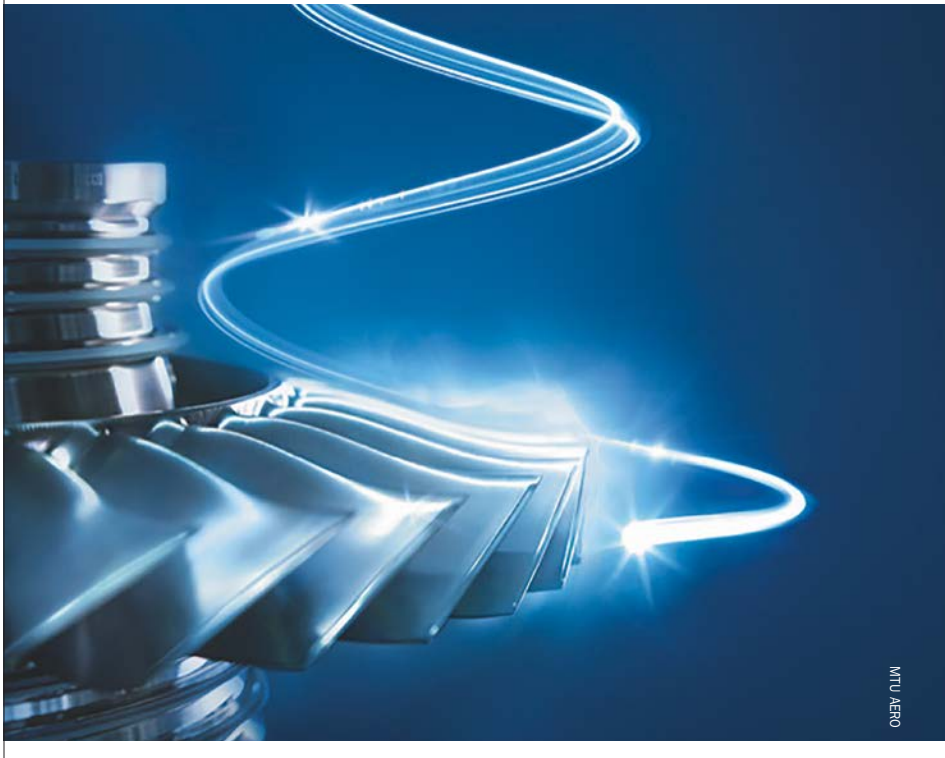
The manufacturers might be down, but they are not out—and the military is riding to the rescue. Defense spending in the U.S. and Europe, especially on developing sixth-generation fighter engines, is taking over from the commercial sector in leading the application of new technologies. "That's where the real technological advances are happening," says McDonald. "This could be the decade where it pays off to have portfolios in defense as well as in commercial."

The shift from commercial to defense had begun well before COVID-19: GE Aviation, for example, explained at last year's Paris Air Show that now that the commercial side has proved the viability, affordability and producibility of new materials including ceramic matrix composites and technologies such as additive manufacturing, the military has the confidence to lead the march into new territory.

Technologies developed for commercial engines have enabled new military capabilities; in turn, military research and development will enable even newer commercial engines decades into the future. It is a virtuous cycle, GE Aviation President and GE Vice Chairman David Joyce told Aviation Week last year. Joyce is handing over leadership Sept. 1 to former Embraer executive John Slattery (see page 16).

"Military is where the commercial business was 10 years ago," Joyce said, with hundreds of engineers and research and development resources being tasked with creating future generations of military powerplants.

In developing its new portfolio of commercial engines, GE Aviation also explored new ways to make them. It invested "billions of dollars," said Joyce, in manufacturing and supply chains. "Additive manufacturing may be the most disruptive technology that I've seen in the industry in a long time," he noted. "It's going to pay off a whole load more in the next 20 years. This is going to be the best [real return on investment] that we've ever done."



MTU Aero is developing new manufacturing techniques for blisks for next-generation GTF engines.

The interruption of the commercial market by COVID-19 might actually accelerate the development of new technologies, Pratt & Whitney President Chris Calio tells Aviation Week (see page 19). The pandemic has forced the engine-maker to "really interrogate" its technology road map and consider carefully where to invest, he says.

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Aerospace Calendar

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Sept. 1-18—RTCA Plenary Sessions/Committee Meetings. Virtual or various locations. See rtca.org/content/upcoming-committee-meetings

Aug. 31-Sept. 1—2020 Humans to Mars Summit (H2M). Virtual event. See exploremars.org/summit

Sept. 3-4—Global Satellite and Space Show. Virtual event. See globalsatshow.com

Sept. 3-4—Military Space Situational Awareness Conference 2020. Virtual event. See smi-online.co.uk/defence/uk/milspace

Sept. 10—2020 Women In Defense National Conference. Virtual event. See womenindefense.net/events/2020/9/10/women-in-defense-virtual-leadership-symposium

Sept. 14-16—CareFlite Emergency Care Update Conference. Virtual event. See careflite.org

Sept. 14-16—Air Force Association Air, Space & Cyber Conference. Virtual event. See afa.org/events/calendar/2020-09-14/air-space-cyber-conference

Sept. 15-17—Commercial UAV Expo Americas. Virtual event. See expouav.com

Sept. 22-24—Full Spectrum Air Defence Digital Conference. Virtual event. See asdevents.com/event.asp?id=22269

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Sept. 2—CAPA Australia Pacific Aviation Summit. Virtual event.

Sept. 14-16—Commercial Aviation Industry Suppliers Conference-Europe. Virtual event.

Sept. 16-17—Aero-Engines Europe. Virtual event.

Sept. 22-24—Aero-Engines Asia-Pacific. Virtual event.

Sept. 23-24—MRO Asia-Pacific. Virtual event.

Oct. 19—Aviation Week Laureates Awards. McLean, Virginia.

Oct. 20-21—Aviation Week DefenseChain Conference. McLean, Virginia.

Oct. 21—Aviation Week Program Excellence Awards and Banquet. McLean, Virginia.

Oct. 27-29—MRO TransAtlantic. Virtual event.

Nov. 10-11—Engine Leasing, Trading and Finance. London.

Nov. 11—Aviation Week A&D Mergers & Acquisitions Conference. Virtual event.

Nov. 17-18—Military Aviation Logistics & Maintenance Symposium (MALMS). Virtual event.

Nov. 18—Business & General Aviation Conference. Los Angeles.

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VIEWPOINT

Can the Pentagon Spend More Smartly?

By **Steve Grundman**

I am surprised by the vigorous hand-wringing this summer over the prospects for defense spending in a Democratic-dominated government beginning in January 2021. There's every indication that the Democrats who may come to office next year with meaningful power over defense budgets subscribe to a bipartisan consensus that defense spending is leveling off in real terms, just as planned in the Trump administration's defense program for 2021-25. Recent indications to the contrary are misleading; worse, they distract from what matters much more about this year's election and the outlook for defense spending.

Last month's partisan rancor over the Defense Department's budget has come to naught. On the left, the amendments of Sen. Bernie Sanders (I-Vt.) and Rep. Mark Pocan (D-Wis.) that would have reduced by 10% the national defense authorization for 2021 were defeated by wide bipartisan majorities, which would have been still larger but for the implausibility of the motions' passage. From the right, off-the-record "experts" raising alarm among investors about imagined plans to reduce the annual Pentagon budget to $550 billion—an implied rate of reduction not seen since the end of the Korean War—succeeded only in reminding us of how easily rank expediency sometimes passes for insight on Wall Street.

By contrast, the summer's telling indicator of the outlook for defense spending lies instead in the strikingly bipartisan $740 billion defense authorization bill that Rep. Adam Smith (D-Wash.) brought to the House floor. Not only did the bill receive a 56-0 vote out of the Armed Services Committee, but Smith, the committee's chairman, also chose to name it in honor of the committee's retiring ranking member, Rep. Mac Thornberry (R-Texas).

More to the point, it is hard to find anything in the views of former Vice President Joe Biden and his campaign advisors—or of the Democrats who lead defense committees on Capitol Hill—to suggest they harbor plans to reset the defense budget outlook. Politico even associated Biden with the slogan "Boost the defense budget" in its tally of presidential candidates' positions. What one does find among Democratic views of defense policy, however, is a conviction that China poses a strategic challenge to U.S. interests, the essential premise of today's historically high peacetime defense budgets and a view that stands in clear contrast to President Donald Trump's ambivalence over China's military-strategic importance and his peculiar admiration for President Xi Jinping.

The defense budget is not impervious to our fraught politics and economy, but no political realignment that could deflect today's bipartisan consensus on U.S. defense spending is likely to emerge before the midterm elections of 2022. If the next administration and Congress fail to quickly stanch the health and economic catastrophe of the coronavirus pandemic, a progressive wave could well roll into Congress in January 2023 with a platform that prioritizes Americans' at-home lives and livelihoods over the U.S. leadership role in the world. Or the midterm election could activate revanchist Tea Party sentiment to anchor Republican recalcitrance against Democratic governance with the familiar practice of trading off the Pentagon's budget to blunt domestic-spending initiatives and contain taxes. Sound familiar? In each of the five budget years of the Obama presidency after Republicans won control of the House in 2010, the congressional defense appropriations reduced the administration's budget requests for the Pentagon by a total of $115 billion.

TOUCH OF LIGHT/WIKIMEDIA

FACING FLAT BUDGET GROWTH, THE MILITARY WILL REQUIRE STRATEGIC FOCUS, NOT DISTRACTION AND AMBIVALENCE.

Against the backdrop of today's bipartisan consensus, the more significant difference about defense spending between the two parties has to do with the prospects for the productivity of those dollars: How much national security can each provide with a $740 billion defense budget? Where Democrats, in the words of former Undersecretary of Defense Michele Flournoy, believe the military-technological competition with China "must be [the Pentagon] leadership's top priority," Defense Secretary Mark Esper spent the week he released this year's defense budget defending the administration's redirection of $4 billion from the Defense Department's procurement accounts to fund the president's border wall. Where Democrats, in the words of Biden's former National Security Advisor Colin Kahl, would put alliances and partnerships "at the top of the agenda," Esper recently had to acknowledge that it will cost billions of dollars not currently in the Pentagon budget to redeploy U.S. forces out of Germany in response to Trump's determination that Germany's government is "delinquent." Facing flat budget growth, the Pentagon will require strategic focus, not distraction and ambivalence, and alliance relations that leverage U.S. defense spending, not compound its costs.

If any hand-wringing is worth doing about politics and defense spending, it would be better put toward building calluses against the hard work of increasing the productivity of defense dollars than polishing old chestnuts about how Democrats are soft on defense.

Contributing columnist Steve Grundman is principal of the consultancy Grundman Advisory and senior fellow at the Atlantic Council.

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