

The Coming Wave of
Aircraft Retirements

Bell's Electric
Anti-Torque System

U.S. Air Force's
Budget Gamble

Bombardier
Back to Business



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AVIATIONWEEK

& SPACE TECHNOLOGY

A photograph of a commercial jet aircraft performing a barrel roll in a clear blue sky. The aircraft is seen from below, with its wings and tail visible. It is leaving a thick, white, curved smoke trail that forms a large loop around the plane. The background is a gradient of blue sky with some light clouds.

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Blue Origin is building a test site for BE-4 and BE-3U engines at Marshall Space Flight Center to supplement its current site in West Texas (pictured).

Based on earlier cooperative-trajectory flight tests involving an A380, Airbus is taking a lead in advancing wake-surfing for energy from a research project to an operational capability that commercial airlines can use to reduce fuel consumption. Technology Executive Editor Graham Warwick's report begins on page 36. Airbus photo.

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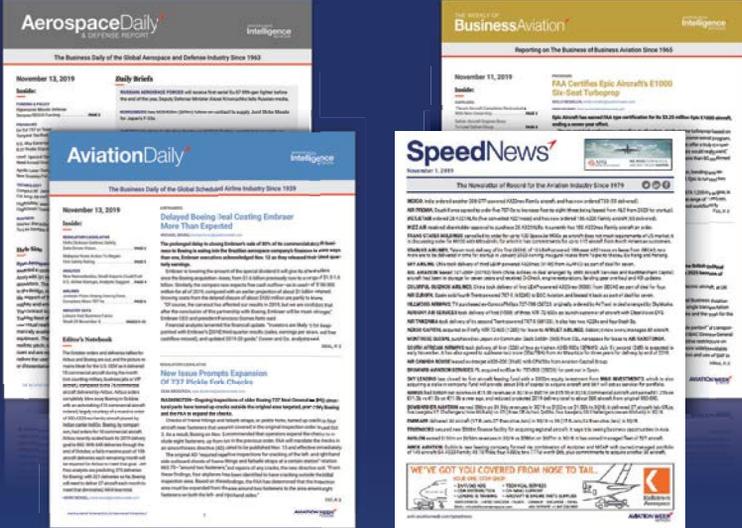
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'THE FASTEST WITH THE MOST-EST'

Reading “Hyper HAWCs” (*Feb. 10-23, p. 18*), I reflected that throughout human history, there has been one way to determine which humans have won wars, obtained the highest standards of living and had the most personal, economic and political freedoms. The prize always goes to those who can most rapidly bring the most advanced capabilities to the desired points of conflict. In other words: Who gets there “the fastest with the most-est.”

Those who failed to understand this simple fact lost their freedoms, their property, their prosperity and worse. Anyone who thinks this has changed is living in a fantasy world. If we fall behind in hypersonics, readers of Aviation Week know what happens next.

Steve Willie, Olympia, Washington

CATAPULT COMMUNICATION

The article “U.S. Navy Carrier Finally Hosts Aircraft” (*Feb. 10-23, p. 24*) brings to mind an earlier *AW&ST* article (*June 17-30, 2019, p. 111*) about the French Navy retrofit of its carrier with an electromechanical catapult system that permitted more launch weight variations than the current steam (I assume) system. Perhaps the U.S. Navy should consider communication with its French counterpart.

Peter Roth, Pleasant Hill, California

BACKFIRE AT BOMBARDIER

Your article “Exit Signs at Bombardier” (*Jan. 27-Feb. 9, p. 8*) scratches the surface of the fundamental problem with a so-called public company having the government as its banker. Bombardier embarked on high-risk aerospace projects because it knew it could transfer that risk to the Canadian taxpayer with C\$4 billion of government handouts over the years. The governments involved purportedly did so to promote an important industry and create jobs. It backfired.

Woefully inadequate execution of the projects by Bombardier has resulted in fire sales of its aerospace businesses and thousands of Canadian jobs lost. Customary corporate and fiscal discipline went AWOL. And yet the politically connected Beaudoin family still has voting control! If the rules of modern corporate governance applied, the control by the Beaudoin family would



BEHIND THE SCENES

Though attendance at the Singapore Airshow was reduced due to global fears about the COVID-19 outbreak, Aviation Week’s team was there to cover the show and conducted a Commercial Aviation & Defense Market Trends Briefing. Speaking at the briefing were (from left): **Paul Burton**, Aviation Week’s Asia-Pacific managing director; Defense Editor **Steve Trimble**; **Craig Caffrey**, senior aerospace industry analyst; **Jens Flottau**, executive editor for Commercial Aviation; **Chen Chuanren**, Southeast Asia and China correspondent for *Air Transport World*; and Senior Editor **Guy Norris**.

be long gone, as would the repeated failures in governance and fiscal discipline.

Martin Abbott, Scottsdale, Arizona

CORRECTING LITTLE MISTAKES

First, thanks for putting out a really great magazine every couple of weeks—I enjoy all of it, even though my aviation career was strictly military (U.S. Marine Corps back-seater in the F-4 Phantom).

That said, I wanted to point out a minor error in the letter “Who Does Better?” in the *Feb. 10-23* “Feedback” section. The conversion of 10,000 liters to 26,400 gal. is off by a factor of 10—it should be 2,640.

Someone once said, “The devil is in the details.” Someone wiser than that said, “Flying is a constant process of correcting little mistakes before they become big mistakes!” Amen to that!

Julian “Jay” Stienon, San Marcos, California

Editor’s note: The reader is correct.

ONLINE, in response to “Why You Should Not Be Ashamed To Fly” (*Feb. 10-23, p. 74*), **ULF.WEBER** writes:

Dear George, sorry to say but I don’t agree with your facts and figures. A comparable train trip in Europe emits only one third (and not 30% less as you stated) CO₂ of a flight, i.e. the

CO₂-footprint of a train trip (including all detours) versus a flight with a great circle distance of 1,000 km is two-thirds smaller. For comparison: CGN-BCN one way, by train = 26.2 kg CO₂, by air = 106.1 kg CO₂. This still excludes the additional climate effects of other GHG emissions, especially for emissions in high altitudes (nitrogen oxides, ozone, water, soot, sulphur). See ecopassenger.org/

And MICHAELM notes:

Unfortunately the US has fallen behind the rest of the world in a balanced transport system. We do need both air and ground. We live in an age where people move around a lot for business and pleasure. The disadvantage the US has over most of the world: We do not have sufficient ground transportation and the rail system we have is still use outmoded diesel trains as opposed to electrified high speed trains.

The tragedy; we do not understand and believe that we have a major shortfall.

CORRECTION:

An item in “First Take” in the *Feb. 10-23* issue (p. 8) should have stated that Myrtle Beach International Airport is in South Carolina.

This item has been corrected online and in our digital archive.

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.



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Congratulations to Air Lease Corporation for supporting the world's fleet for the last decade. As a leading aircraft leasing company, ALC's fleet is comprised of more than 370 aircraft on lease with a globally diversified customer base of 108 airlines in 59 countries. We applaud ALC's commitment to providing cutting-edge commercial air solutions, and look forward to many more years of partnership together.



Carroll Lane has been named president of Pratt & Whitney's commercial engines unit. He was leader of investor relations at Pratt

parent United Technologies Corp. (UTC). He succeeds Christopher Calio, who became president of Pratt & Whitney Jan. 1.

Collins Aerospace has promoted **Stephen Timm** to president from head of the commercial avionics business. He succeeds **Kelly Ortberg**, who is now special advisor to UTC Chairman/CEO Greg Hayes, as the company merges with *Raytheon*. **David Nieuwsma** succeeds Timm as avionics president; he had led the interiors unit. **Kevin Myers** now heads operations and quality; he had been avionics vice president of operations and quality.



Christophe Bruneau has been named vice president of the military engines division at *Safran Aircraft Engines*. Bruneau was CEO of EPI GmbH and of the AES² GmbH joint venture of Safran Electronics & Defense and MTU Aero Engines, which is developing the powerplant for Europe's Future Combat Air System.

Alsalam Aerospace Industries has named **Karl E. Jeppesen** acting president and CEO of the maintenance, repair and overhaul company. Jeppesen had been supply chain vice president at Boeing Defense, Space and Security.

The *National Air Transportation Association* has promoted **Tim Obitts** to president/CEO from chief operating officer. He succeeds Gary Dempsey, who has stepped down.



Sheryl Bunton has been promoted to *Gulfstream Aerospace Corp.* senior vice president and chief information officer (CIO) from CIO. Before Gulfstream, Bunton was worldwide CIO for AGCO Corp. and before that was CIO at Southwire Co.

The *Vertical Flight Society* has appointed **James A. Viola** president and CEO of Helicopter Association International. Viola succeeds Matthew S.

Zuccaro, who has retired.

Opener has hired **Ben Diachun** as CEO. Diachun worked at Scaled Composites for 16 years on key engineering design and flight-test direction and stepped into leadership roles. He was part of the team awarded the Robert J. Collier Trophy in 2004 for the development of SpaceShipOne.

The Association for Unmanned Vehicle Systems International has hired **Richard King** as senior vice president of regulatory and international affairs. He was director of Aviation Information Software, where he brought to market an app providing



single-source access to all 1.5 million FAA safety rules.

Daniel Song has been appointed *Korean Air* managing vice president/director of the Americas, which encompasses Canada, Mexico and South America. Song was managing vice president of passenger networks and sales.

FlightSafety Textron Aviation Training, a FlightSafety division established in April 2019, has named **Rich High** as CEO. He succeeds **Brian Moore**, who has been promoted to FlightSafety International senior vice president of operations. Moore succeeds Dann Runk, who has left the company.

CAE has appointed **Todd Probert** group president of defense and security. He succeeds Gene Colabatistto, who has retired. Probert led Raytheon's command, control, space and intelligence business.

Objectstream has hired **Vaughn Turner** as senior vice president of aerospace engineering. The company supplies information technology and avionics equipment for aviation and cybersecurity clients. Vaughn has



37 years of experience at the FAA and Defense Department.

Lance R. Collins has been selected as the inaugural vice president and executive director of the new *Virginia Tech Innovation Campus* in Alexandria, Virginia. He was the Joseph Silbert Dean of Engineering at Cornell University.

Mitre Corp. has hired **Craig Ackerman** as vice president of operations and business transformation. He was a principal and head of robotic process automation at Chazey Partners.

Milestone Aviation has promoted **Pat Sheedy** to CEO from head of engine-lease underwriting, portfolio management and cargo risk management for the GECAS helicopter-leasing subsidiary.



Patrick Hannigan has been promoted to CEO of *CDB Aviation*. Hannigan, who had been president and chief commercial officer, succeeds Peter Chang, who has retired.

CDB is a wholly owned Irish subsidiary of China Development Bank Financial Leasing.

Aerjet Rocketdyne has hired **Andreas Wagner** as chief human resources officer. Wagner was vice president of human resources for TE Connectivity.

Tony Wood, Meggitt CEO and former president of Rolls-Royce Aerospace, has been named president of *ADS*, the UK aerospace and defense trade organization. He succeeds Colin Smith.

Trust Automation, a supplier of automation technology for industrial and defense applications, has hired **Teddy Ross** as chief operations officer.

HONORS AND ELECTIONS

The National Air and Space Museum achievement trophy has been renamed *The Michael Collins Trophy*, in honor of Apollo 11's command module pilot. Its 2020 recipients are **Charles Elachi**, for lifetime achievement, and the **Hubble Space Telescope Team**, for current achievement. 🌟

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



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DEFENSE

France and Germany have awarded long-awaited contracts totaling €155 million (\$167 million) for the initial demonstrator phase of the Future Combat Air System program, funding 18 months of work led by primes Dassault and Airbus as well as their partners, Safran, MTU Aero Engines, MBDA and Thales (page 29).

The U.S. Air Force's latest five-year budget plan retires significant numbers of RQ-4s, B-1s, KC-10s and nonstealthy fighters and eliminates funding for B-2 modernization (page 48).

Lockheed Martin's development of the Hypersonic Conventional Strike Weapon for the U.S. Air Force is to be terminated after delayed completion of a critical design review in spring 2020.

Pratt & Whitney is protesting a U.S. Air Force plan to award a sole-source contract to GE Aviation for F110 engines to power a future fleet of Boeing F-15EX fighters. Pratt produces the competing F100.



BOEING AUSTRALIA

A Boeing-led Australian team has completed the first major assembly for the Airpower Teaming System loyal-wingman unmanned aircraft it is developing with the Royal Australian Air Force.

Singapore is to collaborate with Airbus on the development of automated aerial refueling capabilities for the A330 Multi-Role Tanker Transport, with its air force providing an aircraft for testing.

BAE Systems flew the first full-scale prototype PHASA-35 solar-powered high-altitude pseudo-satellite unmanned aircraft system for the first time on Feb. 10 at Woomera in Australia (page 28).

China is testing an intercontinental-range hypersonic glide vehicle similar to Russia's deployed Avangard system, the U.S. Air Force said in written testimony submitted to Congress.



PAKISTAN MINISTRY OF DEFENSE

Pakistan announced on Feb. 18 it had conducted a flight test of its indigenously developed 600-km (370-mi.)-range Ra'ad II air-launched cruise missile from a Dassault Mirage III fighter.

COMMERCIAL AVIATION

Bombardier has sold its remaining stake in the A220 program to Airbus for \$591 million, completing its exit from commercial aviation. Airbus now holds 75% and the government of Quebec maintains the other 25% (page 17).

The U.S. government may not renew General Electric's export license to supply CFM Leap-1C engines to Comac—a move that could further delay the Chinese company's C919 narrowbody program.

From March 19, the U.S. will raise already approved World Trade Organization tariffs on imported European commercial aircraft to 15% from 10% as punishment for illegal subsidies.

Airbus is to cut A330 production by about 20% in 2020—to 40 a year—and stabilize the A350 at 9 or 10 aircraft a month, in an acknowledgment of weak demand for widebody aircraft.

Boeing is inspecting all 737 MAXs in storage and adding factory-floor precautions after discovering debris in the fuel tanks of multiple MAXs during routine maintenance on stored aircraft.

Italy's second-largest airline, Air Italy, ceased operations Feb. 11 after majority

VIEW FROM WASHINGTON

Sixth-Gen Sticker Shock

The U.S. Air Force's acquisition chief is bracing for congressional backlash over a revamp of the Next-Generation Air Dominance (NGAD) program that could drive up the average procurement unit cost (APUC) of a sixth-generation fighter.

But the Air Force remains committed to an acquisition strategy for an F-22 replacement that accepts higher upfront costs so as to save money during the sustainment phase, Will Roper, assistant secretary of the Air Force, said Feb. 18.

"The APUC is what?" Roper expects Congress to ask. "And we're going to have to have a really good analysis to show that by operating this way the total cost of ownership is better."

The Air Force had planned to structure NGAD as a conventional procurement, in which a contractor typically loses money during the design phase, breaks even during development and reaps profits over an exclusive, multidecade sustainment period.

But Roper, appointed in 2017, said in early 2019 the strategy had changed. The details are murky, but he has compared the new acquisition strategy to the iPhone business model—where Apple makes its profit by charging a premium at the point of sale.

The upfront cost is higher, but this incentivizes external software developers to create applications for the iPhone at little or no cost to Apple. In a similar way, Roper wants defense prime contractors to transition away from a sustainment model for profits.

shareholder Alisarda decided it could no longer carry the company's increasingly heavy losses.



AIRBUS

Airbus is flight-testing a subscale, 10.5-ft.-wingspan technology demonstrator for a fuel-efficient blended wing/body aircraft at an undisclosed location in central France (page 39).

Delta Air Lines plans to spend \$1 billion over the next decade to reduce or eliminate carbon emissions throughout its business, including improving fuel efficiency and increasing its use of sustainable fuels.

A new U.S. low-cost airline launched by former United Airlines executive Andrew Levy has raised \$125 million and plans to start service by the end of the year with 189-seat Boeing 737-800s.

David Neeleman's new U.S.-based airline has been christened Breeze Airways and aims to be operating by the end of 2020 using leased Embraer E195s. Deliveries of Airbus A220s will begin in 2021.

GENERAL AVIATION

Gulfstream's largest and longest-range business jet, the G700, made its first flight Feb. 14 from Savannah/Hilton Head International Airport in Georgia. Certification is planned for 2022.



GULFSTREAM

Bell is to work with Japan Airlines and Sumitomo Corp. to explore on-demand air mobility services in Japan using Bell's electric vertical-takeoff-and-landing (eVTOL) APT cargo drone and Nex-us air taxi.

Urban air mobility startup Airspace Exploration Technologies has signed a memorandum of understanding with

Spirit AeroSystems to cooperate on developing an eVTOL aircraft.

SPACE

President Donald Trump is requesting \$25.2 billion for NASA in fiscal 2021, and planning to spend \$71 billion through 2025, to fast-track a mission to land astronauts on the Moon in 2024 (page 54).

SpaceX has signed an agreement with Space Adventures, a Virginia-based space travel company, to market a Crew Dragon orbital spaceflight for four privately paying passengers (page 15).

A SpaceX Falcon 9 lifted off on Feb. 17 with a fifth batch of the company's Starlink broadband satellites, boosting the growing constellation to 300 spacecraft (page 34).

NASA has awarded Rocket Lab a \$10 million contract to launch the 55-lb. Capstone cislunar positioning cubesat to the Moon on an Electron rocket from NASA's Wallops Flight Facility, Virginia, in early 2021.

NASA and Boeing are reviewing all the CST-100 Starliner flight software—1 million lines of code—following errors found after the capsule's troubled un-

Mixed Results for GA

Piston Airplanes	16.4	%
Turboprops	11.3	%
Business Jets	15.1	%
Piston Rotorcraft	36.3	%
Turbine Rotorcraft *	8.3	%

*Leonardo Helicopters fourth-quarter deliveries not yet available; 2018 data adjusted to allow comparison.

Business jet deliveries in 2019 were at their highest since 2009, at 809 aircraft, and the piston-aircraft market experienced double-digit growth to a 10-year high, of 1,324 aircraft, but turboprop and helicopter deliveries decreased year-over-year.

Source: General Aviation Manufacturers Association

crewed orbital demonstration flight.

Astroscale will launch a satellite in 2022 to collect images of a rocket upper stage under the first phase of a Japan Aerospace Exploration Agency program to demonstrate commercial space debris removal. ☒

30 YEARS AGO IN AVIATION WEEK

Aviation Week & Space Technology Managing Editor David M. North scored a major scoop in early 1990, becoming the first Western pilot to fly the Soviet Union's advanced Mikoyan MiG-29 fighter. His eight-page pilot report from Kubinka Air Base outside Moscow was featured on our cover of Feb. 26, 1990. Originally told he would fly in the front cockpit, concerns about nasty weather relegated North to the backseat behind Mikoyan's chief test pilot, Valery Menitsky. North spoke no Russian and Menitsky's English was limited, prompting an unusually detailed pre-flight briefing with a translator. Comparing the aircraft's analog cockpit to a late-1950s F-4 Phantom II, North reported that the low-speed performance of the MiG-29 with its wire-and-pulley and servo-hydraulic flight control system "was comparable to that of the F/A-18 with its fly-by-wire control system." His takeaway: In the hands of a skilled



pilot, the MiG-29 was a lethal threat against comparable Western fighters. North later served as editor-in-chief of Aviation Week from 1995-2003.

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UP FRONT

BYRON CALLAN

**SOME OF THE MAIN TALKING**

points on the fiscal 2021 defense budget request and the plan that accompanies it through 2025 are that it aligns resources with the National Defense Strategy and that this year's budget theme is about all-domain operations. The Pentagon called out priorities to sustain readiness and prepare for future challenges with investment in hypersonics, autonomous systems and artificial intelligence. Given a flat top line, the Defense Department had to make tough choices by making program cuts that have been well-documented and are well-covered by this publication.

Shaky Foundations

Questions underpin the
fiscal 2021 defense budget



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The outlines of structural changes in how the Pentagon is preparing for the future are indeed visible in the budget request and plan, but it is unrealistic to expect this budget to have completely framed out all that will be done. Increases in research, development, test and evaluation (RDT&E) spending both in absolute terms and compared to last year's plan for 2021-24 underscore shifts that are underway. It may take at least 2-3 more years to see how some of these RDT&E efforts translate into new programs and will inform how the U.S. will fight in future conflicts.

Much as defense contractor management, analysts and planners will focus on the details in the defense budget, it is important also to factor in some of the assumptions that underpin the budget—the foundation upon which it rests. Here there are questions worth considering.

The first is the real GDP forecast for 2021-29. The Office of Management and Budget (OMB) forecast depends on stable 3% annual real growth every year, which is well above consensus estimates. The U.S. is now in its longest economic expansion ever. Can this be extended into 2021 or beyond? Possibly. Has the U.S.

somehow eliminated the risk of recession from a rapid increase in interest rates, another energy shock, a pandemic or a severe economic crisis in other parts of the world? Very likely not.

Another questionable factor is the new budget and plan's interest-rate assumptions, as there was a big change from prior projections. The OMB and Congressional Budget Office (CBO) do not disclose how they expect the composition of federal debt by debt maturity to change over forecast periods. They usually provide projections only on three-month Treasury bill interest rates and on the 10-year Treasury note. The U.S. Treasury shows that as of Jan. 31, of the \$17.2 trillion in federal debt held by the public, 14% was in Treasury bills with an average interest rate of 1.7%, and 58% was in notes with maturities of 2-10 years at an average rate of 2.1%.

Net interest outlays are a mix of the interest the federal government pays to public holders of that debt and the interest it pays to itself on debt held in federal trust funds. One way to think about the debt burden and the interest expense associated with it is to take the net interest outlay projections and divide them by the total debt the OMB or CBO estimates.

One of the changes the OMB made in its budget projections was to lower interest rate estimates. In recent years, these projections were too high compared to prevailing market levels, as the OMB and CBO both projected rates would return to "normal" levels. In the OMB's mid-session review from this past summer, the implied interest rate (net interest outlays divided by total debt) was 2.3% in 2019 and rose to 3.0% by 2022 and 3.3% by 2025. In the latest budget and plan, the implied rate is flat—at 2.1% in 2020, creeping up to 2.3% by 2025.

This is another questionable factor that could weigh on the foundation of the defense spending plans. If rates do move to higher levels, then outlays will compete with other forms of federal spending. If rates fall further than projected, it may be due to a far weaker economy, which in turn weighs on federal deficits.

A final questionable factor is the deficit projections themselves. The Trump administration again plans reductions in non-defense discretionary spending, which Congress has not supported in the last three budget requests. The share of non-defense discretionary outlays as a percent of total outlays drops to 12% in 2024 from 15% in 2019.

For defense contractor management, planners, analysts and investors, foundations on which the budget plans are based imply that the structural and programmatic changes in the 2021 budget could be accelerated if deficits and interest rates are higher than the plan presumes. Like a high-rise building built to code in an earthquake zone, the Pentagon's structural and spending changes may make defense better able to withstand future macroeconomic tremors and shifts. ☒

Contributing columnist Byron Callan is a director at Capital Alpha Partners.



GOING CONCERNS MICHAEL BRUNO

THE TRUMP ADMINISTRATION IS requesting “flat” defense spending for fiscal 2021 of about \$740 billion, with combined procurement, research, development, testing and experimentation (RDT&E) totaling about \$244 billion—\$4 billion below the current fiscal 2020 figure.

Industry, however, has few worries. For starters, no one in Washington really takes this budget request seriously. While lawmakers always declare the president’s request dead on arrival on the Hill, this year there was more than the usual dismissal by a rival branch of government.

For one thing, the administration’s blueprint relies on an above-average amount of gimmickry known as “Washington Monumenting,” the inside-the-Beltway term for suggested cuts to programs that Congress will never go along with, such as closing the Washington Monument—or in this case, flatlining Lockheed Martin F-35 procurement or cutting the spending on naval warship-building by roughly 20%, as President Donald Trump has proposed.

“Though weapons spending is collectively down in fiscal 2021 versus fiscal 2020—and versus the level in the fiscal 2020 presidential request, and a touch lighter than we were expecting—we see plus-ups to the weapons accounts likely,” analysts at UBS say. As the budget winds its way through Congress this year, they predict \$4-5 billion will be added to RDT&E, likely from off-budget war-spending accounts, much like the process followed for this fiscal year.

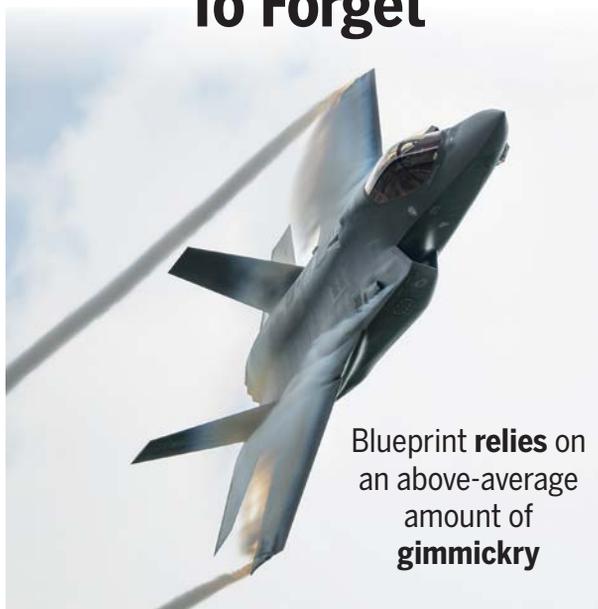
“We see no chance of the proposed budget passing in its current form,” Credit Suisse analysts say.

Second, even Defense Secretary Mark Esper all but said this budget request was a one-time election-year gambit. To be sure, what he volunteered in a speech just days before the official budget release was that the Pentagon’s plan requires 3-5% in annual growth above inflation just to keep up with its own blueprint. Esper said he hopes Washington will return to that practice.

Last fall, Esper initiated a department-wide review of potential savings in the so-called Fourth Estate of the Pentagon, the nonmilitary agencies, which gener-

ated almost \$5.7 billion in potential fiscal 2021 reductions, \$200 million in working-capital fund efficiencies, and another \$2.1 billion in activities and functions realigned to the armed services. Elaine McCusker, deputy undersecretary of defense and comptroller, says savings were derived from proposed cutbacks at defense medical facilities, as well as from dismantling nonstatutory commissions or boards of advisors, among other changes.

A Defense Budget To Forget



Blueprint relies on an above-average amount of gimmickry

SENIOR AIRMAN ALEXANDER COOK/U.S. AIR FORCE

To the administration’s credit, the budget request calls for an increase in several R&D efforts at the expense of procurement volumes. But these are “paid for” by cutting production requests for established programs such as aircraft and missiles, and if anything, Congress has a solid history of adding to procurement of long-running manufacturing programs. Also, proposals such as closing medical facilities do not sit well in communities with significant populations of veterans.

To be sure, there will be changes to defense programs, but as analysts at JP Morgan note, it does not mean contractors will be affected.

“It could be hard to map the impact of these cuts to particular contractors though, and some companies are also deploying capital to mergers and acquisitions that can mitigate the impact of budget-slowng,” the analysts say.

Over the past decade the defense industry lobbied for and received time to make changes to business portfolios so companies could select which parts of the new National Defense Strategy they wanted to pursue. In turn, most of the weapons-producing landscape already comes down to duopolies or small numbers of providers such as the main warship builders, General Dynamics and Huntington Ingalls, or the primary fighter suppliers, Lockheed Martin and Boeing. Each of the primes believes it has largely shaped its business to rely on programs with entrenched, long-term acquisitions where competition is nonexistent or barriers to entry are so high they are insulated.

“As tends to be the case, we expect every major U.S. defense company to say that its programs have done well in the request, and have good support in Congress,” analysts at Vertical Research Partners say. 🗳️



LEADING EDGE

GRAHAM WARWICK

AS AN AGENCY CHARTERED WITH both preventing and creating surprises, DARPA is guaranteed to raise an eyebrow with its annual budget requests.

Past ideas floated by the Pentagon's advanced research projects agency have ranged from flying submarines to satellites that assemble themselves on orbit.

And, being DARPA, the more outlandish the program, the cooler its name.

Two that stand out in the agency's \$3.57 billion fiscal 2021 budget request: LongShot, a long-range weapon that launches from its host aircraft carrying air-to-air missiles to engage multiple targets at close range; and Gunslinger, a gun-armed tactical missile for close air support, counterinsurgency and air-to-air combat.

DARPA's objective is to look beyond what the military services think they want to what they might need in 10-15 years' time. Technologies it develops are intended to transition to the services, but they often drop from sight only to reappear years later in a different guise. DARPA's 2004-05 Grand Challenge has yet to result in fleets of driverless military vehicles, but the competition was the genesis of the entire self-driving car industry.

The agency does not hesitate to end projects early if it wants to move on. And it happily revisits ideas that did not work last time around unencumbered by any stigma of past failure. All of this means there is no guarantee that a DARPA idea will become reality.

But if the new programs planned for 2021 have a theme, it is how to operate in a highly contested environment—how to provide the air cover, ground support and connectivity U.S. forces have come to rely on in the face of integrated air defenses.

LongShot appears to be a follow-on to the Flying Missile Rail concept revealed by DARPA in 2017. This was a device carrying a pair of AIM-120 air-to-air missiles that could remain under the wing of an F-16 or F/A-18 or fly away from the host aircraft, acting as a booster to extend the range of the missiles.

Carried externally on fighters or internally in bombers, LongShot will use a slower-speed, longer-range air vehicle for transit to the engagement zone, where it will launch multiple air-to-air missiles closer to its targets, reducing their reaction time and increasing end-game maneuverability and kill probability.

"Multi-mode propulsion will significantly increase

engagement range," says DARPA, suggesting it could allow aircraft to provide air cover for ground forces while staying outside the reach of air defenses. "LongShot will explore new engagement concepts for multi-modal, multi-kill systems that can engage more than one target," says DARPA.

The Gunslinger project will demonstrate a tactical-range weapon that combines the maneuverability of a missile with the ability of a gun to selectively engage different target types. DARPA is looking for a weapon concept with the aerodynamic, propulsion and payload capacity to enable a wide operational envelope so it can

be launched to transit, loiter and engage ground or air targets.

While the programs sound similar in concept to loyal wingman unmanned aircraft that would team with manned platforms to extend their sensor and weapons reach and increase survivability, both LongShot and Gunslinger have the flavor of more-automated missile systems. DARPA describes Gunslinger as having "algorithms that support maneuvering and target recognition to enable expedited command

decision-making for selecting and engaging targets."

Other new projects in DARPA's 2021 plans include Portable Optical Integrated Network Transceivers (POINT) and Resilient Networked Distributed Multi-Transceiver Communications (RNDMC—think hip hop group Run-DMC). Both relate to means of enabling forces to communicate in electromagnetically contested environments.

POINT will leverage recent developments in optical phased-array transmitters to develop small photonic transceivers with no moving parts, dramatically reducing their size, weight and power so they can fit on mobile platforms and microsats and provide robust free-space optical links at up to 1 Gbps.

RNDMC aims to provide beyond-line-of-sight tactical communications in highly contested environments by developing low-cost expendable, synchronized repeaters that can be hosted on ground platforms, hand-launched UAVs, high-altitude platforms and low-cost satellites in low Earth orbit.

With its recent focus on hypersonic strike weapons nearing fruition, DARPA's 2021 budget request shows it is not easing off on its singular quest to anticipate the U.S. military's possible future needs—however surprising a missile equivalent to the gun-toting A-10 Warthog might sound. ☛

The Next Warthog?

Gun-armed, close-support missiles among DARPA's new projects



U.S. AIR FORCE

THE LAUNCHPAD

IRENE KLOTZ



IN AN UNCHARACTERISTIC MOVE, SpaceX has signed a partnering agreement with an experienced space travel company to sell a Crew Dragon orbital flight for four fare-paying passengers.

Under the arrangement, announced on Feb. 18, Vienna, Virginia-based Space Adventures will market a high-altitude, free-flying orbital voyage lasting 3-5 days aboard a SpaceX Crew Dragon capsule.

Terms of the contract and flight costs were not disclosed, but the price per seat is expected to be about \$50 million.

Following launch aboard a SpaceX Falcon 9 rocket, the capsule would orbit at an altitude of 621-746 mi. (1,000-1,200 km)—roughly 2-3 times higher than the International Space Station (ISS), which circles about 262 mi. above Earth.

private spaceflight services.

“SpaceX is not the small startup it once was,” says Eric Stallmer, president of the Commercial Spaceflight Federation, a Washington-based industry advocacy organization. “I think they want to be competitive—especially in the space tourism market—so I’m not surprised they would go out with a trusted name like Space Adventures, which has a proven track record in providing spaceflight services.”

In a statement, SpaceX President and Chief Operating Officer Gwynne Shotwell adds, “This historic mission will forge a path to making spaceflight possible for all people who dream of it. We are pleased to work with the Space Adventures team.”

Privately owned Space Adventures also has an agreement with Boeing to market seats aboard upcoming CST-100 Starliner missions to the ISS. Star-



“We’d like to break the altitude record for a private citizen orbital flight, which shouldn’t be too difficult,” Space Adventures Chairman Eric Anderson tells Aviation Week. “This would be the highest-altitude orbital flight since Gemini 11, which I think is really cool.”

The mission could take place in late 2021 or early 2022, he adds.

The partnering agreement is a shift for SpaceX, which handles most of its spacecraft manufacturing, testing and flight service business in-house, including even the design and production of spacesuits. SpaceX in 2018 announced it had sold a chartered flight around the Moon aboard its planned Starship deep-space transportation system to Japanese billionaire Yusaku Maezawa.

The agreement with Space Adventures, which previously brokered eight privately financed missions to the ISS aboard Russian Soyuz spacecraft, could give SpaceX a running start in the emerging market for

liner has a fifth seat available that could be sold to a paying passenger, who would accompany four station crewmembers on NASA-purchased rides to and from the orbital outpost.

NASA has contracts totaling as much as \$7 billion for SpaceX and Boeing to design, build, test and operate commercial space-taxi services to the ISS. The contracts, awarded in 2014 under NASA’s Commercial Crew Program, cover up to six operational missions, each of which would carry four astronauts to and from the ISS.

SpaceX is preparing for its final Crew Dragon flight test this spring, a mission that will be the company’s first with people aboard and the first human orbital spaceflight aboard a U.S. vehicle since the final space shuttle mission in 2011.

Boeing’s Starliner program is under review following software problems discovered during an uncrewed flight test in December. ☉

HEAD-TO-HEAD



Boeing's revised NMA strategy appears to have fixed the A321XLR firmly in its sights.

> BOEING'S REVISED NMA DESIGN WOULD BUILD ON PREVIOUS NMA TECHNOLOGY

> THE FOCUS HAS NARROWED TO COUNTERING THE LONG-RANGE A321

Guy Norris and **Jens Flottau** Singapore

When Boeing announced its surprise decision to start afresh with design studies for the new midmarket airplane (NMA), the obvious question was: Where will the company refocus its efforts?

Now, just a few weeks into 2020, the answer may be emerging. Instead of launching a new NMA family to take on the broader 757/767 replacement market, Boeing is leaning toward a design optimized to compete more directly with the long-range Airbus A321XLR.

Offering the first new clues to where product development efforts may refocus in the wake of the company's decision to go back to the drawing board on the NMA, Boeing Commercial Sales and Marketing Senior Vice President Ihsane Mounir says: "We are learning what the [A321]XLR is doing or not. So that also gives you a good idea of what the market may want."

Since Boeing CEO David Calhoun revealed in January that the "NMA project is going to be a new clean sheet of paper," there has been speculation the effort may be redirected to cover a new airliner family that could cover the present 737 MAX as well as

the 757. However, Mounir's comments suggest the prime focus may be shifting to settle primarily on the 200-240-seat, 4,700-nm-range category of the new Airbus. Launched in 2019, the A321XLR will be delivered starting in 2023 and has already received 450 orders, including contracts from both American Airlines and United Airlines.

Provisionally targeted at service entry in 2025, the NMA grew out of 757-replacement studies and over the past five years was expanded to include a successor to the 767. The program was focused on two main versions, the 225-seat NMA-6X and 275-seat NMA-7X, with the larger of the pair expected to be developed first.

"With NMA, we never crossed the line with customers in terms of 'this is perfect for me,'" Mounir says. "It is frankly something we looked at two years ago, and when you look at the market today, you have to re-address

if it still makes sense to have exactly this concept."

He says Boeing has "learned a lot" from the NMA study—including both market expectations on operating costs and pricing, as well as how to develop a new production system targeted at making twin-aisle designs for single-aisle manufacturing costs. "That's going to allow me to do things I haven't been able to in the past," says Mounir. "So now if I take that input and look at the production system maturity, what can I come up with? Is it the same NMA I could do before, or is there something else I could do?"

"The beauty of it is we haven't launched anything, so you can always refine the concept and figure out what the right aircraft is for the marketplace," says Mounir. "The product development team will redirect their efforts to look at a fresh concept and internalize all we have learned through the exercises we have had with customers, but I can tell you we are not flogging anything that we are discussing with customers right now."

The move, if confirmed, also raises questions about Boeing's longer-term replacement strategy for the 737 MAX

and how this might be influenced by the development of a new aircraft sized to compete more directly with the A321XLR. As Boeing conventionally develops families of aircraft, a downward shift in size for any new 757 successor aircraft would likely entail development of a smaller stablemate that would encroach on the upper end of the current 737 range.

Another key question is whether the revised approach will stay with the twin-aisle configuration at the heart of the NMA concept. If it does, the decision to recalibrate around the size of the A321XLR may enable Boeing to revive earlier concepts for codevelopment of a smaller single-aisle derivative sharing common avionics, systems and other features—much as the manufacturer did 40 years ago with the 757/767 programs.

Mounir also scotches speculation that Boeing could dust off its long-abandoned 787-3 derivative as a potential replacement for the larger NMA market sector. “The key to the NMA is the production system—and the production system around 787 produces true long-haul capability with a certain rate and a certain yield. You have got to be able to match yield to pricing, and so if a 787-3 is produced within the same system, I just don’t see how you could do that . . . from a yield standpoint.”

Although Boeing has yet to brief key suppliers such as engine-makers about the new design direction, some manufacturers already agree the pivot toward an A321-size alternate makes sense. MTU Aero Engines Chief Program Officer Michael Schreyoegg says he “would not be surprised if Boeing came up with something similar to the Airbus A321XLR; they have to do something in that space.” The NMA could therefore turn out to be “smaller than originally planned,” he says.

The revised new aircraft concept also opens up interesting options for the engine manufacturers, including potentially reopening the door to Rolls-Royce, which dropped out of the NMA race a year ago after citing concerns about its ability to meet Boeing’s original development schedule with a version of the new UltraFan engine. “We are open-minded and will stay open-minded when we know what Boeing plans to do,” Rolls-Royce President Chris Cholerton said at the Singapore Airshow.

Schreyoegg believes that the time-frame may still be “too tight” for Rolls-Royce to reenter the competition with its first large geared engine design. But MTU, which is partnered with Pratt & Whitney on the geared fan (GTF), believes the shift in timeline “opens up an opportunity for a GTF architecture,” says Schreyoegg. “It is the right architecture,” he says.

With the aircraft now likely to arrive several years later than the

mid-2020s target date of the original NMA project, engine manufacturers will also have more time for technology development. “We can use more advanced materials for higher temperatures,” Schreyoegg says. “Every [additional] year is helpful.”

Check 6 *Aviation Week Editors discuss events at the Singapore Airshow: AviationWeek.com/podcast*

Bombardier Flies Into Uncertain Future as Business Aviation Specialist

➤ ASSET SALES WILL LEAVE IT AS A BUSINESS AVIATION PROVIDER

➤ AIRBUS CONSOLIDATES ITS CONTROL OVER THE A220, WITH FURTHER GROWTH PREDICTED

Michael Bruno Washington, **Jens Flottau** Frankfurt and **Molly McMillin** Wichita

Two generations of aerospace workers and pilots, Bombardier was always known as a scrappy business aviation OEM, even though the Canadian industrial stalwart did more annual business in train-related manufacturing and its origin dates back 83 years as the first snowmobile-maker.

But assuming several recently announced deals close, Bombardier will only be known as a business jet (bizjet) provider—and yet its future may be no less uncertain.

On Feb. 17, Bombardier announced an agreement to sell its rail-car-based Bombardier Transportation to Alstom of France in a deal that is expected to close in the first half of 2021 and net Bombardier \$4.2-4.5 billion. Four days earlier, Bombardier announced it had sold its remaining stake in the Airbus A220, the former Bombardier C Series, for \$550 million. Besides cash at closing, in both cases Bombardier gets relieved of future or external obligations that have been haunting it, such as \$700 million in no-longer-required payments to Airbus or retirement of the Caisse de depot et placement du Quebec (CDPQ) convertible instrument for \$2.1-2.3 billion.

“Following this transaction, Bombardier will be the only major pure play in the bizjet end-market, and we are curious to see how the financial markets receive this,” say JP Morgan

analysts. “Currently, we think the equity market perceives bizjets as facing structural challenges and as unappealing from a growth perspective.”

Bombardier had been in talks with Cessna-maker Textron Aviation over the sale of Bombardier Aviation’s business jet division. But those are widely expected to be shelved if the Alstom deal goes through, several analysts say. At the same time, Bombardier leaders are embracing their coming specialty as a business jet-maker and aftermarket provider, contending the embattled company now will be on solid financial footing and a leading player in the business aviation sector.

“Going forward, we will focus all our capital, energy and resources on accelerating growth and driving margin expansion in our market-leading \$7 billion business-aircraft franchise,” Bombardier CEO and President Alain Bellemare says.

“We’re just coming out of a massive investment cycle, and we feel today that we have the best product portfolio in the industry,” the Bombardier CEO continues. “Our Global family is strong, actually No. 1, and our Challenger 350 and 650 are still best-selling in their class. So when we look at this right now, we feel very good about where we are. We have a very large installed base, and we’ve spent a lot of money expanding our customer support net-

work, and we will continue to grow our aftermarket business moving forward.”

Analysts on a teleconference with Bombardier managers congratulated them for reaching the train deal with Alstom and CDPQ. Still, the Bombardier Transportation and A220 sales leave Bombardier focused on an industry that many observers have almost wished aloud it were not in, considering the sector’s mixed performance in recent years and the widely held belief that the industry is due for consolidation with too many OEMs still competing.

“The market hasn’t been growing and is hampered by having 40 models of business jets competing for those finite sales,” says Brian Foley, a consultant with Brian Foley Associates.

Indeed, while many consultants and analysts saw Textron as the only logical buyer of Bombardier Aviation, Wall Street was not enthusiastic about Textron doubling down on the industry. A few observers have speculated that even as a standalone business aviation company, Bombardier may eventually merge, but only after its publicly traded share price falls or more costs are taken out.

Bellemare says changes will occur at Bombardier Aviation in preparation for business jets being the sole focus, with “opportunities to optimize cost and flexibility.” But overall, Bombardier as a business aviation company should be a cash generator moving forward. It will count the largest such backlog in the industry at \$14.4 billion at the end of 2019, \$1 billion more than rival Gulfstream of General Dynamics. Bombardier’s product portfolio includes the lauded Global 7500 among others, which Bombardier managers think could get produced at a rate of mid-30s per year and already has a backlog “well into” 2023.

Bombardier could provide more insight when it reports financial results for the first quarter on May 7. Meanwhile, analysts agree it has a fighting chance due to lower corporate debt, increasing cash flow and Bellemare’s better reputation in managing business aviation versus trains. “As the sector’s premier bizjet with its four fuselage sections, Bombardier’s Global 7500 backlog likely is well-priced; and its cash profitability should improve nicely as it moves down the learning curve,” say Cowen analysts.

“While we are not currently highly

constructive on the biz jet market due to soft demand, Bombardier is well-positioned across the subsegments, particularly so in the most profitable large cabin segment where it only competes with Gulfstream,” Credit Suisse analysts agree. “Over time, we would expect excess bizjet capacity to be absorbed, which should enable demand to improve for new jets, which should be supportive of Bombardier Aviation over the long term.”

The Alstom deal is slated to close in the first half of 2021, assuming it gains regulatory approval—no fait

Equally important, Airbus is free to consider investing further in the A220. Among others, Airbus is in talks with Breeze Airways CEO David Neeleman about a substantial increase in range for the aircraft, to more than 4,000 nm, which would make U.S. transcontinental and transatlantic missions possible. What is more, airlines such as Air France-KLM have been lobbying Airbus to build an A220-500, a stretched version of the -300 that would compete with the Boeing 737-8 and its own A320neo. It would offer, analysts believe, substantially lower unit costs.

The Global 7500 will be the leading growth driver at Bombardier as a standalone business aviation OEM.



accompli in Europe, as antitrust concerns doomed an earlier train tie-up of Alstom and Siemens. But Bombardier executives and financial analysts see the Bombardier-Alstom deal faring better, as their products are more complementary and there are growing concerns about having enough industrial heft to compete with China. By comparison, the A220 sale to Airbus closed immediately after Canadian and Quebec officials secured their government interests.

For its part, Airbus now not only has access to a massive strategic asset in the single-aisle business, but it also no longer is held back by Bombardier’s financial constraints. Airbus has collected 658 orders for the A220-100 and -300 and is in the process of ramping up production. In addition to the original final assembly facility in Mirabel, Quebec, Airbus also is in the process of setting up another A220 line in Mobile, Alabama, to deliver the first aircraft to Delta Air Lines later this year. Mobile is to produce four aircraft per month when it is in full swing.

Airbus Chief Commercial Officer Christian Scherer says such an aircraft was “not a question of if, but when.”

The A220 is hugely important for Airbus because it enables the OEM to position an A320neo-family replacement upmarket, beginning at 180-200 seats, while still being able to offer an up-to-date product at the lower end of the narrowbody market.

As part of the deal, Quebec will stick to its shareholding in Airbus Canada for three years longer than initially planned and remain a part-owner until at least 2026. Its shares are then “redeemable by Airbus,” giving it the option for full control. Details and conditions of that arrangement are confidential.

Also, Bombardier is selling its A220 and A330 work-package production to Airbus subsidiary Stelia Aerospace, which includes the A220 cockpit and rear fuselage. 🗣️

Check 6 Aviation Week editors discuss what’s next for Bombardier in the crowded bizav market: [AviationWeek.com/podcast](https://www.aviationweek.com/podcast)

MAX Inventory Clearing May Continue Into 2022

- > SIMULATOR TRAINING WILL ADD 2-5 MONTHS
- > SPEED BUMPS INCLUDE FAA INVOLVEMENT AND RESYNCHING SUPPLY CHAIN

Michael Bruno Washington

With the aerospace manufacturing sector expecting Boeing to restart 737 MAX production as early as March or April, suppliers, aftermarket providers and countless other auxiliary businesses are trying to figure out how fast the backed-up pipeline of narrowbodies will get into service—and when things will return to precrisis normal.

The answer, increasingly, is: Don't hold your breath.

Kevin Michaels, managing director of AeroDynamic Advisory, told a subdued Pacific Northwest Aerospace Alliance conference early in February that it will take 18-24 months to push out the roughly 400 undelivered MAXs stockpiled by Boeing, in addition to flying the 387 grounded MAXs parked by customers, along with the almost 100 fuselages aerostructures supplier Spirit AeroSystems has put on blocks in Wichita.

With Boeing's January reversal in endorsing that MAX pilots should undergo simulator training, the requirement—

involved in every delivery of every MAX airplane, [which] we've assumed will continue."

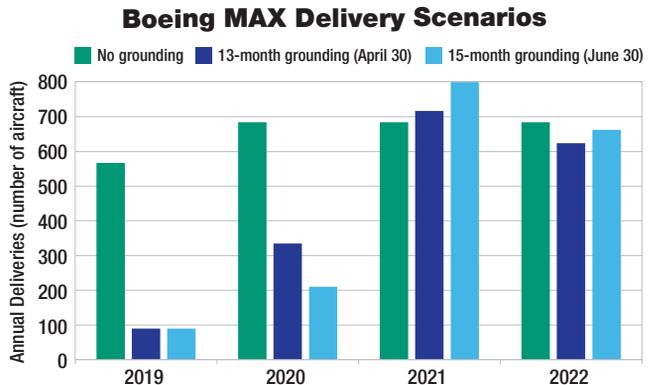
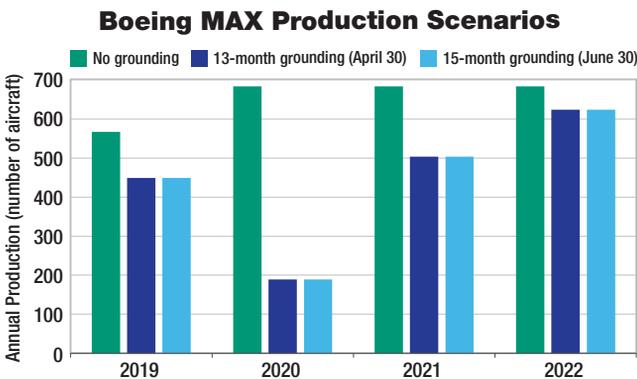
Clearing out Boeing's stored inventory will take about 18 months, the CFO further said.

Michaels said that with all of that factored in, it means the MAX ramp-up will be gradual, with deliveries likely starting in the fourth quarter, which begins in October. Jefferies analysts predicted monthly production starts at an average rate of 21 in the third quarter, beginning in July, with 21 aircraft also being pushed out of inventory every month, for a total of 42 deliveries per month in 2020.

Moody's Investors Service projects cumulative deliveries in the 36 months through December 2022 in two scenarios—production starting April 30 or June 30, 2020—at about 1,675 aircraft for either situation (see charts). This compares with a projected 2,050 narrowbodies for the same period if the grounding had not occurred and Boeing produced at its then-planned monthly rate of 57 from mid-2019.

Still, besides simulator training and FAA involvement in every grounded or parked airplane initially, other speed bumps in returning to normal—i.e., a Boeing monthly production rate of 57 737s and deliveries of around 47, according to the Aviation Week Intelligence Network Fleet Discovery database—are becoming apparent.

For instance, Vertical Research Partners notes that airline customers worldwide must have their training plans for the MAX individually approved by their respective na-



Source: Moody's Investors Service

if mandated by the FAA or other aviation regulators—will add 2-5 months alone to the pushout timeline. There are only 36 known MAX simulators operating worldwide, although major provider CAE continues to build so-called white tail sims for sale.

Once suppliers restart production, it could take up to six months until the first MAX delivery of a new-built aircraft, Michaels told the Seattle-area conference. Boeing CEO and President David Calhoun and Chief Financial Officer (CFO) Greg Smith have cautioned stakeholders that they will build up production "slowly" as Boeing's empty production system resets from its first position, and Smith kept up that tone at a recent financial event.

"When you look at those three lines, they're empty," Smith told a Cowen investor conference Feb. 12. "The needle we're threading is we've got airplanes that are out on the ramp. We've got to get those delivered. We've got our factory, our supply chain and then ultimately customers' ability to take the airplanes. And then, of course, we've got the added element in that delivery now [of] the FAA being

tional regulators, with the FAA looking after U.S. carriers. Mid-February reports that Boeing was inspecting all its stored MAXs after discovering foreign object debris in the fuel tanks of some also add to concerns.

Regardless, whenever it presses forward, the OEM will face discordant suppliers. "For Boeing, increasing production back up will require planning ahead and resynchronizing the global supply chain," say AlixPartners A&D Managing Directors Eric Bernardini and David Wireman.

Forging and castings work will need to start "several" months before assembly, they wrote in a February report, and raw materials such as titanium that are used in the former process have a lead time of about a year. "This means that decisions made now by Tier 3 and 4 suppliers will affect Boeing's 2021 production rate," they wrote. Airbus also could keep increasing its own A320-related production, potentially adding to supply chain pressures.

Others agree. "The global supply chain for aerospace takes time to move," Albany International CFO Stephen Nolan told analysts in February. 📍

Boeing MAX Simulator Training Is Taking Shape

> BOEING IS DEVELOPING RECOMMENDED SIMULATOR SESSIONS

> PILOTS ARE PUSHING FOR SCENARIOS SIMILAR TO THE TWO FATAL MAX ACCIDENTS

Sean Broderick Washington and Miami

Now that simulator sessions are a near-certain prerequisite for getting pilots back into 737 MAXs, Boeing and operators are working through two related challenges: what the new training will cover, and how operators will work it into their return-to-service planning.

Boeing is finalizing the proposed minimum simulator curriculum, but the training is expected to consist of at least four modules, three people who have reviewed drafts tell Aviation Week. The draft modules shared with pilots focus on four topics: operation of the MAX's Maneuvering Characteristics Augmentation System (MCAS) flight control law, MCAS-related emergency procedures, flight-deck ramifications of the MAX's linked flight control computers (FCC), and scenarios that require manual horizontal stabilizer trim inputs.

The MCAS' intended operation is the most straightforward session. The flight control law was added to the MAX to ensure the newest 737 handled like its predecessor in certain rare, flaps-up, high-angle-of-attack (AOA) manual flight profiles. Designed to operate in the background, the MCAS was not included in the MAX flight crew operations manual (FCOM) or training. The system's contribution to two MAX fatal-accident sequences led regulators to ground the fleet and call for changes before grounded MAXs can fly again. Boeing is incorporating the MCAS changes in a broader MAX flight control computer software update and training revamp.

The MCAS' new logic allows only one nose-down stabilizer input cycle per elevated AOA event instead of repeated inputs, as the original version did. It also allows pilots to counter automatic nose-down movement by pulling back on the yoke. Pilots will experience the system's operation as part of the new simulator sessions. In addition, Boeing has modified the MAX FCC logic so that the autopilot cuts out at a predetermined point as

the aircraft approaches a stall.

The training also will put pilots through MCAS-related failure scenarios, including situations similar to the two accident flights, Lion Air Flight 610 (JT610) and Ethiopian Airlines Flight 302 (ET302). In each case, the MCAS—triggered by a single source of faulty AOA data shortly after take-off that told the FCC the aircraft's nose was too high—commanded repeated nose-down inputs. The crews did not respond as Boeing expected pilots would: detecting a runaway stabilizer, using yoke-mounted electric trim inputs to counter the MCAS and toggling the stabilizer trim-motor cutout switches if the problem persisted.

The modified software compares readings from both MAX AOA sensors. A disagreement of 5.5 deg. or more nullifies MCAS activation, one of several safeguards Boeing has added.

MAX pilots also will be shown other changes linked to Boeing's revised flight control system logic that incorporate inputs from both FCCs. Some involve new ways that indicator lights are triggered, factoring in the revised system's added redundancy.

One simulator module will require pilots to use manual trim in different scenarios such as after toggling the trim cutout switches in response to a runaway stabilizer. Investigations triggered by the accidents spotlighted challenges linked to manual trim operations such as when forces on the stabilizer make the center pedestal-mounted trim wheel difficult to turn.

The 737 FCOM provided little detail on such scenarios, though they are covered more extensively in the flight crew training manual designed for instructors, a document most line pilots never see. The revised FCOM is expected to include more information.

The sessions are expected to include struggling with an out-of-trim aircraft, which can put significant forces on the horizontal stabilizer. A preliminary report from Ethiopia's Aircraft Accident

Investigation Bureau says the ET302 flight crew countered uncommanded nose-down stabilizer inputs with limited manual electric-trim inputs, which move the stabilizer more slowly than the MCAS does.

The pilots toggled the stabilizer trim cutout switches to "off." With the stabilizer still pushing the nose down, the captain countered by pulling back on his control column to deflect the elevators up. He told the first officer to try using the manual trim wheel to rotate the stabilizer nose-up. The first officer replied that it "is not working." The crew then cut the trim-motor switches back on, which reactivated the MCAS.

While the report does not provide more details on the manual-trim issue, one theory is that aerodynamic forces on the stabilizer from the combination of the aircraft's speed, nose-up control column inputs and nose-down stabilizer position prevented the first officer from moving the control surface. Boeing's changes to the MCAS prevent repeated nose-down inputs, making severe out-of-trim scenarios less likely. But pilots briefed on the simulator session plans have urged Boeing to include a variety of manual-trim scenarios, including ones that incorporate higher airspeeds that crews will face if nose-down inputs result in a dive.

"In the new [MCAS] software, the nose can be pulled back up, but there will still be some" nose-down movement, one 737 pilot says. "Now I'm left with electric trim, which is not as responsive as MCAS, so getting the nose up will take a little time. If we hit the cutout switches and move to the trim wheel, what does that feel like? We want to know."

The manual-trim module is the only one of the four that could apply to 737 Next Generation (NG) pilots as well, since the scenarios are not linked to the MCAS. It is unclear if any of it will be integrated into 737NG training.

MAX pilots will see another change in the new FCC software. In a move to incorporate more human-factors principles into flight decks, the flight director—a guidance aid that prompts pilots to climb, descend, or turn to follow the path programmed into the flight management system—will drop off primary flight displays during upsets. The change temporarily removes noncritical information from the pilots' field of view. "If I'm in a stall, my designated target altitude is pretty low on my list of concerns," one MAX pilot says.

The simulator sessions are expected to take 90-120 min. Complementary computer-based training will cover the four simulator scenarios, providing videos and other lessons that support what pilots will experience firsthand.

In early January, Boeing announced that it would recommend simulator sessions as part of all MAX pilot training. The move reversed a position that was a key selling point for its newest narrowbody: the ability for qualified 737 pilots to transition to the MAX without costly and time-consuming simulator work. While the FAA and other regulators will have the final say

who request time in Boeing simulators. If simulator training requests exceed Boeing's training capacity, Boeing will consider many factors when prioritizing requests, including regulatory approval of training, timing of MAX aircraft deliveries and the customer's overall access to simulator training."

Training cannot start until the curriculum is approved. The FAA declines to publicly discuss time frames for signing off on training and the MAX software modifications, but Boeing is anticipating that approval will come by midyear. Airlines have assumed they will need 1-2 months to incorporate the

would set Southwest up for an early October MAX return. Southwest has three MAX simulators and expects to bring three more online by summer, followed by three additional ones in the second half of the year. "That will give us at least six MAX simulators available for training by the time the aircraft is released to fly, and that will significantly reduce our training time from where we started," says Chief Operating Officer Mike Van de Ven.

Southwest operated 34 of the 387 MAXs grounded and has another 27 among the 400 MAXs Boeing is storing for customers. "Those combined 61 aircraft are our most reliable source of lift once the aircraft is cleared to fly," Van de Ven says. "We believe that we can manage around 5-10 aircraft a week from this collective pool to be reintroduced to the operation. So it will take at least a couple of months for those aircraft to return to service. And our crewing is in place today to operate them."

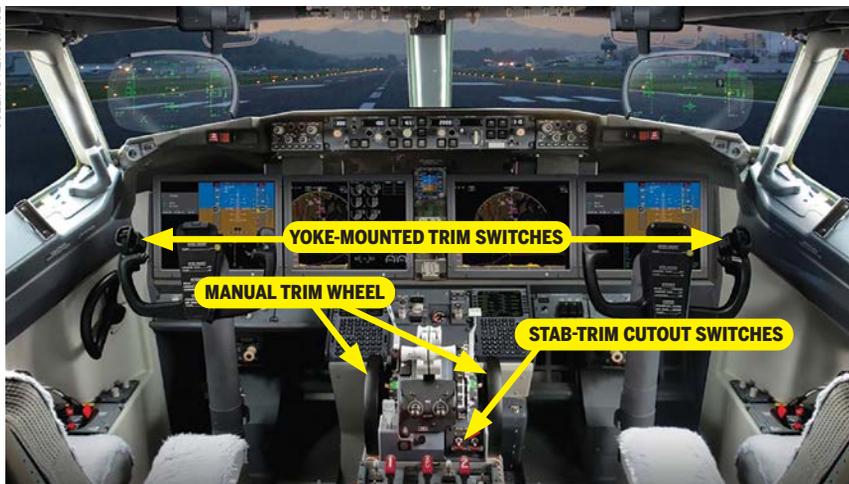
American Airlines has 37 grounded MAXs—24 in its fleet and 13 more in Boeing's inventory. It has one simulator, with a second on order. President Robert Isom says the carrier is "sketching out a number of different scenarios" to ensure it has the resources to get the MAXs back up "as soon as possible" following FAA approval.

United Airlines has one fixed-base MAX simulator and is adding three full-flight devices by midyear. "We actually feel really comfortable in terms of where we are relative to simulator capability," Chief Operations Officer Greg Hart says. The Chicago-based carrier had 14 737-9s when the fleet was grounded and was slated to take delivery of 16 more by the end of 2019 and 28 in 2020. Like all other MAX customers, its 2020 plans remain up in the air because of the grounding and a delivery schedule that must align with Boeing's measured production restart.

"At this point, we're assessing the impact of the [planned] schedule," says United Chief Commercial Officer Andrew Nocella. "But we do not anticipate flying the MAX this summer."

Boeing is not saying how quickly production will ramp back up once it restarts. The company plans to focus on getting built, undelivered MAXs out to customers as production slowly ramps up. Consultancy AeroDynamic Advisory projects a restart rate of 12-18 per month, with 52 aircraft per month not occurring until well into 2022. 🛩️

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The 737 runaway-stabilizer (stab) checklist emphasizes using yoke-mounted main electric trim switches and control columns to adjust pitch. If necessary, stab-trim cutout switches can disconnect the trim motor, and pilots can move the stab by hand using the manual trim wheel. These scenarios are expected to be part of new simulator sessions being developed for the MAX.

on minimum training requirements, Boeing's revised position is expected to become part of the de facto standard, even if regulators take the unexpected step of not accepting it.

Putting pilots through simulator sessions adds complexity to airlines' return-to-service plans. There are 36 MAX simulators available globally, with more coming online. Boeing has eight and is "in the process of acquiring two more" by midyear, the company says. It will work with customers that need simulator access, coordinating with providers that have capacity.

"We are working with several training providers as we thoroughly prepare to meet anticipated simulator training demand," Boeing says. "Recognizing that full-flight simulators have a finite capacity, Boeing will do everything it can to support customers

MAX upgrades, train pilots and begin adding MAXs to flight schedules. Adding simulator sessions adds time.

Southwest Airlines on Feb. 13 pushed its MAX-free schedules out to Aug. 10, from early June, and other carriers will follow. Given Boeing's current projections and the likelihood of simulator training, getting MAXs into revenue service before the fourth quarter could be challenging. "The timing remains uncertain, and we're working through all of that right now," Southwest CEO Gary Kelly says. "Assuming for a second that the simulator training [is] 2 hr, it will take us at least a couple of additional months from where we were to get all of our pilots through that training."

Put together, Southwest's ramp-up from FAA approval to revenue flights could take four months. That means an early June FAA approval

CAAC Backs Airline Mergers as Epidemic Response

> TRAFFIC GETS MODEST BOOST AS SOME CHINESE RETURN TO WORK

> CARRIERS ARE MAINTAINING LINKS WITH GLOBAL HUBS

Bradley Perrett Sydney

Mergers and capacity reductions among Chinese airlines may result from the COVID-19 virus epidemic, as the Civil Aviation Administration of China (CAAC) says it supports reorganization of the industry as part of its response to the crisis. The agency said on Feb. 12 it is also asking departments to provide additional relief for the industry in paying charges and taxes.

Passenger traffic for mainland Chinese airlines since Lunar New Year's

help enterprises get through this crisis.”

At the end of 2018, China had 51 passenger airlines, according to an official count issued in May 2019. No new ones have been licensed since then. There are so many not because, as elsewhere, they include a profusion of little regional airlines—in fact, China has just one—but mainly because so many cities and provinces have sponsored the establishment of local mainline carriers. These operate standard six-abreast narrowbody airliners.



STATE-OWNED ASSETS SUPERVISION AND ADMINISTRATION COMMISSION

Day (Jan. 25) has been 70% lower than the corresponding holiday period in 2019, the CAAC says, adding that the average load factor has been lower than 45%. Nonetheless, this understates the immediate situation. The mainland Chinese carriers planned on Feb. 13 to operate only 29% of their scheduled flights, according to local consultancy VariFlight. A few days earlier, activity appeared to have stabilized at about a third of the schedule.

On various days in the first week of February, four carriers did not fly at all: Air Travel, Fuzhou Airlines, Genghis Khan Airlines and Grand China Air. All are now back in the air, however.

Listing the steps it is taking, the CAAC says: “We are supporting reorganization by combination, with optimization of capacity, according to the needs of aviation enterprises. We will

The CAAC has long been dissatisfied with the multiplicity of airlines, which undermines profitability with high competition and could jeopardize safety by spreading the limited number of experienced managers among too many company teams. The agency has more or less refused to license new mainline passenger carriers for the past four years. Losses amid the epidemic must be bleeding industry capital, another matter that the CAAC regards as critical to maintaining safety.

For immediate relief, the CAAC has suspended a charge of a few dollars per passenger that airlines pay into an aviation infrastructure fund. Commercial aviation is also among the industries that have been given a little tax relief as a result of the virus outbreak. And flights run specifically as part of the government's efforts to combat the

epidemic—for example, by delivering urgent supplies—are exempt from charges such as landing fees.

“The CAAC will continue to seek fiscal policies from other government departments to support aviation enterprises in relation to controlling the epidemic,” the agency says, giving no details. Carriers are not publicly complaining about losses or asking for government help; doing so during a national crisis would be politically incorrect.

One factor helping the industry must be a drift back to work by people who were in their hometowns celebrating the Lunar New Year when the epidemic became an acknowledged emergency in the last 10 days of January. However, the boost in traffic is modest compared with the usual surge of travelers at the end of the holiday.

For example, Shanghai's two airports, Pudong and Hongqiao, handled 130,000 and 70,000 passengers, respectively, on the peak day at the end of the 2019 Lunar New Year holiday. This year, Feb. 9 should have been the peak, yet Pudong and Hongqiao handled only 48,000 and 27,000 passengers, respec-

Chinese carriers, including China Eastern Airlines, have been rushing supplies and medical staff to areas hit by the epidemic.

tively. Still, the two airports' Feb. 9 total passenger volume was up 45% on the average traffic flows measured over the three previous days, indicating some back-to-work traffic.

As foreign airlines have suspended flights in response to a lack of demand, China has told its airlines to keep international links open—at least minimally. They are flying even when no seats have been sold, according to a well-placed industry source.

The country still has 710 international air routes that are open—operated by 77 Chinese and foreign airlines—the CAAC says, giving no comparative pre-epidemic figures. Tellingly, the agency adds that there are only 2,610 international flights a week, meaning the average route is being served about once every two days. And 29% of international flights are by freighters.

The agency stresses that China is still connected to major international hubs, such as Frankfurt, London, Los Angeles, New York, Paris and Tokyo. ☛

—Research by Ryan Wang

Boeing and Airbus Need More Widebody Orders From China

> 787 PRODUCTION IS CUT BACK TO BUY MORE TIME

> COVID-19 OUTBREAK COULD DELAY FLEET EXPANSION

Jens Flottau and Guy Norris Singapore

On paper, the Singapore Airshow could not have come at a better time. Trade tensions between the U.S. and China appear to be easing, opening the door for much-needed widebody orders to sustain production rates of key programs. Trade shows are an ideal platform for final negotiations (and announcements) of big aircraft orders.

But the reality was very different. The 2020 Singapore Airshow will be remembered as the slowest of its kind in recent memory, a result of the COVID-19 coronavirus outbreak that kept many from traveling to Singapore, let alone finalizing deals. Airlines across Asia are busy dealing with the collapse in demand and protecting near-term cash flow.

Chinese carriers are operating around one-third of their usual capacity, and many airlines in surrounding countries with exposure to China are almost equally affected. Major fleet investment decisions will have to wait until the situation stabilizes.

Nonetheless, Boeing is hopeful it will be back in business with Chinese airlines soon, as trade tensions are abating. The impact on aviation of COVID-19 is “a temporary shock,” Senior Vice President for Commercial Sales and Marketing Hissane Mounir said at the show.

“There is a lot of pent-up demand in the widebody market,” Mounir said. As a result of the trade tensions with the U.S., carriers from Asia’s biggest market “have hit the pause button, but the fundamentals are still there,” he noted.

Boeing recently announced it will cut 787 production down further to 10 aircraft per month from 12, and some analysts have voiced concern that the manufacturer may have to go below 10 if China does not reenter the market soon.

Mounir, however, sees Boeing staying at 10 “for a couple of years and then going back up again.” He pointed out that “widebodies are a two-year

CHINESE AIRLINES New Widebody Direct Orders and Deliveries				
	Boeing 787		Airbus A350	
	Orders	Deliveries	Orders	Deliveries
Air China	15	14	30	10
China Eastern	19	19	20	7
China Southern	10	10	20	6
Hainan Airlines	34	34	—	—
Sichuan Airlines	—	—	10	—
Xiamen Airlines	12	12	—	—
Ruili Airlines	6	—	—	—
Okay Airways	5	—	—	—
Totals:	101	89	80	23

Note: Mainland Chinese airlines have placed no direct orders for the Boeing 777X or the A330neo. Sources: Airbus and Boeing

lead-time play [from the time the order is placed], so when China reopens, it is still two years to go.”

In other words: There is no time to lose.

The numbers show that if Chinese airlines want to grow their widebody fleets, they will have to order additional aircraft from OEMs, unless they are prepared to take on more leased capacity. The latter is typically not so easy, as lessors try to avoid speculative orders for widebodies, given the high risk involved.

For Boeing, there are very few outstanding orders for 787s in China. Combined orders total 101 aircraft from seven airlines: Air China, China Eastern and China Southern Airlines, Hainan Airlines, Xiamen Airlines, Ruili Airlines and Okay Airways (see table). Eighty-nine have already been delivered. Ruili and Okay have yet to receive their first 787s, having ordered six and five, respectively.

There are no Chinese airline orders for the 777X, either. Hong Kong-based Cathay Pacific bought 21 of the aircraft in 2013.

Airbus has some aircraft on its backlog for China—a total of 57

A350s have been ordered directly and not been delivered. However, its China presence is entirely based on one model, as carriers in the country have not placed orders for the other long-haul model in the Airbus portfolio, the A330neo. Airbus was forced to cut A330 production to 40 aircraft in 2020 because of the slow demand. It delivered 53 last year.

Once air travel recovers after the COVID-19 crisis subsides, demand will be defined not only by replacement needs, but also by growth ambitions.

Overall in the Asia-Pacific region, Airbus says it has a 57% market share in widebodies, as measured by its current backlog: 288 long-haul aircraft are to be delivered to the region, compared to 218 from Boeing. “The A350 has completely changed the momentum,” says Francois Caudron, senior vice president of marketing.

Mounir sees the 787-10 in particular as being “at the beginning of something special.” He continued: “People

see it as a 777-200ER replacement. Now they are talking to us about improving the capabilities of it a bit.” He declined to disclose what these improvements would entail.

Boeing’s head of commercial sales is very bullish about 777X prospects. “The market space is enormous,” he said, pointing to the installed 777 base of 1,481 aircraft globally. He predicts a “huge peak” in replacement demand in 2023 and 2024, which is when some of the early 777-300ER deliveries come up for replacement. Boeing delivered the first -300ER in 2004.

Mounir said he is “frustrated by people saying that we have not sold enough 777Xs.” In April 2003, a year before the -300ER entered service with Air France, Boeing had 87 orders for the type, according to its own database. There are currently 309 firm orders for the 777X.

Mounir also noted that the A380 is no longer available, and further sales of the 747-8 passenger version are unlikely. Therefore, he contended that the 777-9 has little competition in the market for very large aircraft. The A350-1000 has around 50 fewer seats, depending on configuration. ☪

Air Transport Aircraft Retirements Are on the Rise

- > GLOBAL FLEET RETIREMENTS PICKED UP IN 2019, DESPITE THE 737 MAX GROUNDING
- > ANNUAL RETIREMENTS ARE PROJECTED TO KEEP CLIMBING EVEN AS DEMAND REMAINS STRONG

Sean Broderick Miami and Washington

Aircraft retirements have been lagging for several years due in part to strong demand for lift, cheap fuel prices and a spate of issues with new models designed to replace older ones, but now they appear to be on the rise, even as some contributing factors—such as the Boeing 737 MAX grounding—remain unresolved.

Figures from consultancy Oliver Wyman indicate that the number of aircraft removed from the global fleet rose in 2019. While the numbers are not ironclad—recent years’ retirement figures are difficult to gauge since aircraft that are parked could return to service under certain conditions—they suggest a long-expected shift is underway.

After three consecutive years of retirements below its forecast totals, and a net figure that fell to about 500 annually, Oliver Wyman says preliminary data shows net removals jumped in 2019, surpassing 700 aircraft. That is equivalent to about 2.5% of the global fleet of 27,500 Western-built commercial aircraft that the company tracks.

“In 2019, we would have expected retirements to slow down,” Oliver Wyman Vice President Tom Cooper said at Aviation Week’s Aero-Engines Americas conference. “Somewhat counterintuitively, the number of retirements in 2019 increased. We’ve been digging hard into that.”

Cooper said the company’s latest multiyear fleet forecast, due out in the coming weeks, will show a “significant increase in what we’re forecasting in retirements.”

Aviation Week Intelligence Network Fleet Discovery database figures also suggest a surge is imminent. Last year ended a five-year stretch during which total removals averaged 594 per year. The next five years will see annual retirement figures average 1,122, Aviation Week’s latest forecast shows.

While air transport’s macroenvi-

ronment remains favorable, signs of a slowdown could push more aircraft out of fleets. Global air traffic growth slowed to 4.2% in 2019, the latest International Air Transport Association (IATA) figures show. Although hardly panic-inducing, that figure is a significant dip from 2018’s 7.3% increase and is the first full year since 2009 that has seen traffic fall below the longer-term 5.5% annual growth trend. Air cargo fared even worse, falling 3.3% last year—the sector’s first year-over-year decline since 2012.

Demand is not expected to be hampered by rising fuel costs. Global fuel prices in early February were down about 15% from a year ago, IATA says. They remain stable and reasonable by historical standards and are not projected to create airline-cost headwinds anytime soon.

Given a generally positive macroenvironment, an uptick in retirements seems counterintuitive, particularly considering fleet-related issues plaguing operators. The 737 MAX grounding, which started in March 2019 and is still in effect, has removed 800 narrowbodies from fleets—many of them



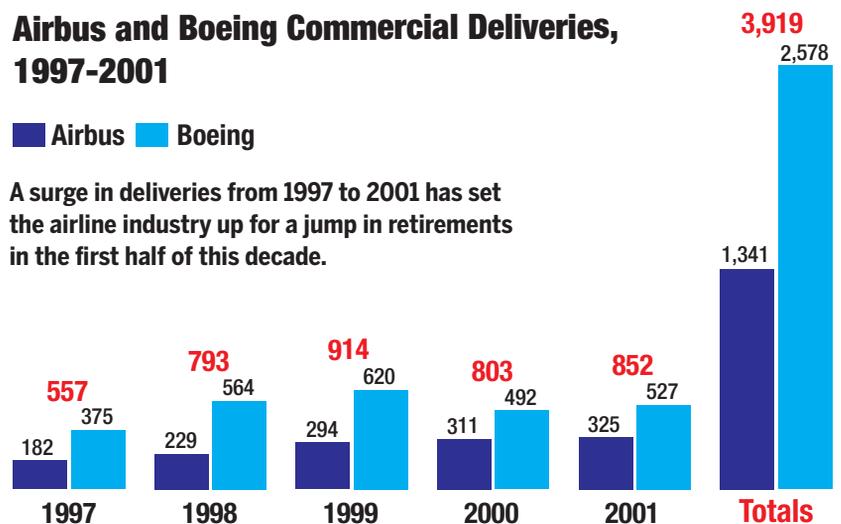
earmarked as replacements for older, less efficient narrowbodies.

Operators have responded by extending leases and, in limited cases, spending money on aircraft they had planned to retire. Airbus continues to experience delays on its A321neo production line, forcing operators such as JetBlue Airways to reshuffle short-term fleet plans. Nagging issues with Rolls-Royce Trent 1000s have left some Boeing 787 operators with-

Airbus and Boeing Commercial Deliveries, 1997-2001

■ Airbus ■ Boeing

A surge in deliveries from 1997 to 2001 has set the airline industry up for a jump in retirements in the first half of this decade.



Sources: Boeing and Airbus



Aircraft retirements are projected to climb in the next several years, and some figures suggest the trend started in 2019.

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out their full allotment of widebodies, giving added life to some older models—such as Virgin Atlantic’s Airbus A340-600s—tapped for replacement.

These issues have combined to keep some aircraft around longer than airlines had planned. But for the most part, operators are sticking by their big-picture fleet strategies. For instance, American Airlines parked its last 26 MD-80s last fall, even as its 24 MAXs sat in limbo. Extending the MD-80’s service life with engine overhauls and other maintenance was deemed too costly, and pilots were needed for other aircraft.

Allowing useful lives to drive retirement dates and assuming operators can get about 25 years out of an average airframe, simple math shows that the industry is due for an increase in removals. An early-1990s delivery rush saw Airbus, Boeing and McDonnell-Douglas (which merged with Boeing in 1997) deliver 2,045 aircraft, almost 682 per year, in 1991-93. Demand then fell off, as did deliveries, totaling 1,224, or 408 per year, in 1994-96.

But airline fortunes changed again, and combined annual deliveries from the two dominant manufacturers jumped during the next five years, averaging 783 per year through 2001

(see graph). That delivery spike means the balance of the 4,000 Airbus and Boeing airframes that entered service then will be due to leave the fleet through 2026.

Meanwhile, 737 MAX operators hope to reintroduce their grounded narrowbodies sometime in 2020, assuming regulators sign off on mandatory changes stemming from probes into two fatal accidents. Although the MAX’s return to service (RTS) could expedite a few retirements, the consensus is that airlines will continue to stick to their fleet plans and make adjustments in their networks.

“As a result, we believe the MAX impact on airline capacity will be a factor for several years, and even with [an] RTS in mid-2020, we do not see a surge in retirements or sudden removal of existing narrowbody aircraft unless there is a marked drop in demand for lift from the airlines,” Canaccord Genuity analyst Ken Herbert says.

While the retirement uptick is business as usual for fleet planners, it has significant ramifications for the aftermarket. Older aircraft leaving the fleet reduce operators’ maintenance needs but also provide used serviceable material (USM) feedstock, which helps operators—and maintenance provid-

ers—lower maintenance costs.

Market dynamics have created shortages on several popular platforms, particularly among narrowbody aircraft. The MAX grounding has kept some comparable older-generation models in service, leading to a scarcity of used parts for CFM International’s venerable CFM56 model and the IAE V2500 at a time when they are needed most. Even before the MAX-induced demand pressures, annual shop visits for both models were on the rise. They are not expected to peak until sometime in the middle of this decade.

The situation has driven up prices for used engines and forced suppliers to change their sourcing strategies. GE Aviation, which consumes more USM than any other company, has been eyeing younger assets to ensure it has adequate supply to feed its network of overhaul shops.

“We are doing a lot more legwork up front, looking further forward [to gain an] understanding of retirement schedules before engines ever come into the market,” says Rudy Bryce, GE Aviation’s general manager of material and TrueChoice transition. “We’re looking to structure deals that would provide an exit strategy with a very flexible timeline. That’s one of the things that all of us are looking for in the market—to go further back in time with the objective of acquiring the material at the right price.”

Demand for narrowbody lift combined with the MAX’s grounding have further pressured CFM56 parts supply in particular. Overhaul demand continues to rise, suggesting that a steady stream of USM will be consumed. But the release of some 800 grounded MAXs into the fleet over a year or two could help jump-start the flow of serviceable parts.

The spike in capacity from the MAX will exacerbate the natural retirement cycle that is getting ready to boom. Assuming a CFM56 needs a shop visit every eight years or so, the 24-year mark becomes a de facto retirement date for many of the engines, as a third full overhaul is deemed too expensive.

Deliveries of 737NGs started in 1997 and averaged about 230 per year from 1998 to 2002. Deliveries of Airbus A320ceos proceeded at a similar clip. Starting in 2022, the aircraft and engines still in service from that period will begin to hit their prime retirement windows. 🌐

Collins Aerospace Nears Completion of Drone Data Link Project

- > COLLINS PLANS FIRST COMMERCIAL C2 RADIO
- > CONTROL LINK WORKS WITH VARIOUS DRONES

Bill Carey Washington

Collins Aerospace is nearing completion of a nine-year project with NASA to develop a command-and-control (C2) data link waveform that has informed the C2 certification basis for unmanned aircraft to safely fly in controlled airspace.

Over seven generations and flight-test campaigns since 2011, the avionics manufacturer and NASA have developed the command nonpayload communications (CNPC) data-transmission waveform supporting DO-362, the RTCA specification for unmanned aircraft C2 data link minimum operational performance standards (MOPS).

Published in September 2016, DO-362 is specified by the FAA in Technical Standard Order (TSO)-C213, which provides guidance for manufacturers applying to the agency for TSO authorization, or design approval, to build CNPC radios operating in the C band (5040-5050 MHz).

Since release of the TSO in 2018, the FAA has sought revisions to the underlying requirements to address concerns over radio frequency (RF) interference and spectral efficiency. RTCA's Special Committee-228 for unmanned aircraft systems (UAS) is working on updated DO-362A MOPS, which it expects to complete in June. The revised standard likely will be referenced in a new TSO-C213A.

Once the TSO is updated—and upon release by the Federal Communications Commission (FCC) of spectrum management rules for UAS—Collins Aerospace is positioned to be the first manufacturer to build a commercial C-band CNPC data link radio for UAS, a product the company has branded the CNPC-5000.

On Nov. 25, the FCC released a public notice seeking comment on issues related to UAS operations in the L band (960-1164 MHz) and the C band from 5030-5091 MHz spectrum that was recommended for allocation for UAS by the World Radiocommunication Conferences in 2007 and 2012. Comments were due Dec. 26.

Collins executives acknowledge that it may be a couple of years before the necessary authorizations become available.

"It's still a little bit dynamic, but I think it's fair to say we're committed to seeing this through and bringing appropriate products to market after we've spent such a good time laying the groundwork for it," says John R. Moore, associate director of autonomy and mission engineering solutions.

What is more certain is that Collins' jointly funded project with NASA to develop the CNPC data link waveform will

end on Sept. 30. The sixth and seventh generations of the waveform have provided validation data to support development of the DO-362A MOPS.

The project originally started as a three-year effort, then was extended twice, to total nine years, says Moore. The first three generations of the waveform were analyzed by an earlier RTCA standards committee, SC-203, "which was not headed to a MOPS or a TSO," says Moore. "It was just a sandbox learning exercise of the art of the possible."

RTCA disbanded SC-203 in 2013 and replaced it with SC-228, which is more narrowly focused on developing performance standards for C2 and detect-and-avoid systems on large drones transiting through lower altitudes to Class A airspace above 18,000 ft.

Collins built a series of prototype radios to house the waveform, which NASA tested at numerous sites with differing terrain around the U.S. where the agency has RF authorizations.

The NASA Glenn Research Center Lockheed S-3B Viking twin-engine jet has served as the workhorse of flight-testing



Prototype CNPC-1000 (left) and CNPC-5000 data link radios.

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campaigns, complemented by a single-engine Beechcraft T-34C turboprop and Collins-supplied Beechcraft A36 Bonanza single-engine piston aircraft operated by the University of Iowa.

Collins started building the radio hardware that it now calls the CNPC family during development of the fourth generation of the waveform, Moore says. Jim Williams, then the first director of the FAA's UAS Integration Office, asked the company to build a DO-362-compliant, small form factor radio that he could demonstrate on a 44-lb. Insitu ScanEagle.

In 2014, the parties tested the ScanEagle fitted with a CNPC-1000 radio operating in the L band at Naval Support Facility Dahlgren, Virginia.

Collins initially focused on testing the C2 waveform within the L band, which the NASA project also authorized with the C band. The waveform can be adapted across frequency bands; it uses time-division multiple access as the method to transmit data over an RF channel on uplink and frequency-division multiple access on downlink.

Three years into the waveform development effort, the Defense Department raised concerns over the data link interfering with military TACAN (tactical air navigation) and civilian DME (distance-measuring equipment) radio navigation systems, which both operate in the L band.

The project then shifted to emphasize the C band spectrum that was originally allocated for the never-fielded Microwave Landing System. Adapting the waveform to operate in the C band was a more difficult problem, says Moore.

“CNPC requires many closely spaced, narrowband channels. We’re trying to build tiny channels and pack them really close together at higher frequencies, so it is a technically harder job to do,” he explains.

“When the L-band allocation was restricted to us, it would have been easier to move to a lower frequency, but there was no appropriate safety spectrum available that was identified for the purpose,” says Moore. “So for the past three years, the focus has been exclusively on C band to solve the technical challenges in these higher frequencies.”

Collins was able to use L-band prototype radios operating close to the upper UHF frequencies dedicated to the rail industry to provide freight carrier BNSF Railway with a C2 data link to fly the 110-lb. Latitude Hybrid Quadrotor-60 for rail inspections (*AW&ST* Oct. 14-27, 2019, p. 56). The FAA chose BNSF as a “Pathfinder” partner in 2015 to demonstrate drone operations beyond visual line of sight (BVLOS) of the pilot.

“When that [L-band] safety spectrum wasn’t going to become available in the near term, we were able to use the same radios. They were able to reach the UHF frequencies with little modification,” says Kevin McElroy, Collins Aerospace associate director of marketing and strategy for mission and advanced solutions.

“We are able to use those early prototypes, running the waveform, and [to operate] it over a ground network of towers. We’ve been doing 200-nm BVLOS flights since 2016 in New Mexico with BNSF,” McElroy adds.

As demonstrated on the ScanEagle, the C2 radio can be adapted to small drones—the CNPC-1000 operating in the L band weighs 203 grams (7.2 oz.), about the weight of an iPhone, says Moore. The bigger issue is how much power a small UAS has available to operate the data link. The CNPC-1000 consumes 8 watts of power to transmit at 1 watt.

“The key thing I would like to point out is in all of these configurations we share a common modem card and a common waveform that was the vision all along,” says Moore.

“You have to have slightly different packaging for the power levels, and you have to have a different radio frequency card that has all those adjustments for which spectrum you’re broadcasting in,” explains Moore. “But we’re able to isolate those changes just to that RF card, so that the core of the radio—the waveform and the modem, the heavy processing—is actually common across all of these.”

Plans call for fitting the General Atomics MQ-9B SkyGuardian with a prototype CNPC-5000 radio to demonstrate flights of a large drone in controlled airspace under NASA’s UAS in the National Airspace System Project. With a maximum takeoff weight of 12,500 lb., the SkyGuardian will be the largest among unmanned aircraft of various sizes flown during the Systems Integration and Operationalization testing this summer. 📍

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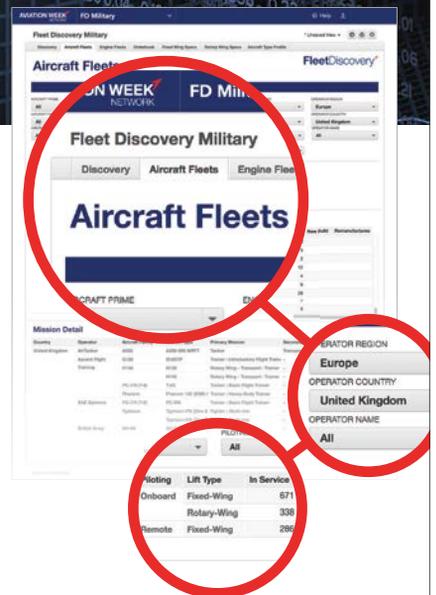
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First Step to Year-Round Endurance



- > PHASA-35 FLOWN MANUALLY AND AUTONOMOUSLY AT WOOMERA
- > CARRIED REPRESENTATIVE ELECTRO-OPTICAL CAMERA PAYLOAD

Tony Osborne London

BAE SYSTEMS

BAE Systems and Prismatic are targeting stratospheric test flights for later this year after the first flight success with their PHASA-35 high-altitude pseudo-satellite (HAPS).

That first hop, on Feb. 10 at the Woomera Test Range, Australia, marks the first major milestone for the Prismatic-developed solar-powered aircraft since BAE's takeover of the Farnborough, England-based company last fall. It is also another sign of progress for the fledgling HAPS industry, particularly after two weather-related accidents involving the pioneering Airbus Zephyr during trials in Western Australia.

No details have been released about flight endurance, altitude and performance on the initial trip, but the flight was used to validate predicted data as well as the flight control system, aerodynamic and propulsion system performance, says Greig Doherty, BAE's chief engineer for solar-powered high-endurance, long-endurance programs.

"With that flight under our belts . . . we have now got the ability to go for a second higher-altitude, longer-endurance flight we are trying to do later on this year," he says. Doherty says the data collected was "scalable" and could now be extrapolated "to either long-duration operations or high-altitude operations."

A dawn launch allowed the aircraft to get airborne in gentle wind conditions, with clearance for the flight to proceed after "careful meteorological planning," says Doherty. The team launched weather balloons and radiosondes that were used to gather tactical weather data prior to the flight.

Once in the air, PHASA-35 (Persistent High-Altitude Solar Aircraft) operated under full autonomous control, including a precise landing in the face of "significant side winds," according to details released by Prismatic. Pilots also undertook manual control from the ground control station.

The flight was sponsored by the UK's Defense Science and Technology Laboratory and the Australian Defense Science and Technology Group and flown under Australian military airworthiness requirements.

Prismatic and BAE Systems built two prototype PHASA-35 aircraft over 20 months during 2018-19, but some of the risk associated with flying was reduced through the use of a quarter-scale model, PHASE-8, a 28.7-ft. wingspan Reynolds number demonstrator that could recreate aerodynamic characteristics of PHASA-35 operating at high altitude, but while operating considerably lower. Two of the PHASE-8 platforms have also been supplied to the U.S. military.

Like the Zephyr and other HAPS platforms, PHASA-35 has been designed to operate in the benign conditions of the stratosphere at altitudes of up to 60,000 ft. for up to a year at a time, soaring on its 35-m (114-ft.) wingspan while carrying a payload of up to 20 kg (44 lb.).

PHASA-35 uses solar cells that cover the upper surface of the wing and the horizontal stabilizer to provide power to the electric motors and on-board systems and sensors. The solar panels also regenerate the lithium-ion battery cells to provide power at night.

The long cycle life associated with lithium-ion paves the way for the

A dawn launch allowed the BAE/Prismatic team to take advantage of benign wind conditions. The aircraft was recovered safely later in the day, despite strong crosswinds.

yearlong endurance Prismatic has promised for the platform (*AW&ST* July 16-29, 2018, p. 31).

PHASA-35 carried a representative payload, an electro-optical camera, and systems to manage it thermally and electrically. Doherty also notes that the ecosystem of the aircraft allows for payload and control data to use separate communications systems. "The payload can be controlled and monitored directly by a particular nation or operator. . . . That means that any security considerations around data can be segregated away from the vehicle itself," he says.

BAE got involved with Prismatic in May 2018 through a collaboration agreement and announced it would purchase the company last September.

Drew Steel, the marketing lead for the PHASA-35 platform, says the development of PHASA-35 has piqued customer interest, potentially as a component of a layered intelligence, surveillance and reconnaissance capability.

BAE's involvement has brought experience in flight control laws, controllability, data packaging and sensor management, notes Steel, lessons learned from more than a decade developing UAV capabilities that ultimately resulted in the Taranis unmanned combat air vehicle. With "fair winds," Steel suggests, BAE and Prismatic believe they could offer a customer an initial HAPS capability within 12 months of the completion of the flight-test program. ☉

Defense Industry Wants To Maintain Momentum for European FCAS

- > PHASE 1B, TO BEGIN IN 2022, WILL INDUCT SPANISH INDUSTRY
- > AIR CHIEFS PLAN TO SIGN FCAS CONVERGENCE AGREEMENT AT BERLIN ILA AIR SHOW IN MAY

Tony Osborne Toulouse

German parliamentary approvals to fund the demonstrators for the European Future Combat Air System (FCAS) have been hailed as a major milestone, yet there appear to be plenty more dramas to come.

Industry had been increasingly impatient over Berlin's political fumbling of support for the initial Phase 1A demonstration, worth €155 million (\$170 million), funded equally by Paris and Berlin. Contracts had been expected at last year's Paris Air Show; even a January deadline agreed between French and German leaders came and went.

That deadline followed warnings from industry. And at the end of January, the air chiefs of the French, German and Spanish air forces wrote jointly in the French newspaper *Le Figaro*, stressing the importance of the project and warning that it must progress or risk losing momentum. The partner countries want to bring FCAS into front-line use in 2040.

"All this while we must intensify our multinational collaboration efforts, in order to encourage the development of a common strategic vision, contributing directly to the defense of Europe," the air chiefs wrote.

The nod from the Bundestag emerged just hours prior to the release of Airbus' 2019 results on Feb. 13. The funding pays for the first 18 months of work—Phase 1A—to develop the demonstrators and mature new technologies by prime contractors Dassault and Airbus as well as their partners, MTU Aero Engines, MBDA, Safran and Thales.

There will be four strands to the demonstration program, the most significant being the flight-testing of the fighter aircraft technology demonstrator representative of the Next-Generation Fighter (NGF) design, with Dassault acting as prime and Airbus as a main partner.

The program will also work on technology for the remote carriers, the reusable unmanned aircraft systems that will operate alongside the fighter as a loyal wingman or to provide electronic warfare or surveillance capability. Airbus will be the lead on development of the remote carriers, with MBDA as a main partner.

Airbus, with Thales, will work on development of the combat cloud network that will connect the NGF with other platforms, including the remote carriers as well as other fighters, tankers and intelligence-gathering assets, likely using advanced within- and beyond-line-of-sight communication methods.

Meanwhile, the fighter demonstrator will use an engine featuring technologies planned for the future NGF powerplant. Work on this demonstrator engine—likely based on the Safran M88 from the Dassault Rafale—will be led by Safran, with MTU as main partner.

Airbus says a simulation environment will be jointly developed by the company as well, to "ensure consistency between demonstrators."

Phase 1B is where the challenges could begin to mount, as it requires considerably more investment than 1A, likely well in excess of €1 billion (\$1.1 billion), begging the question: If German politics can hobble progress over investments worth less than €100 million, what would the delays be if the investments required are 3-4 times as much?

Phase 1B also will involve induction of Spanish industry into the demonstrator program, including Madrid's chosen industry lead, Indra, whose role has been protested by Airbus since the decision was announced last September.

"We think it's a mistake to select Indra as the Spanish coordinator for the FCAS," says Airbus CEO Guillaume Faury, adding that the company lobbied for the decision to be

reviewed. He contends Indra lacks experience in the development of combat aircraft and the systems that will support the FCAS.

Airbus had been widely expected to lead the program in Spain, given its experience building the A400M in Seville and performing local assembly of the Eurofighter. "This is something we have shared with the Spanish government, and we have offered our hands to reverse the situation and make sure the best support is given from Spain to the FCAS and that Spain is getting the best from the FCAS," Faury adds.

Spain does not seem to be listening. On Feb. 18, Madrid announced Spanish industry partners that will begin working on the program in support of joint concept studies with France and Germany, perhaps as early as May. According to the Spanish defense ministry, Airbus' Spanish business will support development of the fighter and low-observable technologies. ITP Aero will support the engine development, with work on sensors and systems to be performed by Indra. A partnership of three companies—GMV, Sener Aeroespacial and Tecnotbit-Grupo Oesia—will work on the remote carriers.

"This industrial alliance has already been notified to Germany and France . . . so that negotiations can begin to meet the planned objectives and achieve the full integration of Spain into the NGWS [Next-Generation Weapons System] project before the summer of this year," Spanish defense officials say.

Industry is looking for a smooth transition from Phase 1A to 1B in order to meet a target of flying a fighter demonstrator in 2026.

"We shouldn't underestimate the huge progress which has been made for a program of that magnitude and complexity," Faury tells Aviation Week. "I am positive and optimistic [based] on the work which has been done over the last two years. We will play the role we think we have to play at each and every milestone of the program."

Phase 1B is expected to get underway in 2022. Prior to that, the three air chiefs have agreed to try to bring greater convergence between their operational needs and are hoping to sign a document "specifying this common vision" at the ILA Air Show in Berlin in May. 🇪🇺



DAN HAWKINS/U.S. AIR FORCE

New Technologies Enable Students To Achieve More per Flight Hour

- > THIRD ITERATION OF USAF PILOT TRAINING NEXT IS UNDERWAY
- > U.S. AIR FORCE, AIR NATIONAL GUARD, NAVY AND MARINE CORPS AND ROYAL AIR FORCE PILOTS ARE ENROLLED

Tony Osborne Los Angeles and London

An experimental U.S. Air Force pilot training scheme is looking beyond conventional flight simulators and classroom academics in a bid to produce better pilots.

Air Education and Training Command's Pilot Training Next (PTN) program, now in its third iteration, has the potential to transform military flight training. While it is primarily aimed at producing a better pilot, more readily equipped for new-generation aircraft, it could also be used to train them more cheaply and quickly than ever.

Two phases of PTN have already successfully delivered pilot graduates to training units for fighters, bombers and air mobility aircraft, and what was a largely Air Force-driven program has now widened to include pilots from the Air National Guard, Navy, Marine Corps and UK Royal Air Force (RAF).

At its heart are major changes to

the scripting of pilot academics and the introduction of new synthetic training technology, explains Lt. Col. Ryan Riley, commander of Detachment 24, the PTN experimental training unit at Joint Base San Antonio-Randolph in Texas.

"Most military training, whether it is at a technical school for aircraft maintenance, firefighting or becoming a pilot . . . does not [provide] access to much of the academic content; it is doled out through a script or timeline," Riley says.

But PTN provides the students with early access to training content prior to the beginning of a course, allowing them to learn at their own pace with a learning management system that prepares them for tests.

"We produce over 1,000 pilots every year in the U.S. Air Force, and regardless of their background—if you have

PTN-trained pilots are using off-the-shelf gaming computers with virtual reality headsets that can be purchased at a fraction of the cost of full-flight simulators.

1,000 flight hours or zero time—you get the same experience," says Riley.

"Through PTN, the student-centered learning is focusing on not only how you learn as a student but also what your background is, what your capabilities are, and then harnessing that," he adds. "The whole point of this is to figure out the learning style of each individual and tailor it to their need."

Supporting the new approach is the use of so-called immersive training devices (ITD), essentially high-specification but commercially available gaming computers equipped with high-definition virtual reality (VR) goggles.

The PTN students have access to 30 of the devices and can use them throughout the course, unlike with the high-fidelity and costly simulators normally associated with military training.

"The high-fidelity full-flight simulators provide high-quality training, but they are also high-demand, low-density," says Riley. "With the ITDs, you are providing high-demand, high-density, and so now, at any point if a student is struggling with a concept, they can jump into an ITD."

Using the ITDs, the trainees can practice maneuvers and procedures many times before they step into real aircraft.

"The students will never do something for the first time in flight; they are going to fly multiple iterations before they are actually flying in the plane," says Lt. Col. Robert Knapp, Detachment 24's operations officer.

The students get the same amount of flight time, he notes. "We are just redistributing the focus of the learning," he adds.

"The students are better prepared and get a lot more out of every flight hour. . . . [It is] much more valuable than the traditional system," Riley says.

The PTN courses have the students

fly around 80 hr. in the Beechcraft T-6 Texan II. Some 15 officer students and five enlisted students, along with 13 instructors, took part in the first PTN training course that ran from February to August 2018. Of the 20 students, two washed out, and one destined for F-16 training opted to come back for some T-38 training before going back to the F-16. The second course, in January-August 2019, featured students and instructors from the U.S. Air Force, Air National Guard, Navy and RAF, while the 2020 iteration brings in the first Marine Corps student.

The U.S. Army, also inspired by PTN, revealed plans last year to introduce VR simulators at its training facility at Fort Rucker, Alabama.

In the latest iteration of PTN, the program is using T-6Bs loaned from the U.S. Navy with advanced cockpits that PTN modified with an avionics system designed specifically for the curriculum.

“In the initial stages, the systems were exploratory and very buggy,”

“The students will never do something for the first time in flight;

they are going to fly multiple iterations before they are actually flying in the plane.”

Riley says. “The flight model didn’t fly like the real airplane, and the system would crash if you opened one window too many.”

In the latest version, many of the software bugs have been ironed out, flight models have been improved, and moves are underway to increase the level of data analytics.

Agreements with the Air Force Research Laboratory and NASA are paving the way for the use of algorithms to monitor student biometrics, potentially allowing instructors to understand when the students

have become task-saturated.

“PTN will continue for a few more iterations,” says Riley. But he notes that as PTN-developed technologies are subsumed into the wider training system, the program will continue to look at other new technologies to enhance the training system. “The technologies could apply to any skill set that is complex to learn,” he says.

“With the students under the VR headset, they can do an entire walk around an airplane in life-size and scale; if they want to see the electrical system, you can remove the outside skin of the aircraft,” he explains.

Riley says he is encouraged by industry’s interest in the PTN program, with some big vendors now working on developing “ITDs of their own,” he notes. “I know what we’re doing is the right way . . . but it is probably going to be something totally different five years from today,” he adds.

The third phase of PTN began in January and is expected to run until July-August of 2020. 📍



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Bell Achieves Electric Anti-Torque Flight First

- > EDAT DEMONSTRATOR IS MODIFIED BELL 429 LIGHT TWIN
- > GENERATOR AND MOTORS SUPPLIED BY SAFRAN

Tony Osborne London

Bell has been quietly flight-testing an electric anti-torque system in a technology demonstration that could be a building block for its work on electric vertical-takeoff-and-landing (eVTOL) mobility systems.

The company's Electrically Distributed Anti-Torque (EDAT) testbed is a highly modified Model 429 twin-engine light helicopter that uses four fixed-pitch electrically driven fans mounted in the vertical stabilizer, replacing the conventional tail rotor.

erating costs. But in the last few years, noise has become an ever-increasing concern, and that has put pressure on our engineering team," says Sinusas.

Most helicopter noise is caused by the interaction between the main rotor and the tail rotor, so using ducted anti-torque systems can reduce the noise levels.

Such ducted systems are not new; after all, Airbus' fenestron dates back to the 1960s. But the use of an electric system means that when the helicop-

ically actuated anti-torque controls, the pedals now provide commands to a fly-by-wire system that controls the output of the four fans. The air-cooled fan motors are powered by a liquid-cooled generator running off the aircraft's two Pratt & Whitney Canada PW207 turbines. Wires connecting the generator with the motors run down the tail boom, where the tail rotor shaft once sat.

The motors and generators are provided by Safran, which has also worked on the company's Nexus eVTOL platform.

The fixed-pitch, variable-speed fans are capable of operating in both forward and reverse directions, depending on the pilot's pedal inputs.

Having four fans also boosts redundancy. Although not yet tested in flight, ground tests have indicated that the pilots would still have some level of anti-torque performance even if three of the four fans were inoperable. Tail rotor failure on a conventional helicopter can be dangerous, if not catastrophic.

Another factor is responsiveness, says Sinusas. "A single large fan or two medium fans are going to experience rotational inertia, so it is going to be less responsive," he notes, prompting engineers to adopt the quad configuration.

Prior to flight-testing, the company established a systems integration laboratory to test EDAT before installation, but the team has found it easy to make adjustments to the system once installed on the aircraft.

"We have already had several optimizations and changes, just based on feedback from pilots, and it is much quicker to do than with a mechanical system," says Sinusas.

Several OEMs have studied the potential of electric anti-torque systems. Leonardo Helicopters tested a modified AW139 tail rotor as part of a research program funded through the European Union Clean Sky 1 initiative, and an electric fan-based anti-torque system featured in Bell's FC-X concept rotorcraft was unveiled in 2017 (*AW&ST* March 26-April 8, 2018, p. 29).

The next steps will see flight-envelope expansion of the EDAT as well as further optimization, particularly in terms of weight.

"We do see it as a steppingstone to the fully electric aircraft," says Sinusas. "We feel like it should make the certification paths for these technologies easier." 

A fly-by-wire system controls the anti-torque system, fed by input from the pilot's pedals.



BELL HELICOPTER

Although the rotorcraft industry has been exploring the potential of electric anti-torque systems, Bell's EDAT is the first to make it to flight, with testing beginning in full public gaze—but seemingly unnoticed—last May.

The EDAT only came to light when a video appeared on social media of the testbed hovering near Bell's Mirabel, Quebec, facility, showing the distinctive quad-fan configuration.

The largely self-funded research, which also received financial support in the form of grants provided by the Ottawa government in 2018, is primarily in response to customer calls for greater safety and reduced noise levels, says Eric Sinusas, EDAT program manager and program director for light aircraft.

"Customers have been asking us to do more about safety and the direct op-

ter is not requiring the maximum anti-torque thrust, the rotational speed of the fans can be reduced, lowering tip speeds and noise levels. The company would not reveal specific noise levels with the EDAT, but recorded data "shows that it is significantly quieter than a conventional 429," Sinusas says.

In terms of safety, conventional tail rotors have always been a hazard, particularly while the aircraft is on the ground with engines running. The EDAT's anti-torque system, however, can be shut down while the main rotor is still turning. And there may be operating-cost benefits as well: Eliminating complex tail rotor gearboxes and shafts removes the need for inspecting and maintaining them.

But fitment of the EDAT has required significant modifications from nose to tail. Rather than mechani-

Powering Up

- > BLUE ORIGIN OPENS ALABAMA ENGINE FACTORY
- > SATURN V TEST STAND BEING REFURBISHED
- > ULA TO RECEIVE TWO BE-4s IN MAY

Irene Klotz Huntsville, Alabama

Blue Origin founder Jeff Bezos likes to talk about a future where millions of people are living and working in space. But in present day terms, that comes down to big-ticket construction projects, building and testing rockets and executing a solid business plan that charts a path to profitability.

To that end, Kent, Washington-based Blue Origin unveiled its latest asset: a 350,000-ft.² (32,500-m²) factory and office complex in Huntsville, Alabama. The facility is close to NASA's Marshall Space Flight Center—where Blue will conduct engine testing—and to United Launch Alliance

not only Blue Origin—its rocket engine supplier—but also SpaceX and Northrop Grumman.

Whatever the outcome, Blue Origin is confident its \$200 million-plus investment in the new rocket factory is warranted. "As we've said since the beginning of New Glenn, our business case closes with commercial customers," CEO Bob Smith tells Aviation Week. "While we are dedicated to being a national security space provider, and we're going to do everything . . . to be part of that, it's not going to change what we do in terms of our development of New Glenn."

With BE-4 engines part of two Air Force launch service proposals, Smith adds: "We are highly confident we are going to be one of the national security providers for these engines."

New Glenn will fly with seven BE-4s, providing 3.85 million lb. of thrust at liftoff. Blue plans to recover and reflly New Glenn's first stage and is designing the BE-4 for 25 reflights with minimal refurbishment between launches.

Development of the BE-4 began quietly in 2011. Originally intended solely for Blue Origin's New Glenn rocket program, ULA joined the effort in 2014 as it looked to replace the Russian-made RD-180 engines on its workhorse Atlas V rockets—a response to trade sanctions following Russia's

invasion of Ukraine's Crimean Peninsula. Unlike previous large engines, the BE-4 uses liquefied natural gas as fuel rather than kerosene, to cut costs and improve reusability. Using an oxygen-rich staged combustion cycle, the BE-4 is capable of producing 550,000 lb. of thrust with deep throttle capability for landings.

Speaking to reporters after a ribbon-cutting ceremony to mark the factory's opening, Blue Origin officials said they expect to complete BE-4 development work in Kent in the next 3-4 months then move into engine prequalification over the summer. The first of three final development engines is about to begin testing.

By the time prequalification begins, the overall design of the engine will be complete, and work will move on to fine-tune valves, set spring loads and make other adjustments. Particular attention will be paid to bearings and materials in high-temperature areas to ensure the engines will be able to meet reusability requirements.

A pair of what Blue calls "flight readiness" engines, produced in Kent, are due to be delivered to ULA in May for integration tests with the Vulcan rocket. Production engines will arrive later in the year. The Huntsville factory meanwhile will focus on producing a "site certification" engine this summer.

Blue Origin still has several large construction projects on its plate as well. The company is refurbishing the Marshall Space Flight Center's historic 4670 Saturn V test stand so it can be used for static test firings of the BE-4 and BE-3U. The company also is building a launch site at Cape Canaveral AFS in Florida to prepare for New Glenn's inaugural flight in 2021. 🚀

Blue Origin is building an engine test site for BE-4 and BE-3U engines at Marshall Space Flight Center to supplement its current site in West Texas (pictured).



BLUE ORIGIN

(ULA), which is buying Blue's BE-4 engines for its new Vulcan rocket. Blue Origin also will outfit its own New Glenn rockets with BE-4 engines.

The factory, which opened on Feb. 17, stands empty for now, but over the next several weeks equipment for production and assembly of the BE-4 and BE-3U engines—which will be used to power New Glenn's upper stage—is due to arrive. By 2022-23, Blue Origin plans to be manufacturing 42 engines per year at Huntsville—half BE-4s and half BE-3Us.

Most of the BE-4 production in Huntsville will be for ULA's Vulcan, which is not initially designed to be reusable. Vulcan uses two BE-4s to power its first stage.

ULA's business case rests heavily on winning one of two pending U.S. Air Force contracts to launch national security spacecraft. The competition pits ULA, which currently handles the bulk of the military's launch business, against

With Successful Launch, OneWeb Network Grows To 40

- > NEXT LAUNCH SCHEDULED FOR MID-MARCH
- > RIVAL SPACEX STILL WORKING ON SPECTRUM RIGHTS BEYOND U.S.

Irene Klotz Washington

With 300 Starlink satellites in orbit, it may appear that SpaceX is well ahead of the competition in a quest to build high-speed, low-latency global internet networks, but to OneWeb founder Greg Wyler it all comes down to spectrum.

“The number of satellites isn’t important. It’s all about spectrum rights,” Wyler says. “How many cell phone companies go and build towers before they actually have the right to use them? You must have the frequencies first; otherwise, how do you design and develop the systems?”

On that front, OneWeb is in the pole position, with clearance from the U.S. Federal Communications Commission and the International Telecommunication Union (which allocates global radio spectrum and satellite orbits) to operate in K_a (20-30 GHz) and K_u (11-14 GHz) frequency bands to provide global internet connectivity.

The company has completed or is in the process of building half of its planned 42 ground stations worldwide and is working to secure landing rights to bring data down on a country-by-county basis. OneWeb also now has 40 spacecraft in orbit and another 34 satellites headed to the Baikonur Cosmodrome in Kazakhstan for launch in mid-March.

With monthly launches slated aboard Russian Soyuz rockets flying from Baikonur, Russia’s Vostochny Cosmodrome and Arianespace’s Kourou, French Guiana, launch sites, OneWeb plans to begin customer demonstrations by the end of 2020, followed by full commercial service for maritime, aviation, government and industry users worldwide in 2021.

Last March, Arianespace and OneWeb added flights for the qualification launch of the Ariane 6 booster, targeted to fly at the end of 2020, and two additional Ariane 6 rockets—either in the 62 version, which can accommodate 36 satellites, or the 64 version, which can handle 78 spacecraft—starting in 2023. Each OneWeb satellite weighs about 325 lb.

Operating from near-polar orbits approximately 745 mi. (1,200 km) above Earth, OneWeb needs about one-quarter as many satellites as SpaceX’s lower-altitude Starlinks to achieve global coverage, according to Wyler.

On Feb. 7, a Soyuz 2-1b rocket, outfitted with a Fregat upper stage, lifted off from Baikonur at 2:42 a.m. local time to add 34 OneWeb satellites to an initial six spacecraft launched a year ago. OneWeb did not fly prototypes.

The new spacecraft were released, two at a time, in BBQ-roll maneuvers from their payload dispenser starting 71 min. after launch and continuing for more than 2.5 hr.



ONEWEB/ARIANESPACE

A batch of 34 OneWeb satellites inside a Ruag-built dispenser, was lowered on top of a Soyuz Fregat upper stage prior to launch.

OneWeb Satellites, a joint venture of OneWeb and Airbus Defense and Space, built the satellites, the first from a new factory in Florida located near NASA’s Kennedy Space Center.

OneWeb’s Satellite Operations Centers, located in Virginia and London, began contacting the spacecraft as they were released into initial orbits 280 mi. above Earth and began firing their plasma thrusters to maneuver to their operational orbits.

OneWeb and SpaceX are the first of several companies planning to offer high-speed, low-latency internet services via satellite. SpaceX already has delivered 300 Starlink satellites into orbit but does not as yet have authorization to operate beyond the U.S.

In January, SpaceX was added to the Australian Communications and Media Authority’s Foreign Space Objects Determination list, a preliminary step for applying for ground station licenses in Australia to communicate with the Starlink satellites.

SpaceX declined to comment on the status of its requests to operate in countries beyond the U.S. 🌐

Starliner Gives Boeing a Hard Lesson in How Not To Verify Software

> 1 MILLION LINES OF CODE TO BE REVERIFIED

> NASA LAUNCHES SAFETY ASSESSMENT OF BOEING

Irene Klotz Cape Canaveral

Boeing's CST-100 Starliner, a reusable capsule designed to ferry astronauts and fare-paying passengers into low Earth orbit, may look like previous generations of spacecraft, but appearances can be deceiving.

"We are no longer building hardware in which we install a modicum of enabling software," says Patricia Sanders, who chairs the long-standing NASA Aerospace Safety Advisory Panel (ASAP). "We are actually building software systems, which we wrap up in enabling hardware, yet we have not matured to where we are uniformly applying rigorous systems engineering principles to the design of that software."

Case in point: The Starliner, which returned from an abbreviated flight test rife with potential software problems. One error manifested shortly after launch when the capsule missed an orbit insertion burn to reach the International Space Station (ISS) because its timer was set 11 hr. ahead of the actual mission elapsed time.

The problem was compounded by some type of interference—still under investigation—that prevented flight controllers from communicating with the Starliner via NASA's Tracking and Data Relay Satellites. By the time communications were restored, the Starliner had expended so much fuel firing steering thrusters that managers decided to pass on the ISS docking and salvage what they could of the flight demonstration, including a successful deorbit, reentry and parachute landing in New Mexico.

But the Starliner's troubles were more serious than had been suspected. During its Feb. 6 meeting, the safety panel disclosed a second software error that was discovered as Boeing engineers pored over lines of code prior to the Starliner's deorbit on Dec. 22. The error misconfigured a thruster, which could have caused the service module to bump into the crew capsule following separation after the deorbit burn.

If the anomaly had not been cor-

rected, "it would have led to erroneous thruster firing and uncontrolled motion during service module separation from deorbit, with the potential for catastrophic spacecraft failure," says ASAP member Paul Hill, a former NASA flight director.

The independent review team assessing the Starliner's Orbital Flight Test (OFT) is not expected to complete its work until the end of February, but NASA and Boeing said on Feb. 7 that the panel had found multi-



The Starliner was hoisted atop a United Launch Alliance Atlas V in preparation for its orbital flight test.

CORY HUSTON/NASA

ple areas where the software verification process failed.

"The process broke down in many areas," says NASA's spaceflight chief Douglas Loverro. "We don't know how many software errors we have. We don't know if we have just two or we have many hundred." The fault is not entirely Boeing's, Loverro adds. "Our NASA oversight was insufficient—that's obvious . . . and good learning for us."

NASA also launched an organizational safety assessment into Boeing in an attempt to root out potential systemic issues. The agency last year conducted a similar review of SpaceX, which is developing a second crew

transportation system. SpaceX is on track for a crewed flight test of its Dragon capsule this spring.

"We need as a nation—and we have an obligation—to have multiple providers that can get us access to low Earth orbit," NASA Administrator Jim Bridenstine told reporters on Feb. 7. "That's part of what the Commercial Crew program is all about. We are working very hard to understand what the [Starliner] anomalies are, remedy those and move forward."

NASA and Boeing agree it is too early to say if a second uncrewed Starliner test flight will be required prior to flying astronauts, a mission that had been targeted for this year. Nor would Boeing comment about how long it would take to reverify the Starliner's entire flight software, about 1 million lines of code.

"On the OFT mission, we suc-

cessfully exercised about 66% of the scripts that we have, but we're not taking that at face value," says John Mulholland, Boeing Starliner program manager. "We are going to have our team go back and fully verify the correct implementation of all the software, in partnership with NASA."

For now, NASA is counting on SpaceX to continue the program's momentum—particularly with ISS staffing ramping down as NASA's contract for crew ferry flights aboard Russian Soyuz capsules comes to an end. Currently, the last U.S.-purchased seat is reserved for veteran NASA astronaut Chris Cassidy, who is scheduled to launch in April. ☛

COOPERATIVE BENEFIT

- > SIGNIFICANT PROMISE BUT SUBSTANTIAL CHALLENGES FOR WAKE SURFING
- > AIRCRAFT SYSTEMS, PLANNING TOOLS AND OPERATING PROCEDURES ARE KEY

Graham Warwick Orlando, Florida



ONE IN A SERIES

When Airbus in November announced it would demonstrate energy-saving automated formation flight in 2020 using two A350s, and Boeing subsequently revealed it had flight-tested the concept in 2018 with two 777s, it was a signal that a long-known technique could soon be ready for prime time.

Air-wake surfing for efficiency has a long pedigree of consistent research results that show an aircraft can save fuel by flying within the updraft created by the wingtip vortices shed by another—reclaiming energy left in the atmosphere by the lead aircraft's lift-induced drag.

Since researchers at Germany's Technical University of Braunschweig proved the concept in flight in 1984, achieving a 15% power reduction by manually flying two Dornier Do 28s wingtip behind wingtip, multiple demonstrations with different aircraft types have shown fuel savings from wake surfing ranging from 8-18%.

So why are operators, commercial or military, not already using the technique to improve efficiency? And why is it being looked at now? One reason is the availability of the avionics required to enable automated wake surfing, particularly automatic dependent surveillance-broadcast (ADS-B).

"Why now? ADS-B is now mandatory in the U.S., so we have the avionics to make this possible," says Al Sipe, chief engineer for aviation efficiency at Boeing. "Why are we not doing it?

The fuel savings are not small. We have the capability. But the regulations say don't do it. So the next step is getting the regulations changed."

With the benefits firmly established, Boeing's test in 2018 with its 777F ecoDemonstrator flying behind another FedEx 777F and Airbus' Fello'fly demonstration this year are developing systems and procedures airlines can use to safely and robustly take advantage of wake surfing.

"We have done enough tests to be confident we can do this with commercial aircraft," says Sipe. "We think we will do it first with cargo aircraft, and we are working with Airbus on the regulatory aspects," he told the American Institute of Aeronautics and Astronautics SciTech conference in January.

Attention is shifting to the next steps: developing the safety case and taking it to the regulators to get the rules changed; agreeing on the procedures between aircraft, operators and air traffic control (ATC) that will enable wake surfing; and developing the business case for implementation.

There are two things wake surfing is not. The first is a drag reduction tech-

nique. Instead, to maintain steady, level flight within the updraft from the wake vortex, the aircraft must pitch nose-down so it is descending relative to the upward moving air. The lift vector, normally vertical, is tilted slightly forward. This counters some of the drag, requiring less thrust to maintain horizontal flight. This reduces fuel consumption.

The second is traditional formation flying. Military aircraft fly in close formation, a few wingspans apart. Commercial aircraft would fly in extended formation, up to 1 nm apart, on what the industry prefers to call "cooperative trajectories." This greater distance—10 or more wingspans for commercial aircraft—reduces the fuel-saving benefit but eases the workload on the pilots.

While the physics of wake surfing are on a firm footing, there are many technical and operational questions still to be answered. In a formation, only the trail aircraft sees a fuel saving. "Who gets preference? Is that an airline problem or an ATC problem?" asks Sipe.

Nelson Brown, a test engineer who worked on NASA Armstrong Flight Research Center's Automated Cooperative Trajectories (ACT) flight-test project in 2017, cites the example of existing airline agreements to exchange pilot jump-seat rides and suggests a "benefit today, pay back tomorrow" marketplace could emerge.

There is also the question of how big the fuel savings will be in actual operations. Tests of a prototype automated wake-surfing system conducted by DARPA, the U.S. Air Force Research Laboratory and Boeing in



Earlier Airbus wake-surfing tests with an A350 behind an A380 delivered a 12% fuel saving.

AIRBUS

2012-13 using a pair of C-17 airlifters achieved a 10% fuel saving over more than 90 min. in extended formation.

But 10% is a best case and will not be achieved all of the time. "If we can argue that the trail aircraft in a formation can see an 8% reduction in fuel burn consistently; the pair will save approximately 4% during this phase of

flight," Tristan Flanzer, Boeing flight controls engineer, told the conference.

"The aircraft are not in formation all the time, so accounting for other phases of flight, such as departure and landing, the savings may be reduced to 3%," he says. There is then the matter of what fraction of an airline's fleet will be in a formation at any time. "If half of all flights are paired off, the system level saving is 1.5%. So the real benefit is an order of magnitude lower," says Flanzer.

This is still a significant saving, but wake surfing for efficiency is not just a technical challenge. "There needs to be a clear value proposition for the airlines, a well-defined conops [concept of operations] to understand the technical and operational needs, a provably safe system architecture and a plan to certify the system," he says.

Boeing is proposing a conops with four distinct phases: premission, departure and single flight, cooperative trajectory operations, and split and post-flight. It assumes: aircraft are equipped with upgraded autopilot and autothrottle, ADS-B "In" and flight deck alerting updates; pilots have been trained in manual recovery from wake-induced upsets; and operations

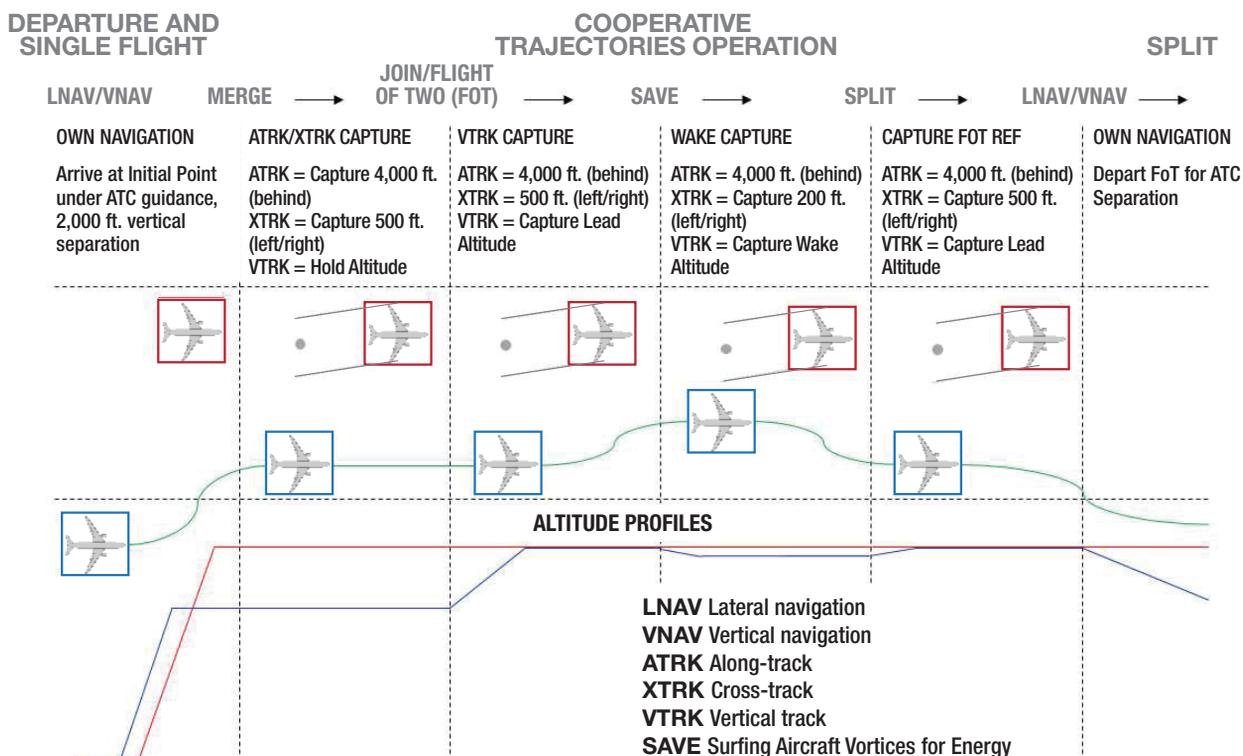
have been approved. Unless they are ex-military, commercial pilots will not have experienced flying in extended formation, so training is important.

The premission phase begins months in advance, with strategic planning to adjust flight schedules and maximize the opportunities for cooperative flying. Once aircraft pairs and schedule times have been identified, detailed flight plans are produced for each aircraft. Prior to departure of the first aircraft, the crews of both will conduct a preflight briefing of lead/trail responsibilities and rendezvous information. Both crews will monitor the continued viability of cooperative operations up to departure.

The aircraft may be leaving from different airports, at different times, so their departures must be closely coordinated. "Any delay is most efficiently absorbed while the second aircraft is still on the ground," says Flanzer.

Current winds aloft strongly influence achievable formation benefits, and airlines will have to be flexible on departure times to get a wind-optimal routing for a formation that avoids incurring a large detour that costs fuel, Tobias Mark, a researcher at German aero-

Concept of Operations for Cooperative Trajectories



Source: Boeing

space center DLR, told the conference.

Once both aircraft are airborne, their onboard flight-management systems or ground-based interval management is used to adjust speed and coordinate arrival at the rendezvous point under ATC-assured separation with 2,000 ft. vertical spacing between the aircraft.

The cooperative trajectory operations phase has four subphases. The first is merge, the transition from ATC-assured horizontal separation of 5-50 nm to station-keeping managed by the crew of the trail aircraft. Using data transmitted by the lead aircraft, the trail aircraft stabilizes approximately 1 nm behind it and 500 ft. to the left or right of the predicted position of the lead aircraft's wake vortices.

The two aircraft then join, the crews informing ATC they have assumed responsibility for separation and the lead aircraft taking leadership of the flight. ATC then deals with the pair as a flight of two operating within a 2,000-ft. block of altitude.

Now in stabilized formation, the trail pilot engages cooperative-trajectory mode to begin wake capture and tracking. Lead-aircraft data and own-ship information is used to predict wake position. With autopilot and autothrottle engaged, the wake capture function moves the trail aircraft into the ideal position—about 200 ft. from the vortex—based on ride quality and fuel saving.

The C-17 flights and NASA's ACT tests involving a pair of Gulfstream GIIIs reported only "light chop" when surfing the wake, but it is a trade between ride quality and fuel saving. The crew can "turn the knob," Brown says, surfing the wake more closely for fuel saving when passengers are awake, but moving further away at night to improve ride quality while they sleep. There will also be some threshold of atmospheric turbulence beyond which wake surfing is not possible, he says.

Once joined, the trail aircraft flies automatically, a situational-awareness display showing the crew its position relative to both the lead aircraft and its predicted wake. If the lead aircraft needs to change speed, altitude or heading, the intent is transmitted to the trail aircraft, which may have to move away from the wake during the

maneuver. To avoid crossing the wake, a prevention and recovery function can command the trail aircraft away from the wake to avoid upsets and loads.

On reaching a preplanned point on the route, the pair will split, the lead aircraft notifying ATC, which reestablishes standard separation between them. "[Cooperative trajectory] operations will only be conducted during the cruise phases of flight, so ATC-supportable separation must be achieved at the latest by 150-200 nm from destination," says Flanzer.

The takeaways from this conops, he says, include the need for tools for both strategic and detail mission planning, the importance of ADS-B and of leveraging existing interval management

for the actual wake-surfing phase, he says, adding: "For other aspects of the join, it does provide enough accuracy." There are also ways to improve or augment ADS-B.

Accuracy of the wake prediction could be increased by adding wind data to the information broadcast by the lead aircraft, and a proposal to add these messages to the next standard of ADS-B, Version 3, is on the table, says Sipe. Mode S Enhanced Surveillance (EHS) already has this information, but the aircraft's transponder must be interrogated for the data, and normally only ground radars do this.

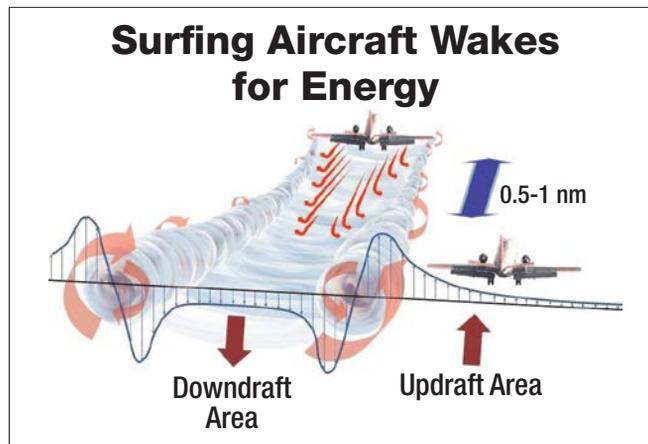
For Boeing's 777F ecoDemonstrator flight test, Aviation Communication & Surveillance Systems modified its traf-

fic collision alert system (TCAS) to perform airborne interrogation of the lead aircraft for EHS data. The system sent ADS-B and EHS data to a flight-test laptop that hosted the wake prediction algorithm on the trail aircraft. The laptop then sent a command to the autopilot's localizer control law, which was used to keep the aircraft on station relative to the wake. "ADS-B plus TCAS may work," says Flanzer.

For maximum aerodynamic benefit, wake position

must be known to within a few percent of wingspan, around 10 ft. for large commercial aircraft. This is beyond the 30-m (100-ft.) accuracy normally assumed for unaugmented GPS. If both aircraft are viewing the same satellites, they can navigate relative to each other with much greater accuracy, but this would require new ADS-B messages, and "we can't count on the aircraft in a formation always seeing the same satellites," he says. "We are going to need some way to sense position inside the wake," says Sipe.

Despite the challenges that still lie ahead, wake surfing for efficiency continues to show promise, for both commercial and military operations. Maj. Will Guthrie, a U.S. Air Force Reserve tanker pilot who is also a FedEx pilot, says the cargo airline has several aircraft flying in the same direction, to Los Angeles and San Francisco, London and Paris, just minutes apart every day. "There is no reason not to link up so the trailing aircraft can take the benefit," he told the conference. 🌐



Source: DLR

tools during the transition, and the requirement for new autopilot submodes.

The concept is based on predicting, rather than measuring, the wake position. When the trail aircraft is following behind by 20 wingspans, or about 4,000 ft, the vortices shed by the lead can drift significantly. The rate at which the wake sinks depends on the lead's type, weight and speed, while the rate at which it drifts depends on winds aloft. Predicting position requires data from the lead aircraft.

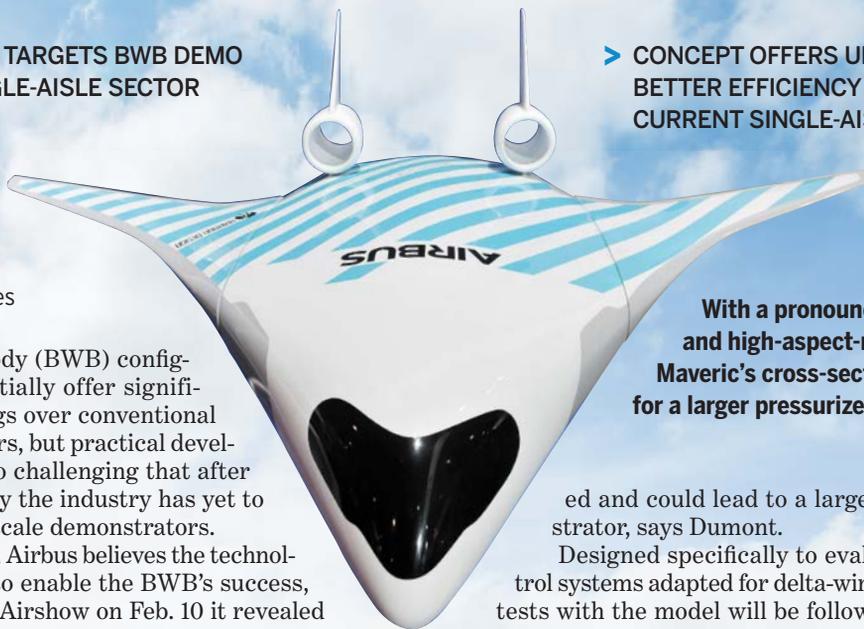
"Absent a sensor to detect the wake, we have to use an aircraft-to-aircraft data link," says Flanzer. "ADS-B is appealing because of its prevalence, but does it provide enough information and resolution to predict the wake? And how do we provide enough integrity to maintain safe separation?" The consensus is that ADS-B alone is not adequate.

For the level of reliable wake prediction necessary for routine commercial cooperative-trajectory operations, ADS-B data alone is likely insufficient

Maveric Move

➤ AIRBUS TARGETS BWB DEMO AT SINGLE-AISLE SECTOR

➤ CONCEPT OFFERS UP TO 20% BETTER EFFICIENCY THAN CURRENT SINGLE-AISLES



Guy Norris Los Angeles

Blended wing body (BWB) configurations potentially offer significant fuel savings over conventional tube-and-wing airliners, but practical development has proved so challenging that after three decades of study the industry has yet to progress beyond subscale demonstrators.

Despite the hurdles, Airbus believes the technology is now available to enable the BWB's success, and at the Singapore Airshow on Feb. 10 it revealed that it has been secretly flight-testing an experimental version of the flying-wing configuration since mid-2019.

Disclosure of the Maveric (Model Aircraft for Validation and Experimentation of Robust Innovative Controls) technology demonstrator comes amid growing signs that only disruptive new airliner configurations will be capable of meeting the ambitious emission-reduction targets of the future. Over the next 30 years, Airbus aims to cut emissions of nitrogen oxides by 90%, CO₂ by 75% and noise by 65% compared to current aircraft.

To get there, Airbus is exploring several radical concepts, the latest of which is the BWB. Others under study include the AlbatrossOne flexible-wing demonstrator and the Nautilus boundary-layer ingestion initiative with ONERA, the French aerospace research agency. Near-term advances Airbus aims to introduce on its current products include laminar flow control, which has been recently tested on an A340 demonstrator as well as on an A350 testbed. Airbus is also working with Rolls-Royce toward flight tests of the E-Fan X hybrid electric propulsion demonstrator in 2021.

"The environmental pressure we are under and the fact [that] we need to disrupt [the state of the art] to reach emissions objectives in 2050 forces us to drive down avenues we wouldn't have gone down earlier," says Jean-Brice Dumont, executive vice president of engineering for Airbus. Although acknowledging that the BWB concept is not new, he adds that recent advances could make it more feasible today. "What makes us wish to revive the BWB now?" he asks. "Some technologies have improved; we can make the aircraft lighter, and the flight controls and computing capabilities are one level higher. The equation was not resolvable, and now we believe it is."

The Maveric demonstrator is 6.5 ft. long with a 10.5-ft. wingspan. Powered by twin podded model-aircraft turbojets, mounted above the aft deck of the 24.2-ft.²-area wing, the aircraft first flew in June 2019 at an undisclosed location in central France. The aircraft is still being flight-test-

With a pronounced nose section and high-aspect-ratio wings, the Maveric's cross-section is optimized for a larger pressurized-cabin volume.

ed and could lead to a larger-scale demonstrator, says Dumont.

Designed specifically to evaluate flight control systems adapted for delta-wing designs, flight tests with the model will be followed by a second round of studies to evaluate wider aspects of the configuration including safety, manufacturability, airport compatibility, maintenance and support. "Let's be clear: We are studying this as an option," says Dumont. "We have already learned a lot, and tests have helped us understand the flight behavior of this kind of configuration in a real flight condition. So far, we have a green light, which is why we are unveiling it, and we are continuing with a more extensive study."

The BWB flying-wing configuration, originally conceived by McDonnell Douglas in the late 1980s, offers potential operating efficiency improvements because lift can be generated across the fuselage as well as the wings. Additional benefits include reduced form drag, an efficient span-loaded structure and greater space above the wing for higher-bypass engines. BWBs are also attractive because they can more easily support nonconventional hybrid-electric and, perhaps ultimately, all-electric propulsion systems.

As part of this pursuit, Airbus says the Maveric also forms part of a broader group of advanced technology studies that will help guide future product development. Some of these projects, including the EcoPulse distributed propulsion demonstrator unveiled last year, will influence decisions on which technology may be tested in a larger-scale demonstrator. "To take this concept further, we will need to fly a 'Scale 1' or larger demonstrator, but before that we must answer questions about airport interface issues and the propulsion system," says Dumont.

"What's the best fit for the BWB?" he asks. "Right now, we have two podded engines, but is it the right formula? In parallel we are testing the EcoPulse with Daher and Safran in France, which is teaching us quickly about flight controls and power controls for distributed propulsion. So we are converging this into a potential product. I'd say the next step would be flying this at a larger scale, but at exactly what scale and when I don't know."

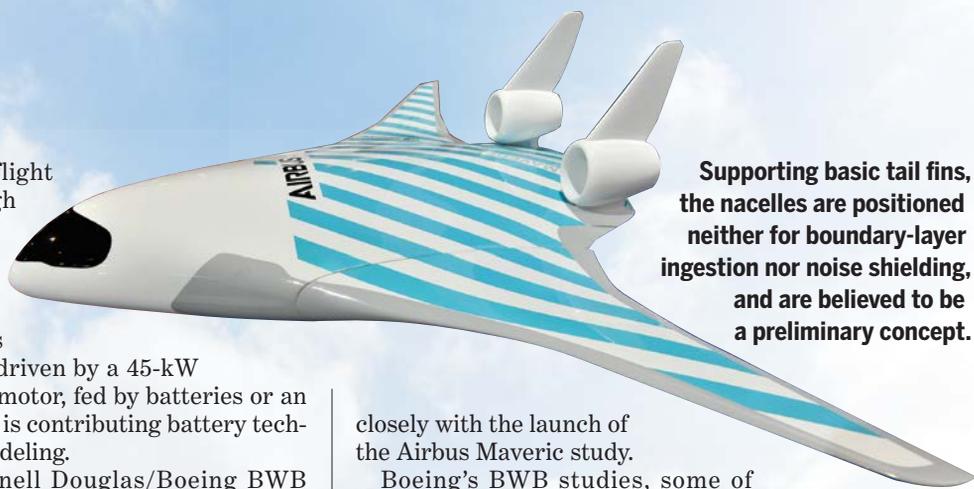
Under the EcoPulse project Daher, Airbus and Safran are modifying a TBM 900 turboprop as a distributed-pro-

AIR MOBILITY

pulsion demonstrator for flight tests by mid-2022. Although the aircraft will retain its standard nose-mounted engine and propeller, the TBM will be modified with three small propellers on each wing. Each will be driven by a 45-kW Safran ENGINEUS electric motor, fed by batteries or an auxiliary power unit. Airbus is contributing battery technology and aerodynamic modeling.

Unlike the first McDonnell Douglas/Boeing BWB studies, which focused on larger-capacity airliners and freighter versions, the Maveric is aimed at the smaller single-aisle market. Airbus believes an A320-size BWB could be around 20% more efficient than the current generation and appears to target the regional and narrowbody airliner sector that NASA envisaged with its proposed Ultra-Efficient Subsonic Technology (UEST) subsonic X-plane demonstrator program in 2016-17.

Conceived as potential follow-ons to the X-59 Quiet Supersonic Technology low-boom demonstrator, the provisional UEST lineup included three blended designs from Boeing, Dzyne Technologies and Lockheed Martin—the latter of which proposed a hybrid wing body. Although NASA's subsonic project was subsequently redirected from BWBs to focus more on hybrid-electric technology concepts, the timing of the original UEST effort coincides



Supporting basic tail fins, the nacelles are positioned neither for boundary-layer ingestion nor noise shielding, and are believed to be a preliminary concept.

closely with the launch of the Airbus Maveric study.

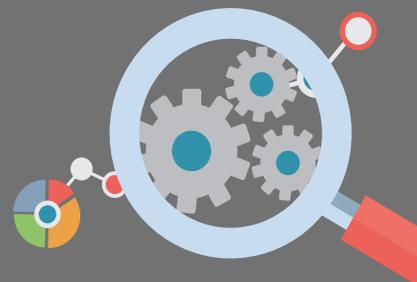
Boeing's BWB studies, some of which were conducted with NASA from 2006 to 2013 under the X-48 project, focused mostly on flight characteristics but also included many potential passenger and cargo configuration evaluations. These mostly favored freight over passenger roles because of perceived concerns over emergency egress and situational awareness issues associated with the predominantly windowless cabin. But BWB designer Dzyne says cabin layouts will allow better access to exits than current single-aisle aircraft as well as options for extra windows such as skylights. Airbus believes future single-deck cabin concepts could include exit designs and display screen technology to make BWBs more acceptable to the traveling public.

"We need to come up with disruptive options and enter service at the earliest possible date to bring benefits by 2050. The clock is ticking," says Dumont. ☺

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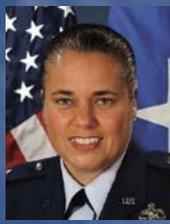
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REFUELING REVI

> U.S. AIR FORCE ANTICIPATES COMMERCIAL REFUELING AWARD IN 2020

> THE SERVICE IS NOT CONVINCED OF KC-46 DESIGN FIX PROPOSAL

Lee Hudson Washington

The U.S. Air Force, forced to finally confront a gap in the nation's aerial refueling needs, plans to pay industry for commercial services as it does with intertheater airlift.

Over the past year, Air Mobility Command (AMC) has worked with U.S. Transportation Command (Transcom) on fleshing out the idea of using vendors for commercial tanking in a noncombat environment, Lt. Gen. Jon Thomas, deputy AMC chief, tells Aviation Week.

"There is an opportunity for a thin-slice capability that could relieve some stress on the force to do things like refueling for test and evaluation or refueling for training events that are in support of others," he says. "But our Air Mobility Command tank crews don't get a whole lot of training benefit out of [moving] foreign military sales aircraft."

The rationale is that any little bit will help morale. The U.S. military's aerial refueling community "is the most stressed and probably the one that's pushing the red line or exceeding the red line" when it comes to the amount

of time pilots and crew are deployed compared to being at home, Army Gen. Stephen Lyons, Transcom commander, said at the Atlantic Council.

"We have to figure out a way to mitigate the delayed fielding of the [Boeing] KC-46," he said.

Soliciting industry for commercial tanking capability is not a new concept inside the Pentagon—the Navy has aerial refueling contracts with a commercial vendor. But Thomas is quick to point out a key difference: The Army, Marine Corps and Navy all use the drogue aerial refueling method that requires more pilot maneuvering. The Air Force uses a boom that can pump up to 880 gal. per minute while the drogue system can pump 220-290 gal. at the same rate.

In December, the military hosted its second commercial tanking services industry day, and the knowledge gained

is giving Thomas confidence the Air Force is making progress toward its goal of establishing initial capabilities.

"We've identified a set of requirements," Thomas says. "Depending on how they choose to provide the service and where they operate from, there's a lot of different variables that could probably be in the realm of 6,000-10,000 hr. per year."

The military is still working out a slew of variables with industry on the pay structure. For example, he notes, should the Air Force pay per flying hour, or pay a fee that is based on a combination of fuel delivery and distance?

Thomas anticipates the military will hold a third industry day because the iterative process is helpful for the Air Force to understand what is in the realm of possibility. The plan is to award a contract by the end of 2020, he says.

"Based on the dynamics and complexity of the whole thing,

The U.S. Air Force continues to buy KC-46 aircraft that require substantial fixes.

MARK WAGNER/AVIATION-IMAGES.COM



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we think that's a reasonable stretch goal," Thomas says.

AMC issued a request for information in 2018 for a commercial refueling service that can handle 7,000 hr. annually. Airbus and Lockheed Martin joined forces to respond as the service determines the way ahead.

In 2019, Omega Air Refueling took delivery of the first two former Royal Netherlands Air Force KDC-10 aircraft that they could potentially use to provide tanking services to the U.S. Air Force. The KDC-10 joins the company as its first boom-equipped tanker. Omega currently owns and operates a small fleet of tanker aircraft, with four different configurations approved to support Navy and Marine Corps aircraft.

One possibility to ensure enough refueling capacity is delaying retirement of the Boeing KC-135. The Air Force plans to divest the KC-10 fleet while retaining some of its KC-135 aircraft into the 2050s. Citing concerns about the gap, Congress in its fiscal 2020 defense policy bill says it will block the military from retiring primary inventory KC-10 aircraft in that fiscal year.

Thomas dispelled the rumor of the military selling retired KC-

10s to industry and then buying them back as commercial service aircraft.

"At this point, we're not contemplating any transfer of USAF aircraft to some other entity in order for them to come back to us and provide air refueling services," Thomas says. "That's just not the way we would want to approach it, because if we have those tankers available then we want to be able to fly them ourselves."

Recently retired KC-10 aircraft would reside at the Aircraft Maintenance and Regeneration Center in Tucson, Arizona, commonly referred to as "the boneyard." The military could decide to take the tankers out of storage if the aircraft are needed in a major contingency.

Although there is still work to do on the Boeing KC-46, the Air Force is already thinking about a "bridge tanker" known as the KC-Y, which is envisioned as a nondevelopmental commercial derivative air refueling tanker. This is what the service intends to buy after the last KC-46 is delivered in 2028 and before it purchases a new clean-sheet design tanker known as the KC-Z, Thomas says.

"We are trying to accelerate KC-Z as much as possible" because there are larger modernization bills the Pentagon has to pay in the late 2020s, he says.

The Air Force is working on the initial capabilities document for the KC-Z, and once it is wrapped up, an analysis of alternatives will begin. Much of the work centers on deciding what type of tanker the Air Force will need beyond 2030 to support the joint force. This includes defining the range, payload and communications suite needed, Thomas says. The service

must also determine if the KC-Z will be unmanned or optionally manned.

The tanking shortfall is intensified by ongoing KC-46A Pegasus program delays. "It's really hard for us to consider the KC-46 part of our operational capacity," Thomas says.

In January, Air Force Chief of Staff Gen. David Goldfein sent a letter to Boeing asking the company to focus on the KC-46 program even as it is fixing the 737 MAX.

"The Air Force continues to accept deliveries of a tanker incapable of performing its primary operational mission," Goldfein wrote.

The KC-46A program still faces unresolved Category 1 deficiencies revolving around the remote vision system (RVS) and the boom telescope actuator. A Category 1 deficiency means the government has identified risk that jeopardizes lives or critical assets. The problem with the RVS is what the Air Force calls a "rubber sheet" effect that distorts the image on the visual display used by the boom operator during refueling operations. The actuator on the refueling boom needs to be more sensitive to smaller receiver aircraft, such as A-10s and F-16s. Boeing has agreed to pay for the RVS design fix while the Air Force will pay for the design change to the actuator.

Thomas is not sold on the fact that Boeing's design proposal for the RVS will meet the program's performance parameters. This is based on evidence the service has seen to date, he adds.

The company contends that getting the KC-46A program back on track is a top priority. "We're committed to see that through and see it through the right way," Boeing CEO David Calhoun says. "It's going to finish beautifully." ☒



Airbus Pays High Price for A400M Export Assumptions

— Tony Osborne Toulouse —

THE REBASELINING OF CONTRACTS FOR THE A400M airlifter signed last summer should have lifted what former Airbus CEO Tom Enders called a “Damocles sword” from over the company.

However, the sizable €1.2 billion (\$1.3 billion) charge revealed by the company when it announced its 2019 financial statements suggests that the A400M-inflicted financial pain is far from over. CEO Guillaume Faury told analysts the airlifter program could continue to weigh on the company’s bottom line, to the tune of €2 billion, into the mid-2020s.

The latest charge relates to costs associated with export assumptions. By now, the OEM had hoped that it would have secured an additional export order for the aircraft—beyond the four-aircraft order from Malaysia.

An order from Saudi Arabia would have been in the offing, but Germany’s “repeatedly extended” ban on exports of defense equipment to Riyadh means a deal remains out of reach.

The German export ban to Riyadh has also triggered a second charge of €212 million related to the delivery of a border security system. Berlin’s embargo has been extended

through the end of March.

Faury said the outlook for sales was “increasingly challenging,” and that the company would “reassess the future exports” for the aircraft.

A Saudi order could open up the regional market for the A400 at a time when airlifter orders are in the doldrums.

“You’d think [transport aircraft would] do well, given high defense spending and the need for strategic mobility,” says Richard Aboulafia, vice president of analysis for the Teal Group.

He says the military airlift market saw a 19% drop in deliveries during 2018-19.

“The A400M went from one per month to eight per year,” Aboulafia says. “It doesn’t look like there is going to be much that saves that program from oblivion.”

Airbus had made significant progress over the past year with the A400M, achieving simultaneous deployment of paratroopers from both paratroop doors and completing dry contacts as part of the company’s plan to certify the aircraft for helicopter aerial refueling by 2021. The contract rebaselining adjusted aircraft delivery, tactical capability and retrofit profiles and rewrote maintenance contracts in a bid to lift part of the financial burden of the program off the OEM. Nonetheless, the A400M has now cost the company over €5 billion in the last four years. The company recorded charges of €436 million in 2018, €1.3 billion in 2017 and €2.2 billion in 2016. 🌐

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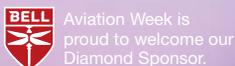


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U.S. Air Force Plans \$3 Billion Mobility Fleet Makeover

- > USAF PLANS BUDGET SHIFT OF UP TO \$3 BILLION FOR LOGISTICS
- > AIR MOBILITY COMMAND PROBES INDUSTRY FOR COMMUNICATIONS UPGRADES



At least 179 KC-46As and 300 KC-135R/Ts will need upgrades to perform existing and new roles planned after 2028.

Steve Trimble Washington

Air mobility fleet and logistics system that the U.S. Air Force regards as vulnerable and underutilized is about to receive a potential \$3 billion makeover.

To address the underutilization, the Air Force will modify a fleet designed for two missions—airlift and air refueling—to perform a third function as a new communications hub in a decentralized, networked command-and-control system.

As the air mobility fleet acquires a more critical role, its value as a target for potential peer adversaries rises. In response, the Air Force plans to upgrade onboard sensors and defenses, with options ranging from traditional countermeasures and decoys to an emerging class of hit-to-kill interceptors.

The Air Force will look for new and creative ways to lighten the load—literally—on the air mobility fleet, as long-range missiles and cyberattacks are expected to further strain the ground-based hubs of a global logistics system, including forward-based repair and supply depots.

The elements of the recently launched “logistics under attack” initiative reflect a new understanding within the Pentagon of how potential warfighting scenarios with peer adversaries in the future will be different.

The Air Force submitted a fiscal 2021 budget plan that proposes to transfer billions of dollars over the next five years to four initiatives: enabling joint all-domain command and control, accelerating the Northrop Grumman B-21 program, investing in new offensive and

defensive space assets and developing the logistics-under-attack initiative.

“We are no longer thinking it’s a good assumption that we will have unfettered access to logistics,” Air Force Chief of Staff Gen. David Goldfein said at a Center for a New American Security event. “We’ve been able to move personnel equipment at a time and place of our choosing. That’s a bad assumption for the future.”

Fighters and bombers are designed with the assumption that they will be targeted and attacked. Over the past decade, the Air Force Research Laboratory has experimented with stealthy designs for the mobility fleet, including the Speed Agile concept. A survivable concept for an advanced airborne refueler remains in the study phase within Air Mobility Command (AMC) but likely will not emerge until Boeing delivers the last KC-46A in 2028.

By then, the Air Force expects to have 179 KC-46As, 300 KC-135R/Ts and hundreds of C-130H/Js. Current KC-135s and C-130s are equipped only with infrared countermeasures for short-range, heat-seeking missiles. The KC-46As are delivered with infrared countermeasures and radar-warning receivers installed but no radio-frequency countermeasures. The fleet’s communications capability is likewise unimpressive. The KC-46A is the first mobility aircraft to enter service with Link 16, while the KC-135s have only UHF/VHF-band ARC-210 radios. “We have got to do better than that for our aircrew,” says Lt. Gen. Jon Thomas, AMC’s deputy commander.

In 2018, the Air Force launched a program to install the Real-Time Information in the Cockpit system

on 50 KC-135s, which provides access to Link 16 and the Mobile User Objective System satellite constellation. But AMC has larger plans for improving situational awareness in mobility cockpits.

On Feb. 3, AMC released a request for information, seeking responses from potential suppliers for a wing-mounted beyond-line-of-sight communications pod for KC-135s and KC-46s. At that point, the air-refueling fleet would have access to much of the same information now provided to command-and-control aircraft such as the Boeing E-3C fleet.

“Once you’ve got that situational awareness, then what do you do with it?” Thomas asks. “That’s when you have the systems that are either countermeasures or self-defense systems. But it all starts with situational awareness.”

In addition to traditional radio-frequency countermeasures such as chaff, the mobility fleet may in the future have other options for countering radar-guided threats. The Air Force Research Laboratory has begun Phase 2 of a program to develop the Miniature Self-Defense Munition (MSDM), an air-launched interceptor for targeting advanced air-to-air missiles.

The Air Force is also working on other concepts to reduce the mobility fleet’s vulnerability, such as forward-basing 3D printers that can produce spare parts locally.

“Does the future actually look like 3D printers, right, and stacks of material, as opposed to the large logistics chains that we built?” Goldfein asked. “How do you think about that and leverage technology? How do we articulate to the Congress, the American people, the importance of flowing portions of our materiel forward and then actually starting to park it in different places?”

—With Lee Hudson in Washington



BOEING

TOUGH CHOICES

- > NUCLEAR MODERNIZATION REMAINS A TOP PRIORITY
- > ARMY TRUNCATES CHINOOK BLOCK 2 UPGRADE PROGRAM

Lee Hudson Washington

The Trump administration is requesting a flat budget for national security of \$740.5 billion in fiscal 2021 to keep military equipment relevant to counter threats from China and Russia. The task of evaluating the request falls to Congress, which is already pushing back on some of the specifics.

“Without growth for inflation,” says Deputy Defense Secretary David Norquist, “we had to make additional tough choices and major cuts in some areas in order to free up money to continue to invest in the high-end fight.”

Pentagon officials stress there are several winners in this year’s budget plans: Nuclear weapons modernization, for example, would get almost \$29 billion. Hypersonic weapons would land \$3.2 billion. Missile defense would receive \$20.3 billion, space-related programs \$18 billion—including \$15.4 billion toward the new Space Force, and air dominance-related programs would get about \$57 billion. Pentagon officials dwelled less on the losers—such as the Air Force’s plan to retire aircraft and the Army’s plan to upgrade Boeing CH-47 Chinooks—both unable to free up funding for modernized platforms. In the past, lawmakers have added back funding to keep older aircraft active. Will they do so again?

NUCLEAR MODERNIZATION

Nuclear modernization is a priority for the Pentagon because there is not much margin in the schedule between the end-life of legacy systems and when the new equipment is slated to enter service. This includes the Ground-Based Strategic Deterrent, Northrop Grumman B-21 Raider, Long-Range Standoff Weapon, missile warning technology and the Columbia-class ballistic missile submarine. China and Russia are both modernizing their nuclear arsenals, while the U.S. lags, administration officials contend.

“We must proceed with modernization. Sustainment and modernization of our nuclear forces has transitioned from

The CH-47 Block 2 is an upgrade that aims to increase the heavy helicopter’s carrying capacity enough so that it can haul a Joint Light Tactical Vehicle.

something that we should do to something that we must do,” U.S. Strategic Command chief Navy Adm. Charles Richard says in written testimony submitted to the Senate Armed Services Committee. “Continuing to maintain the Nation’s strategic deterrent needed to meet the challenges of the global security environment and to realize Presidential and Departmental guidance defined by the National Defense Strategy (NDS), National Military Strategy (NMS), and Nu-

Funding Request for Key Defense Programs (U.S. \$ millions)

Fiscal Year	2021	2022	2023	2024	2025
F-35A	\$5,293	\$4,886	\$4,804	\$4,796	\$4,841
F-35B	1,359	2,182	2,547	2,710	2,779
F-35C	2,462	2,500	2,975	2,985	3,137
KC-46	2,850	2,249	2,401	2,962	2,838
ABMS*	302	449	590	1,088	832

*RDT&E request

Source: Defense Department

clear Posture Review (NPR) requires continued Congressional support, budget stability, and on-time appropriations.”

There is already vocal opposition from a member of the Senate Appropriations Committee against the Trump administration pursuing development of hypersonic and nuclear weapons. Sen. Dianne Feinstein (D-Calif.) says hypersonic missiles are an entirely new class of weapon the U.S. does not need in its inventory.

“This unnecessary spending is likely to spark a new arms race with Russia and China. Simply put, these are not the

priorities on which we should spend taxpayer dollars—particularly at the expense of critical domestic programs—and I will do everything I can to block them,” Feinstein says. “Now the president is proposing a budget that dangerously increases spending on new nuclear weapons and leaves funding for nuclear nonproliferation programs flat. The United States should be working to rid the world of nuclear weapons, not creating new types and a larger stockpile.”

AIRCRAFT RETIREMENTS

The Pentagon will get pushback from Capitol Hill about proposing the retirement of 29 legacy tankers in the fiscal 2021 budget even as the successor Boeing KC-46A Pegasus is not considered operationally viable.

The Air Force is recommending the retirement of 13 KC-135s and 16 KC-10s. The tanker shortfall is not a new problem for the service. Citing concerns about the gap, Congress in its fiscal 2020 defense policy bill blocked the military from retiring primary inventory KC-10 aircraft in that fiscal year. “We do have a requirement out there to keep 479 tankers, and we will continue to do that,” Navy Vice Adm. Ron Boxall, resources and assessment director for the Joint Staff said during the budget rollout.

Boxall said the Pentagon will watch the KC-46 program closely and adjust the tanker fleet as necessary to maintain

CHINOOK BLOCK 2

For the second year in a row, the Army is trying the same budget gambit—truncating the CH-47F Block 2 upgrade program. The fiscal 2021 budget request again attempts to defer Block 2 upgrades for conventional-forces Chinooks but includes money to upgrade special operations forces MH-47Gs.

The Army proposed deferring Chinook upgrades for five years in the fiscal 2020 budget request. However, Congress bypassed that by injecting \$28 million for advanced procurement for the CH-47 Block 2. Three of the four defense oversight committees rejected the Army’s initial plan and during conference agreed to fund the program.

The service contended that deferring the program for five years was necessary so that it could instead reinvest in Future Vertical Lift and other modernization priorities. However, Chinook Block 1 cannot lift the heavier equipment the Army has in its inventory, such as the Joint Light Tactical Vehicle that is replacing the Humvee. The Chinook Block 2 effort includes lighter, one-piece fuel cells, a redesigned electrical system, strengthened airframe, uprated transmission and advanced composite rotor blades. Additional funding for Chinook Block 2 would boost Boeing’s CH-47 assembly line. Last fall, the State Department approved a potential sale of 10 CH-47F Block 1 aircraft to the United Arab Emirates.

This follows approval in July of the sale of up to 16 CH-47 Block 1s with extended-range fuel tanks to the UK.

SPACE FORCE

There will be “pretty intense oversight” of the Space Force by Congress, according to the top Republican on the House Armed Services Committee.

The fiscal 2021 budget request is the first delivered to Capitol Hill from the Pentagon since establishment of the Space Force as the sixth armed service. The nascent branch requested \$15.4 billion, consisting mostly of \$10.3 billion for a research and development program, \$2.4 billion for procurement and \$2.5 billion for operations and maintenance. The fiscal 2021 budget request does not include funding for personnel.

“I think all of us expected it to be a crawl, walk, run sort of situation,” says committee Ranking Member Mac Thornberry (R-Texas). “They want to transfer about 100 people over [from the Army], so I think we need to look at that.”

Thornberry acknowledged there is “bureaucratic ranking” in terms of the Space Development Agency (SDA) and how it fits into the Pentagon. When a shakeup occurs inside a large organization such as the Defense Department, “people start grabbing pieces,” he says. “And so that’s obviously still a work in progress.”

The Pentagon is requesting \$288 million for the SDA: \$216 million for advanced component development and prototypes and \$72.4 million for advanced technology development. Additionally, the Pentagon is requesting \$103 million to continue funding the Space Rapid Capabilities Office under the Space Force.

“The most important thing is we made a good start on spending more time and attention on space,” Thornberry says. 🗣️

Funding Request for Nuclear Research (U.S. \$ millions)

Fiscal Year	2021	2022	2023	2024	2025
Ground-Based Strategic Deterrent	\$1,524	\$2,536	\$3,034	\$3,072	\$3,031
Long-Range Standoff Weapon	\$474	\$359	\$395	\$410	\$359

Source: Defense Department

the 479-tanker requirement. The Air Force framed the KC-10 and KC-135 retirements as a tough choice but worth the risk. “We can’t continue to fund everything that we have in our force today,” because the service must pay for equipment the military will need in 2030, says Maj. Gen. John Pletcher, deputy assistant secretary for budget.

ADVANCED BATTLE MANAGEMENT SYSTEM

For the first time, the Air Force is proposing a large investment in the Advanced Battle Management System (ABMS) that is designed to replace the Northrop Grumman E-8C and Boeing E-3 fleet. The funding profile outlined in the new budget request is \$3.26 billion over the next five years, including \$302 million in fiscal 2021. The service is using a crawl, walk, run approach in developing the new technology. The Air Force plans to install a ground-based communications gateway on the Kratos XQ-58 Valkyrie and on the KC-46.

Once it is possible to deploy an airborne communications network, the service will introduce a cloud-like processing system outfitted with applications that take on the role usually performed by airborne battle managers. The Air Force has briefed congressional defense committee staffs on the ABMS concept, but some are skeptical. A Capitol Hill staffer familiar with the program doubts the other services will support the Air Force’s vision. The ABMS model also appears unlikely to be embraced by industry because the construct requires companies to cede intellectual property rights, the staffer tells Aviation Week.



An Era of Hard Decisions Begins as U.S. Defense Spending Stagnates

- > A \$705 BILLION BUDGET REQUEST OVERALL
- > MORE FUNDING FOR NEXT-GENERATION FIGHTER AND ENGINE



Steve Trimble Washington and Singapore

Managing a flat or slightly declining budget is easier when the topline is over \$700 billion, but some programs feel the pinch more than others.

The U.S. Air Force's requested \$169 billion share of a proposed \$705 billion defense budget for fiscal 2021 reflects the dilemma facing fiscal planners. Although continuing to insist the Air Force needs scores of additional combat squadrons, service officials are proposing to accelerate retirements of dozens of aircraft across fighter, mobility and ISR (intelligence, surveillance and reconnaissance) fleets. The savings would be used to fund development of capabilities that mainly would be realized only after passing through several risk-prone years with an inconsistent military acquisition system.

Specifically, the Air Force proposes through fiscal 2025 early retirement of 44 A-10 attack aircraft, built by Fairchild Republic; 17 B-1 bombers, built by Rockwell; 24 Northrop Grumman RQ-4 Block 20 and 30 unmanned aircraft systems (UAS); 10 contractor-operated MQ-9 UAS, built by General Atomics; and 16 McDonnell Douglas KC-10 and 13 Boeing KC-135 refuelers.

Bucking a trend, the Air Force canceled the Hypersonic Conventional Strike Weapon (HCSW) to focus on a more advanced boost-glide missile as interest grows in hypersonic air-breathing cruise missiles. The requested fleet reductions also follow the Air Force's decisions during the last budget cycle to retire the Northrop Grumman E-8C Joint Stars in fiscal 2025 and remove funding for the final planned member in the Lockheed Martin Space-Based Infrared Satellite (SBIRS) constellation in the fiscal 2019 budget.

"We had to make additional tough choices and major cuts in some areas in order to free up money to continue to invest in the high-end fight," Deputy Defense Secretary David Norquist said.

The proposed cuts in fiscal 2021 could have been worse.

An early January backlash by combatant commanders forced Air Force Chief of Staff Gen. David Goldfein to walk back even deeper fleet reductions, originally worth \$30-35 billion in operating savings over the next five years. The Air Force has declined to specify which fleets were spared, but budget documents released to Congress suggest the Lockheed U-2 was involved. The Air Force dismissed a reference to a fiscal 2025 retirement date for the high-altitude ISR aircraft

The U-2S (represented above by a TU-2S in background, landing) appears poised to survive its erstwhile successor, the signals-intelligence and communications relay versions of the RQ-4 unmanned aircraft system.

as a typo, but one that strangely appeared twice in the same document.

Although inconsistent with the Air Force's message that it needs to grow to 486 combat squadrons to meet operational requirements, the proposed fleet reductions since last year have a consistent purpose. The overall defense budget has stagnated since peaking at \$716 billion in fiscal 2019, falling to an enacted level of \$704 billion this fiscal year and edging up to a proposed \$705 billion for fiscal 2021. With no top-line growth, the Air Force is financing an ambitious modernization strategy by leveraging savings from early fleet retirements and terminating certain upgrades.

"Our adversaries have designed their forces to exploit our vulnerabilities, and unless we evolve, they will someday face a force they have readily trained and equipped themselves to defeat," said Maj. Gen. John Pletcher, the Air Force's budget director, speaking to reporters on Feb. 10. "We cannot allow that to happen."

But the Air Force's approach carries near-term risks. Fewer aircraft would be available now so more advanced capabilities can be developed for later. The Air Force applied a similar strategy when a budget-sequestration policy was imposed in fiscal 2012, leading to the retirements of hundreds of A-10s and Lockheed Martin F-16s with no immediate replacements.

"We are seeing the fleet literally fall off a cliff," said a source familiar with the Air Force's budget plans. "The replacements are not ramping up fast enough or soon enough."

In the view of some commanders, Goldfein's original proposal for extracting \$30-35 billion in savings assumed too much risk in the near-term. The 2018 National Defense Strategy commits the Air Force's leadership to prepare now for a war with China by the end of the decade. But the commanders in the field are calling for more—not fewer—resources now, to deal with current threats.

"The combatant commanders are focused on the next year to two to three years, and the service chief is looking at 10 to 15 years," said Gen. Charles Brown, commander of Pacific Air Forces, describing the tension between officers in his position and the service chiefs in the Pentagon.

Although some capabilities are being subtracted, the Air Force's budget request restores funding for some long-sought modernization programs.

A Next Generation Adaptive Engine (NGAP) program appears for the first time in the fiscal 2021 budget documents. As of last year's budget cycle, the Air Force planned to wrap up by 2021 the Adaptive Engine Technology Demonstrator (AETD) program, which aims to demonstrate a 45,000-lb.-thrust turbofan with three-stream airflow technology for the Lockheed F-35. The lack of a funded transition path for adaptive engine technology prompted frustrated lawmakers to slash the AETD budget by \$200 million and chastise the Air Force. With over \$400 million committed through fiscal 2024, the NGAP program appears to fund development of a follow-on design, which perhaps could be tailored to a future twin-engine fighter.

Moreover, the Air Force last year reduced the five-year budget for the Next Generation Air Dominance (NGAD) program by half, or \$6.6 billion, nixing prospects to launch full-

scale development of a replacement for the Lockheed Martin F-22 as early as fiscal 2023. But the fiscal 2021 budget offers a brighter outlook in the long-term for NGAD, with spending exceeding \$2 billion annually for the first time, starting in fiscal 2025.

The F-16 fleet also is due for a major—and long-awaited—upgrade in the fiscal 2021 budget. The Air National Guard has upgraded 72 F-16s with Northrop Grumman APG-82 active electronically scanned array radars since fiscal 2017. The Air Force now plans to expand the upgrade to 330 more fighters, including upgraded mission computers and displays that were not available for the first 72 aircraft.

A subset of the F-16 fleet then will join the core of an advanced fleet of nonstealthy fighters, including the Boeing F-15EX, that will be tasked with defending air bases and the

ating philosophy. The Marine Corps, for example, adopted a new strategy in July 2019 that calls for tighter integration with the Navy. The fiscal 2021 budget request stops short of formally adjusting the program of record for the short-takeoff-and-vertical-landing F-35B, but proposes to cut the planned procurement by half, to 10.

But the biggest new Air Force commitment is devoted to the Advanced Battle Management System (ABMS), with \$3.26 billion requested over the next five years, including a \$302 million down payment in fiscal 2021.

In the near-term, the goals of ABMS are modest. An initial "on-ramp" event staged in December allowed the F-35 and F-22 to exchange data through a ground-based communications gateway that reconciled the waveforms of incompatible low-probability-of-intercept data links used by both aircraft.



The initial focus of the Advanced Battle Management System provides an airborne communications bridge for the F-35 (left) and F-22 (right), but it eventually will expand to replace command suites on E-8C and E-3 fleets with automated systems.

U.S. AIR FORCE/JEREMY T. LOCK

homeland from attack by combat aircraft and cruise missiles.

Overall, requested funding for tactical aviation procurement remains high in the fiscal 2021 budget submission. The Pentagon is seeking to buy 118 fighters, including five to be procured under the Special Operations Command's new Armed Overwatch program. Requested funding for the F-35 appears to decline from the fiscal 2020 enacted level, to 79 for next year from 98 this year. Still Congress tends to insert funding for increased F-35 purchases each year, including an additional 18 in fiscal 2020.

But service-specific line items for the F-35 reflect new changes in oper-

During the next two on-ramp events, the Air Force plans to install the communications gateway on the Kratos XQ-58 Valkyrie, a potential new airborne communications medium for the Air Force's different stealth fighters. A similar role also would be demonstrated by the Boeing KC-46 tanker.

Ultimately, the Air Force wants to expand beyond gateways. Once the service can deploy a seamless and resilient airborne communications network, the ABMS program plans to introduce a cloud-like processing system, with applications that automatically perform the role played by airborne battle managers on the E-8C and Boeing E-3 fleets today. ☛

Once-Abandoned Light-Attack Acquisition Revived, Again

- > SOCOM RELEASES \$898 MILLION BUDGET FOR ARMED OVERWATCH
- > ARMED CROPDUSTERS, TURBOPROP TRAINERS, LIGHT JETS IN MIX

Steve Trimble Washington and Singapore

U.S. Special Operations Command (SOCOM) has revived hopes for acquiring a light-attack aircraft fleet only a year after the Air Force abandoned a previous attempt.

The Defense Department's fiscal 2021 budget request includes \$106 million for SOCOM to acquire the first five of potentially 76 light-attack aircraft that could be divided into two fleet types to perform a newly defined Armed Overwatch mission, according to budget documents and industry sources. Overall, SOCOM plans to spend \$898 million over the next five years on the Armed Overwatch program, the documents show.

In terms of technical complexity, a light-attack aircraft ranks near the bottom of the list for modern air combat platforms, requiring only a propeller system for propulsion, off-the-shelf sensors and relatively simple munitions. Despite this inherent simplicity, acquiring a light-attack capability has eluded multiple attempts by the Air Force since Air Combat Command defined the OA-X requirement in 2008.

The Air Force first sought to acquire a wing of light-attack aircraft as counterinsurgency operations in Iraq and Afghanistan were peaking in 2009. But service officials ultimately canceled the Light Attack and Armed Reconnaissance acquisition program a year later, settling for acquiring a fleet of Sierra Nevada/Embraer A-29 Super Tucanos initially on behalf of the Afghan Air Force. U.S. operations in Iraq and Afghanistan since have decreased, but the need for a relatively inexpensive aircraft that can provide air support in low-threat environments, such as Africa, never went away.

A second Air Force attempt to acquire a light-attack fleet began in 2017, but progress has been slow. Congressional frustration finally peaked after a January 2019 announcement by the Air Force, which suspended a planned acquisition program for up to 350 light-attack aircraft to be split between special-operations and conventional air

force squadrons. In response, lawmakers took the rare step of handing direct appropriation authority for light attack to SOCOM, which normally relies on the conventional service branches to acquire aircraft on its behalf.

Congress approved the new authority in December, but SOCOM wasted

March 4-5 in Tampa, Florida. To acquire the fleet as quickly as possible, SOCOM has decided to structure the acquisition on an Other Transaction Authority contract, which allows government buyers to start production quickly after demonstrating a relevant prototype. SOCOM has told industry officials to prepare to begin prototype demonstrations as soon as this summer.

SOCOM is considering an acquisition strategy that splits the procurement into two types of aircraft, says Seamus Flatley, vice president of business development for Iomax, a company that offers an armed version of the Thrush 610 cropduster.

The Armed Overwatch mission



Previous attempts to procure a light-attack aircraft have yielded only U.S.-funded acquisitions for other countries, such as the Afghan Air Force A-29 (shown), but under the Armed Overwatch program it appears a lightly armed observation aircraft finally will be delivered to support U.S. special forces.

no time in starting a new acquisition program. Whereas the Air Force devoted three years to a preacquisition experimental phase, SOCOM stood up the Armed Overwatch program within a month of the fiscal 2020 appropriation approval. Within a few weeks, the SOCOM program office released a plan that calls for acquiring the first five aircraft within a year.

SOCOM's streamlined acquisition bureaucracy allows the service to move faster than the conventional armed services. The Armed Overwatch program also does not face competition for funding within SOCOM for more advanced and expensive requirements, as would a light-attack program within the Air Force system.

SOCOM has scheduled an Industry Days event for Armed Overwatch on

could be split between a category of aircraft similar to an armed Thrush or Air Tractor and a type similar to an A-29 or Textron Aviation AT-6 Wolverine. Industry officials also plan to offer armed versions of light jets including the Textron Scorpion and Aero L-39. Czech Republic-based Aero has teamed with Utah-based Boresight to offer a U.S.-assembled, observation-attack variant of the L-39, the U.S. partner confirmed during the Singapore Airshow.

Flatley says Air Force Special Operations Command told him it is interested only in the Iomax aircraft, nicknamed Archangel, for Mission Set 2. An Iomax competitor, Air Tractor's AT-802U Longsword team, has confirmed it plans to respond to SOCOM's call for bidders to attend the Tampa event. ☛

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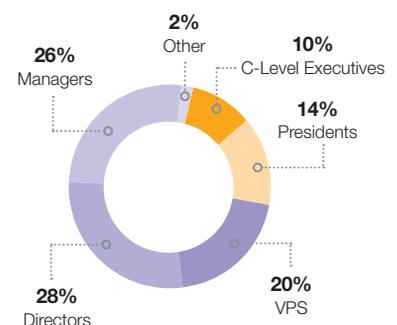
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MDA Embarks on a New Generation of Missile Defense

- > NO FUNDING REQUESTED FOR 20 PREVIOUSLY PLANNED GBIs
- > AGENCY IS STUDYING USE OF THAAD AND AEGIS SYSTEMS FOR HOMELAND DEFENSE

Jen DiMascio Washington

The Pentagon is in the midst of a massive upgrade of its Ground-based Midcourse Defense (GMD) system, designed to protect the U.S. against an attack by an ICBM.

The new Next-Generation Interceptor (NGI) would modernize GMD, arming it with an all-up round that can counter more sophisticated ICBMs. In pursuing the new program, the Missile Defense Agency (MDA) will end the planned purchase of 20 current-generation GMD Ground-Based Interceptors (GBI), after already having canceled a key aspect of that system, the Redesigned Kill Vehicle (RKV). While it works on NGI, the MDA also intends to supplement its defense of the U.S. against ICBMs with shorter-range interceptors that provide regional defense.

The change in course will not be cheap. GMD itself has cost more than \$68 billion over its lifetime. In its fiscal 2021 budget request, the MDA is asking for \$664 million in fiscal 2021 for NGI

to include more sophisticated ballistic missiles and hypersonic weaponry.

The MDA is poised to issue a classified request for proposals to sponsor two contractors through a preliminary design review (PDR) of a new interceptor and kill vehicle—the part of the interceptor that defeats an incoming missile while in space. MDA Director Vice Adm. Jon Hill says the agency plans to award contracts by the end of 2020, with the intention of starting testing in the mid-2020s and putting NGIs in silos by 2027, 2028 or beyond.

“Right now we’re funded through PDR, and you know there’s plenty of arguments out there that you [have] got to go all the way to the [critical design review (CDR)]. We’ll have that conversation when the time is right,” says Hill.

The release of the budget solidifies a plan that has been slowly percolating in the background. Last March, Boeing was put on notice after the RKV—a projectile launched by the GBI booster that is tasked with locating and defeat-

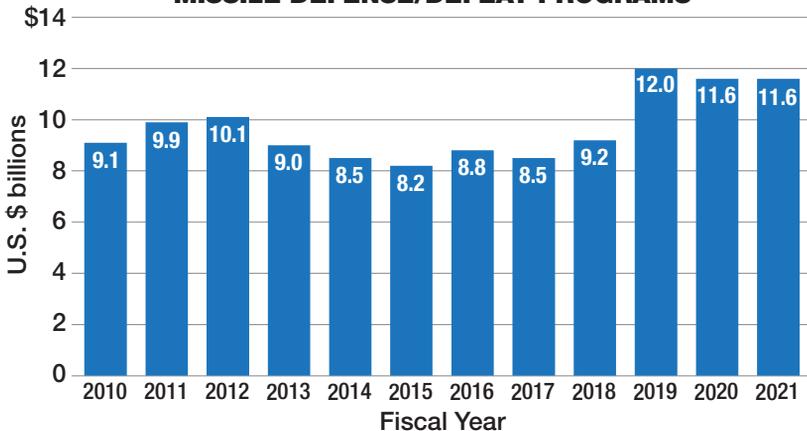
Ground-based Interceptors are emplaced in silos at Fort Greeley, Alaska.

By August 2019, Mike Griffin, the Pentagon’s top research and engineering official, stopped work on the RKV after the MDA had spent more than \$1 billion to develop it, as it was not proving to be reliable. These RKVs were to ride atop the next 20 GBIs, a project overseen and integrated by Boeing, which Congress had approved in 2018 after a spate of North Korean missile tests.

In concert with ending the RKV, Congress rerouted that funding to the NGI, and the MDA conducted a review of options for the interceptor. Coming out of that assessment, budget officials say they will not buy the 20 new GBIs as the military embarks on NGI development. New NGIs are so far being planned to be placed in silos that were to be inhabited by GBIs, according to Hill. “The current intention is for the Next-Generation Interceptors to be able to work with both current and future sensor systems,” says MDA spokesman Mark Wright.

From a security standpoint, existing GBIs will still protect the U.S. from foreign missile threats, says Hill, but he adds that over time their reliability will begin to fall off. While the NGI program works its way through development, the MDA plans to supplement GMD with a layered network of theater-range systems—the Terminal High-Altitude Area Defense System (THAAD) and the Aegis Standard Missile-3 (SM-3) Block

Pentagon Budget Request for MISSILE DEFENSE/DEFEAT PROGRAMS



Source: Defense Department

and another \$4.3 billion through fiscal 2025. It is an amount that will grow over time and that some worry could pull funding from other urgent priorities, as the type and number of missile threats from other countries evolves

ing the incoming ICBM in space—did not meet the needs of its CDR. The Government Accountability Office noted problems with the program meeting its cost and schedule goals “with no signs of arresting these trends.”



DEFENSE DEPARTMENT

get request was flat for fiscal 2021, a trend likely to continue. In the years ahead, the military will have big bills for its nuclear modernization budget and to recapitalize its conventional forces, which will hit about the time budgets for NGI would need to swell to support procurement of the system.

Meanwhile, in the near-to-midterm, the U.S. is likely to be dealing with a limited North Korean threat. Over time, the threats will grow in number and sophistication. Given challenges with the budget—not to mention technical challenges with developing a successful kill vehicle—Rose wonders if that money could be applied elsewhere.

Kingston Reif, director of disarmament and threat reduction policy at the Arms Control Association, is skeptical the MDA can deliver an NGI on its current timeline. “Congress must be extremely wary of allowing the Pentagon to repeat the mistakes that have plagued the GMD system in the past,” he says. “In particular, the development, procurement and fielding of the NGI should not be schedule-driven but based on the maturity of the technology and successful testing under operationally realistic conditions. Accelerating development programs risks saddling them with cost overruns, schedule delays, test failures and program cancellations—as has been the case with the GMD program and other missile defense programs to date.”

The expansion of U.S. homeland missile defense may be viewed as a provocation by Russia and China “and likely prompt them to consider steps to further enhance the survivability of their nuclear arsenals in ways that will undermine the security of the United States and its allies,” Reif says. “The costs and risks of expanding the U.S. homeland defense footprint in this way greatly outweigh the benefits.”

But like all proposals, it will be up to lawmakers to decide and is likely to be a point of interest in the year ahead.

“This is the single biggest muscle movement in the 2021 budget proposal, and Congress will be scrutinizing carefully whether the administration has a compelling vision and realistic funding stream for the short, medium and long term,” says Tom Karako, director of the missile defense project at the Center for Strategic and International Studies. 🗳

2A—to fill any gaps in defending the U.S. from North Korean missile attacks.

“What this budget really does for us is it starts to say, ‘Let’s take advantage of these regional systems that have been so successful and are very flexible and deployable,’” Hill says.

In 2020, the MDA will test the SM-3 Block 2A missile against an ICBM.

“When we prove that we can take out an ICBM with an Aegis ship or an Aegis Ashore site with an SM-3 Block 2A, then you want to ramp up the evolution of the threat on the target side, right? We’ll want to go against more complex threats,” Hill says.

That will require upgrading the combat system used by Aegis ships so it can process data from new sensors and engage with a missile. Adding the ability to launch SM-3 Block 2A missiles on ships or from Aegis Ashore sites will give combatant commanders the additional flexibility they have sought, he adds. A future commander could then choose to launch a GBI, THAAD, SM-3 or, when it is ready, NGI.

Such an interim solution using regional systems is still far from a reality.

The Pentagon is requesting \$139 million in its fiscal 2021 budget to “initiate the development and demonstration of a new interceptor prototype to support contiguous U.S. defense as part of the tiered homeland defense effort,” the MDA’s budget materials

state. That involves developing hardware and software and conducting demonstrations leading to a flight test in fiscal 2023.

One other potential gap in the missile defense architecture is in Pacific-based radars that would have cued GBIs to protect against an attack on Hawaii.

The “Pacific radar is no longer in our budget,” Hill says. Today, forward-deployed AN/TPY-2 radars and a deployable (sea-based X-band) radar work with the GMD system in that region. Plus, Aegis ships can be repositioned, he adds. “We realize we need to take another look at that architecture,” he says, which will focus on the Pacific region.

Missile defense experts are not un-supportive of the effort to build a new NGI. But they do question whether the cost will leach funding for other important priorities.

Frank Rose, a senior fellow at the Brookings Institution, points out that GBIs are built using 1990s technology and as a development prototype tasked for an operational mission. That means that requirements such as reliability, survivability and suitability were afterthoughts.

Despite the sound logic involved in moving toward a new interceptor, “I see a couple of challenges,” he says. That includes that the Pentagon’s bud-

STARRY-EYED

- > MOON AND MARS EXPLORATION ARE TOP NASA BUDGET PRIORITIES
- > THE PLAN DELAYS THE SLS UPGRADE

Irene Klotz Cape Canaveral

Jim Bridenstine, the ever-buoyant head of NASA, was almost giddy when he unveiled President Donald Trump's budget request for the fiscal year beginning Oct. 1, which would hike the agency's share of federal spending to more than \$25.2 billion—about 12% more than its current allocation.

"This is one of [the] strongest budgets in NASA history. . . . It is up to us to deliver," Bridenstine said during a televised address from NASA's Stennis Space Center in Mississippi, where the core stage for the agency's first Space Launch System (SLS) rocket is being prepared for a static engine firing later this year.

The SLS is a key but expensive part of NASA's plan to expand human presence beyond low Earth orbit, an initiative intended to lead to astronaut missions to Mars in the 2030s, following a series of expeditions to the lunar surface and establishment of a small outpost in lunar orbit under the Artemis program.

Although NASA has been largely spared from divisive and derisive partisan politics, it may be a hard sell—particularly during an election year—for Congress to buy in to a Trump-backed expedited Moon program that skeptics view



The core stage for the first Space Launch System Moon rocket was lowered into a test stand at Stennis Space Center in Mississippi for a static test firing later this year.

NASA Budget Spotlights Exploration, Not Science

- > MISSION TO MAP MARS ICE PROPOSED
- > BUDGET PLAN SHRINKS SCIENCE SPENDING 12%

Mark Carreau Houston

A big boost in spending for human exploration at NASA comes at a cost to the agency's science programs, which would take a 12% cut under the budget proposed by President Donald Trump for the fiscal year beginning Oct. 1.

The spending plan, unveiled Feb. 10, includes a third attempt at canceling the Wide Field Infrared Survey Telescope (Wfirst), a companion to the James Webb Space Telescope for the exploration of dark energy and the search for chemical biosignatures in the atmospheres of planets beyond the Solar System. Congress has consistently restored funding for Wfirst, as well as for the Stratospheric Observatory for Infrared Astronomy that the White House again seeks to cancel.

Trump's budget request of \$25.2 billion for NASA—a 12% hike over current levels—includes \$6.3 billion for science, an \$832.4 million, or 11.6%, reduction from current spending.

The plan includes funding to begin the Mars Sample-Re-

turn and Mars Ice Mapper missions. The sample-return initiative, a cooperative effort with the European Space Agency that is planned for a 2026 launch, would follow the Mars 2020 rover scheduled to launch this summer. The rover is expected to reach Jezero Crater, an ancient lake and river delta on Mars, in February 2021 to seek out evidence of past habitable environments as well as to gather and cache samples of rocks and soil for return to Earth.

The sample-return mission would feature a lander and robot-arm-equipped rover to collect the Mars 2020 rover samples, the first-ever rocket to launch from the Martian surface and a Mars orbiter to stow the samples for a return to Earth, perhaps by 2031.

The 2021 NASA science budget proposal seeks \$232.6 million to advance work on the Sample-Return and Ice Mapper missions, with spending to rise to \$775 million by fiscal 2025.

Other features of the 2021 NASA science budget proposal include continued development of the Europa Clipper, a mission to conduct a succession of close flybys of the ocean-bearing moon of Jupiter to further assess its potential for life. Congress wants NASA to launch the Clipper on the Space Launch System, which would shave 3.5 years off its journey but cost an extra \$1.5 billion over commercial alternatives.

Overall NASA science spending would increase but would not return to the 2020 level through fiscal 2025, budget documents show. 🌌

as timed to coincide with his possible second term in office.

For example, in December, NASA received just \$600 million of a requested \$1 billion to start work on human-class lunar landers. Then in January, the space and aeronautics subcommittee of the House Committee on Science, Space and Technology passed a bipartisan bill that moves the 2024 lunar landing deadline to 2028, which was NASA's original plan before Vice President Mike Pence last year told the agency to cut four years off the program.

Instead, the House version of the NASA Authorization Act of 2020 calls for the space agency to develop technologies and systems to put astronauts into orbit around Mars by 2033. It also repudiates NASA's plan to develop the human lunar lander under partnering agreements and commercial flight service contracts.

"This bill is not about rejecting the Artemis program or delaying humans on the Moon until 2028," subcommittee Chairwoman Rep. Kendra Horn (D-Okla.) said at the Jan. 29 hearing. Rather, it aims to take "the fiscally responsible approach of focusing the Moon efforts on the goal of being the first nation to set foot on Mars," she said. "NASA can still work to safely get there sooner."

Bridenstine, a former U.S. Representative from Oklahoma, and his team remain undaunted.

"Jim [Bridenstine] has created this [one-NASA] approach," says Deputy Administrator Jim Morhard. "It's a proven strategy that has gotten bipartisan support so far. . . . All parties should have full confidence that we're continuing to move forward to the Moon."

The fiscal 2021 budget request released Feb. 10 not only continues \$4 billion annually for the long-delayed SLS, the Orion deep-space crew capsule and related ground-support systems—programs that already have consumed more

than \$34 billion—but also earmarks more than \$3.3 billion to begin developing human-class landing systems, the long pole in the Trump administration's call to return astronauts to the Moon in 2024.

Ultimately, the agency says it will need to spend \$21.3 billion on human-class landers over the next five years, not including an undetermined amount from industry partners that have yet to be selected. Three companies confirmed they submitted proposals in November in response to a NASA Broad Agency Announcement to develop and demonstrate a Human Landing System (HLS). The contenders are: Boeing; Blue Origin, which is partnering with Northrop Grumman, Lockheed Martin and Draper Laboratory; and Dynetics—which on Jan. 31 became a wholly owned subsidiary of Leidos—partnering with Sierra Nevada Corp.

A fourth proposal is believed to have been submitted by SpaceX, but the company declined to comment. Two or more awards are expected in late March or early April, NASA noted on its procurement website on Feb. 10.

Under fiscal 2021-25 budget plans, the HLS would consume nearly two-thirds of the \$35 billion NASA says it needs to stage a 2024 human mission to the Moon, the first crewed lunar landing since the end of the Apollo program in 1972.

The proposal, however, delays funding for a more powerful, four-engine upper stage for the SLS Block 1B configuration, intended to replace the single-engine Interim Cryogenic Propulsion Stage on the SLS Block 1. With one flight planned per year, NASA now pegs the cost of sustaining the SLS-Orion program at \$2 billion annually, according to Brian Dewhurst, resource management officer for NASA's Human Exploration and Operations division.

The launch date for the first SLS-Orion mission, an uncrewed trial run around the Moon, is under review. ☒

Aeronautics Budget Advances Electrified Aircraft Propulsion Focus

- > ELECTRIFIED POWERTRAIN FLIGHT DEMONSTRATION PLANNED
- > INCREASED EMPHASIS ON URBAN AIR MOBILITY

Graham Warwick Washington

NASA plans to launch an electric propulsion X-plane program in fiscal 2021 as a follow-on to the X-59A QueSTT low-boom supersonic flight demonstrator, which is now scheduled to fly by January 2022.

Funding to begin the Electrified Powertrain Flight Demonstration (EPFD) project is included in the \$819 million sought for aeronautics research in 2021, an increase of 4.5% over the funding enacted for 2020.

But the 2021 request moves \$117 million in funding for ground-test capabilities such as wind tunnels back under the Aeronautics Mission Research Directorate. Excluding this accounting change, funding requested for NASA's other aeronautics programs is reduced to \$702 million.

Funding sought for 2021 would complete preparations to fly the Lockheed Martin Skunk Works-built X-59 and to fly



NASA plans to develop electrified propulsion for a future ultraefficient narrowbody airliner.

the X-57 Maxwell distributed electric propulsion demonstrator in its final, Mod 4, form with a new optimized wing with wingtip cruise propulsors and leading-edge high-lift propellers. The X-57 is scheduled to make its first flight this year.

Also in 2021, the Advanced Air Mobility project is to move from the Airspace Operations and Safety Program to the Integrated Aviation Systems Program, so as to manage large complex flight demonstrations beginning with NASA's Urban Air Mobility Grand Challenge.

In preparation for the EPFD project, the Advanced Air Vehicles Program plans in 2021 to conduct ground-testing of a flight-weight megawatt-class electric inverter under simulated 30,000-ft.-altitude conditions in the NASA Electric Aircraft Testbed. It will also complete the critical design review on a project to demonstrate large-scale power extraction from the high- and low-pressure spools of a turbofan. ☒

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March 7-14—IEEE (Institute of Electrical and Electronics Engineers) Aerospace Conference. Yellowstone Conference Center. Big Sky, Montana. See aeroconf.org

March 10-12—World ATM Congress. IFEMA-Feria de Madrid. Madrid. See worldatmcongress.org/home

March 10-12—International Air Transport Association (IATA) World Cargo Symposium 2020. Hilton Istanbul Bomonti. Istanbul. See iata.org/events/wcs/Pages/index.aspx

March 10-12—American Institute of Aeronautics and Astronautics (AIAA) International Space Planes and Hypersonic Systems and Technologies Conference. Westin Hotel. Montreal. See casi.ca/Hypersonics-2020-Conference

March 10-12—ISTAT Americas. JW Marriott Orlando. Orlando, Florida. See connect.istat.org/Americas

March 13-April 30—RTCA Plenary Sessions. Various locations. See rtca.org/content/upcoming-committee-meetings

March 17-19—Global Aerospace Summit. St. Regis Saadiyat Island Resort. Abu Dhabi. See aerospacesummit.com

March 21-22—Los Angeles County Air Show. William J Fox Airfield. Lancaster, California. See lacitycountyairshow.com

March 23-25—International Conference on Applied Aerodynamics. Prime Institute (ISAE-ENSMA buildings). Poitiers, France. See 3af-aerodynamics2020.com

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March 12—Aviation Week Laureates Awards. Washington.

April 1-2—CAPA Airline Leader Summit: Making Money 2020. Dublin.

April 27-28—Urban Air Mobility Americas. Dallas.

April 27-29—Routes Europe 2020. Bergen, Norway.

April 28-29—Military Aviation Logistics & Maintenance Symposium. Dallas.

April 28-30—MRO Americas. Dallas.

May 7-8—CAPA Americas Aviation & LCCs Summit. San Juan, Puerto Rico.

May 12-13—Aerospace Manufacturing Conference. Charleston, South Carolina.

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Full Circle

If ever there were an illustration of government support distorting markets, it would be Bombardier and its C Series, now the Airbus A220. With its decision to exit commercial aircraft, sell its rail transportation unit and focus solely on business aviation, the Canadian company has come full circle.

Bombardier entered aviation in 1986 when the Montreal-based snowmobile manufacturer acquired loss-making Canadair from the Ottawa government for C\$120 million (about \$90 million at the time). With it came the Challenger business jet, on which government-owned Canadair had spent C\$1.5 billion.

Over the next six years, Bombardier acquired Northern Ireland-based Short Brothers and de Havilland Canada for less than \$90 million combined, and it received more than \$1.6 billion in support from the Ottawa, Ontario and UK governments. It also bought bankrupt Learjet for \$75 million, cementing its reputation as a shrewd dealmaker.

What the governments saw in return, in the place of failing businesses, was an aerospace powerhouse that had turned its \$255 million in knock-down purchases into \$10 billion in annual revenues by 2009 and a workforce that, at its peak of 32,250 in 2001, encompassed more than half the Canadian industry.

Not surprisingly, the governments were willing to continue providing support in the form of both launch aid and export credit. And it was a successful partnership: Bombardier in 2019 said it had repaid \$790 million in royalties on \$596 million of reimbursable loans received between 1986 and 2009. With 1,950 aircraft sold, the \$180 million received in support for the CRJ program had alone repaid \$315 million, it said.

But government confidence in Bombardier proved less well placed when it came to the C Series, its first large commercial aircraft. Developing the 110-150-seater, in parallel with the Global 7500 business jet, required much larger loans—a total of \$816 million in 2009 and 2017, plus about \$150 million from the UK.

The C Series would not have been launched without that government support, and it was not enough. Pro-

gram costs escalated to more than \$6 billion, too much for a company of Bombardier's size. Flawed execution and competitive plays delayed orders and deliveries. The Quebec government stepped up in 2016 with a \$1.3 billion equity investment in the program, but in 2018 Bombardier handed over control of the C Series to Airbus.

The C Series triggered a five-year turnaround effort that has seen Bombardier sell off most of the aviation businesses acquired and built up with that government support, including de Havilland Canada, Shorts, the CRJ and now all of the A220 program, raising more than \$3.4 billion in cash and offloading more than \$1.1 billion in debt and other liabilities to shore up its finances.

The C Series also triggered a wholesale reshaping of the airliner manufacturing industry, causing Airbus and Boeing to launch the A320neo and 737 MAX families and leading long-time rival Embraer into a planned commercial-aircraft joint venture with Boeing.

There are upsides to this upheaval. Airlines are receiving a new generation of fuel-efficient

airliners more quickly than they would have otherwise. Montreal's aerospace cluster has gained Airbus as another OEM. The A220 is proving itself a good aircraft. And the likelihood of those government loans being paid off has increased.

But with the decision to sell off its rail unit, Bombardier is returning to its aviation roots as a business aircraft manufacturer with a workforce barely larger than it was in the early 1990s. It is hard to see where the company could have taken a different route, but it has been a roller-coaster ride, and the governments involved must take some of the responsibility for enabling the decision that took Bombardier to its heights and brought it back down.

When governments subsidize product development, they play with market forces. They do so at the entire industry's peril, tilting the competitive landscape with unpredictable results. It would be better for governments to leave industry to carry the risk of developing new products and instead focus their support on developing the enabling technologies. The payoff could be greater. The need certainly is. ☛

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